



INTERNATIONAL CONFERENCE ON ENGINEERING, SCIENCE, AND TECHNOLOGY

THEME: UTILIZING THE KNOWLEDGE OF ENGINEERING, SCIENCE, AND TECHNOLOGY FOR SUSTAINABLE DEVELOPMENT

CONFERENCE PROCEEDINGS

(FOR SELECTED PEER REVIEWED PAPERS PRESENTED AT ICEST 2023)

DATE: 23RD TO 25TH NOVEMBER, 2023 VENUE: SHELL BUILDING, UNIVERSITY OF CROSS RIVER STATE, NIGERIA



UNIVERSITY OF CROSS RIVER STATE, CALABAR, NIGERIA





International Conference on Engineering, Science & Technology for Sustainable Development

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Lifeline for submission of Abstracts: 31st July, 2023.

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ACCEPTED PAPERS

TRACK A: ENERGY TRANSITIONING FOR GREEN ECONOMY/ ELECTRICAL POWER FOR SUSTAINABLE DEVELOPMENT

| Track Number | Paper Details | Page |
|-----------------|---|-------|
| A4 | Modeling and simulation of proposed Nigeria | 11-17 |
| | bus networks with high penetration of hybrid | |
| | renewable energy for Nigeria future energy | |
| | sustainability and economic development Asuquo Eke ^{a,*} , Okwoche, Andrew ^b , Lattif, Fatoki ^c , John Umuyi ^d , Akpama E. J ^e | |
| A5 | Energy Consumption and Carbon Emissions in | 18-23 |
| | the Nigeria's Household Sector U. I. Okoro ^{*a} , F. I. Abam ^b , M. C. Ndukwu ^c , I. O. Ibor ^d | |
| A6 | Modelling UNICROSS Calabar campus | 24-31 |
| | electricity distribution network for power quality | |
| | improvement using capacitor bank Asuquo Eke ^{a,*} , Patrick Odu ^b , Ojobe, Obasi-Sam ^c , Okwoche Andrew ^d , John Umuyi ^e , Lattif, Fatoki ^f , Sunday Dickson ^g | |
| A7 | Load flow analysis of the University of Cross | 32-39 |
| | River State (Calabar campus) for effective | |
| | planning and energy delivery Ndifreke Okon Udofia ^{a,*} , Asuquo Eke ^{a**} | |
| A10 | Investigation of electrmagnetic radiation from | 40-49 |
| | CRUTECH electric power substation Emmanuel O. Onoyom-Ita ^{a,*} , Sunday A. Ojomu ^a Archibong E. Efiong ^a , Ukoette J. Eka ^b | |
| A11 | The transformative role of artificial intelligence | 50-60 |
| | in smart energy transition for unprecedented | |
| | energy sustainability in Nigeria Emmanuel E. John ^{a,*} , Precious-Chibuzo O. Effiom ^b , Samuel O. Effiom ^a , Patrick O. Odu ^b , Igri O. Uket ^a , Samuel E. Nwankwo ^c , Obasisam O. Ojobe | |
| A12 | Speed control of DC motor using PWM | 61-69 |
| | technique method for industrial applications | |

| | Oku Ekpenyong Nsa ^{a,*} , Emmanuel E. Effiong ^b , Akpan Anthony ^c | |
|-----|--|-------|
| A17 | Modeling and evaluation of Calabar transmission | 70-79 |
| | line network for load flow and transient stability | |
| | for future grid expansion | |
| | Patrick Odu ^{a,*} , Ojobe, Obasi-Sam ^a , Asuquo Eke ^b , Akpama E.J ^b | |
| A18 | Modelling and simulation of an adaptive gain | 80-88 |
| | PID controller for a direct torque fuzzy speed- | |
| | controlled induction machine drive | |
| | Osundina, Emmanuel Mayowa ^{a,*} , Eko James Akpama ^b | |

TRACK B: SUSTAINABLE INFRASTRUCTURE & ENVIRONMENTAL

DEVELOPMENT/SUSTAINABLE MATERIALS & PRODUCT INNOVATION FOR GREEN ECONOMY

| Track | Paper Details | Page |
|--------|--|---------|
| Number | | |
| B1 | Development of cement stabilized interlocking | 89-103 |
| | masonry block cubes using aluminum waste and | |
| | granite powder Hyginus Obinna Ozioko* ^{a,} | |
| B2 | Analysis of rainfall and temperature over a sub- | 104-110 |
| | basin of Lake Chad, Nigeria | |
| | Aminu, A. ^{a,*} , Animashaun I. M. ^b , Otache Y. M. ^c | |
| B3 | Sustainable Materials for Green Economic | 111-122 |
| | Advancement with a Focus on Biosynthesized | |
| | Nanomaterials | |
| | Ukueje Etabiese Wisdom ^{a,*} , Fidelis Abam ^b , Anthony Obi ^a | |
| B4 | Flood mapping of Calabar river using HEC-RAS | 123-135 |
| | and QGIS | |
| | Ibiang, Ibiang Ebri ^{a,*} , Hycienth Edudi ^b | |
| B5 | Analysis of geotechnical properties of solid | 136-145 |
| | waste and natural soil site for structural | |
| | foundation | |
| | F. C. Onyeka ^a , T. E. Okeke ^{b,*} | |
| | , , | |

| B6 | Mathematical modeling of seasonal rainfall prediction and climate change impact in Cross River State: A Case Study Calabar Metropolis J.G. Egbe ^{a,*} , A.A. Enya | 146-153 |
|-----|--|---------|
| Β7 | Development of an extension stand to aid performance in table saw machines Asibong Icha ^{a,*} , Simon Odey ^a , Milliscent Ededet ^a , Happiness Bassey ^a | 154-159 |
| B9 | Assessment of wood waste for energy generation in Benin City, Edo State, Nigeria Milliscent Ededet ^{a,*} , Asibong Icha ^a , Michael Akpan ^a , Emmanuel Ugbong ^a | 160-165 |
| B10 | Comparative analysis of the effect of using groundnut shell and rice husk waste ashes for soil stabilization Ibiang, Ibiang Ebri ^{a,*} , Emmanuel Ewa Ekeng ^b | 166-172 |
| B11 | Urea -formaldehyde free particleboards from wood wastes using glutaraldehyde modified cassava starch as binder Atowon, A. D ^{*a} , Ita. E.O ^b , Ushie, E.O ^c , Ugbong, E.A ^d | 173-179 |
| B12 | Physio-mechanical properties of cement bonded particle board (CBPB) manufactured from three (3) wood species in Cross River State, Nigeria Emmanuel Akomaye Ugbong ^{*,a} , Peter Nentui Etta ^b , Milliscent Ededet ^c | 180-193 |
| B13 | Microstructural developments in plain and slag- blended cements Joseph O. Ukpata ^{a,*} | 194-201 |
| B14 | Performance evaluation of laterite crushing machine for sustainable housing delivery in Nigeria Achema, F ^{a,*} , Bakam, VA ^a , Apeh, ES ^b , Yahaya, BS ^b , Isheni, Y ^a | 202-208 |
| B15 | Development of a Low-Cost Slider-Crank Apparatus for Teaching Purposes Bello RS ^a *, Odey SO ^b , Igwe DC ^b , Onu BO ^a , Nebo EU ^a , Elendu OE ^a | 209-219 |

| B17 | Biodiesel a sustainable fuel: exploring the feedstocks and production process | 220-225 |
|-----|--|---------|
| | | |
| B18 | Assessment of quality of tanker vended water in Enugu metropolis Okorie, J.C ^a , Odenigbo, C.E ^{b,*} | 226-232 |
| B19 | Positive environmental impact of biodiesel as an alternative fuel | 233-236 |
| | B. D. Nkanang ", F. I. Abam", M. C. Ndukwu " | |

TRACK C: COMMUNICATION & CONTROL SYSTEMS/AI FOR SUSTAINABLE ECONOMY

| Track Number | Paper Details | Page |
|-----------------|---|---------|
| C2 | Performance Evaluation of the Travelling Wave | 237-242 |
| | Tube Design for Security and Surveillance | |
| | Operations | |
| | Odo, E. O.º and Ezeburo, I. I.º | |
| C3 | Development of an SMS-based accurate | 243-251 |
| | notification system for improved pipeline | |
| | leakages | |
| | Gertrude A. Fischer ^{a,*} , F. I. Anyasi ^b , Sunday A. Ojomu ^b | |
| C4 | Monitoring of leakages in crude oil/gas pipelines | 252-263 |
| | using a wireless system network internet of | |
| | things (IoT) | |
| | Gertrude A. Fischer ^{a,*} , F. I. Anyasi ^b , Sunday A. Ojomu ^c | |
| C5 | Design and implementation of a university smart | 256-270 |
| | attendance tracking system using geo-location | |
| | and IOT | |
| | Gertrude A. Fischer ^{a,*} , Victor Ojong ^b , Eyo Inameti ^c | |
| C6 | Development of a self-governing system for | 271-279 |
| | optimal navigation of unmanned ground vehicles | |
| | in dynamic path | |
| | Omosefe Jacob ^{*a} , Peter O. Ohiero ^b , Paul B. Anyin ^c | |

| С7 | Refraction algorithm method for the | 280-289 |
|-----|--|---------|
| | development of handover transfer channels for | |
| | GSM networks in Nigeria | |
| | Peter Oritsetimeyin Tim ^{a,*} , Sunday Abayomi Ojomu ^b , Olumide Cornelius | |
| C8 | Evaluation of pathloss exponential of NTA Port | 290-299 |
| | Hacourt signal strength within Calabar | |
| | matropolia | |
| | Emmanuel S. Imoh ^{a,*} , Sunday A. Oiomu ^b , Sampson Bendor ^c , Paul Anvin | |
| | ^d , Eyam Ekum ^e | |
| C9 | Design and construction of microcontroller- | 300-305 |
| | based programmable DOT matrix information | |
| | display system | |
| | Balogun TJ ^{a,*} , Ojomu SA ^b , Philip PA ^c , Effiwatt FO ^d , Ojobe EO ^e , Asuquo | |
| C12 | Design and construction of a UAV air to ground | 306-312 |
| | autonomous channel system | |
| | Paul Okim ^{*,a} Certrude Eischer ^b Paul Betiang ^c Bendor Sampsom ^d | |
| | Archibong Efiong ^e | |
| C14 | Design and development of e-learning for the | 313-323 |
| | Department of Electrical and Electronic | |
| | Engineering, University of Cross River State | |
| | (UNICROSS) | |
| | Etim, Otu Mesembe ^{a,*} , Gertrude Fischer ^b , Asuquo Eke ^c , Paul Anyin ^d | |
| C15 | Design and simulation of a hand motion remote | 324-333 |
| | control system using sensor-based technology | |
| | Ekechi, Faith Onyinyechi ª,*, Gertrude Fischer ^b | |

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Modeling and simulation of proposed Nigeria bus networks with high penetration of hybrid renewable energy for Nigeria future energy sustainability and economic development

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Received 02 November 2023; Accepted 18 November 2023 Abstract: Constant network, system collapse and inadequate energy supply by utility connected to the network leads to the increase in the cost of energy supply by utility companies. The aim of these paper is to model a 74-network using ETAP as a simulation tool for analyzing the impact of the hybrid renewable energy on the network for the country energy sustainability. The reliability of the energy on the network is the priority on the penetration of the solar PV and wind energy. The hybrid gives a better improvement on the network by increasing, improving and power optimization on the network thereby dispatching economically. The inclusion of the hybrid renewable energy to the network results to a stable electrical power on the network, reliable and affordable. Due to the high penetration of the renewable energy to the network, energy supply has improved, affordable, reliable and stable. There is an increase on bus voltages on the network and generally voltage increase. This will help improved the nation economy and sustainable development will be achieved

Keywords: Renewable energy, penetration, power stability, economic importance and development.

1. Introduction

Electrical energy network in Nigeria has been upgraded from 12 bus network to 22 buses, 32 buses and 72 buses network comprises of 22 generators, 68 connections with different load points, on the network, [1,3] using kanji swing bus in some cases, the total installed capacity of the network is about 14,280 MW with an increase in generator to 14 generators. [3,4, 5] The economic development deeply depends on the stability of electricity on the area. The increase in energy generation, the increase in economic and social development of the nation. [6] thereby, improve the welfare of the people. [7] high penetration of renewable(hybrid) into the network gives a better effect on the bus voltage, voltage drop, energy stability, and reliability of the energy on the network and its connections with the inclusion of the renewable energy on the network, energy stability is certain, economic and social development will improve and a voltage profile also improved on the network. Thus, increase in energy generation, result to end user satisfaction on usages from the utility company. There is an increase in investment on the network due to increase in development [8, 11, 20]. According to [1, 11] the impact of renewable energy on existing network is numerous, starting from the energy improvement and energy sustainability. It enhances effective energy delivery and equip the network on future energy considerations. It maintains that, the major drawback is the issue and challenges on integration. According to [3, 14], economic advancing of a nation is a major advantage of improving electrical power network. According to [17, 16], high penetration of energy (renewable) to the already build electrical network reduces costs of energy to the whitening users although it might not be immediately that most of it effect releaseMethod.

2. Method

Modeling electricity network of 72 buses, 14 generators and 69 lines connections is done using ETAP19.0. The load flow simulations on the network is modelled using fast decouple method as follows Voltage equation for $(k+1)^{\text{th}}$ iteration is

$$A(x^{1}) = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix}; \text{ by choosing } A(x^{1}) = \begin{bmatrix} J_{11} & 0 \\ 0 & J_{22} \end{bmatrix}$$
(1)

$$\Delta P = J_{11} \Delta \delta \tag{2}$$

$$\Delta Q = J_{22} \Delta |V| \tag{3}$$

The principle is based on the following.

$$\frac{\partial P_i}{\partial \delta_k}$$
 is much larger than $\frac{\partial Q_i}{\partial \delta_k}$ approximately zero and $\frac{\partial Q_i}{\partial |V_k|}$ is much larger than $\frac{\partial P_i}{\partial V_k}$ approximately zero.

By incorporating these approximations in Jacobian equation we have

$$\begin{bmatrix} \frac{\partial P_2}{\partial \delta_2} & \cdots & \cdots & \frac{\partial P_2}{\partial \delta_4} \\ \vdots & J_{11} & & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ \frac{\partial P_4}{\partial P_4} & \cdots & \cdots & \frac{\partial P_4}{\partial \delta_4} \end{bmatrix} \begin{bmatrix} \Delta \delta_2 \\ \vdots \\ \Delta \delta_4 \end{bmatrix} = \begin{bmatrix} \Delta P_2 \\ \vdots \\ \Delta P_4 \end{bmatrix}$$

$$\begin{bmatrix} |V_2| \frac{\partial Q_2}{\partial |V_2|} & \cdots & \cdots & |V_4| \frac{\partial Q_2}{\partial |V_4|} \\ \vdots & \vdots & J_{22} & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ |V_2| \frac{\partial Q_4}{\partial |V_2|} & \cdots & \cdots & |V_4| \frac{\partial Q_4}{\partial |V_4|} \end{bmatrix} \begin{bmatrix} \Delta \frac{|V_2|}{|V_2|} \\ \vdots \\ \Delta \delta_4 \end{bmatrix} = \begin{bmatrix} \Delta Q_2 \\ \vdots \\ \vdots \\ \Delta Q_4 \end{bmatrix}$$
(4)

The equations are decoupled in nature

Thus

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} H & 0 \\ 0 & L \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \frac{|\Delta V|}{|V|} \end{bmatrix}$$
(6)

This is the Decoupled Newton Method

It can be further factored out as;

 $[\Delta P] = [H][\Delta \delta] \tag{7}$

$$[\Delta Q] = [L]x \left[\frac{|\Delta V|}{|V|} \right]$$
(8)

$$H_{ik} = L_{ik} = \left| V_i V_k \right| (G_{ik} \sin \delta_{ik} - B_{ik} \cos \delta_{ik}) \quad i \neq k$$

The elements of the Jacobian Equation 8 can be simplified as:

$$H_{ik} = \frac{\partial P_i}{\partial \delta_k}$$
 and $L_{ik} = \partial Q_i \frac{|V_i|}{\partial |V_i||}$

From Eq. 9 & 10

$$\frac{\partial P_i}{\partial \delta_k} = P_i = \left| V_i V_k Y_{ii} \right| \cos \theta_{ii} + \sum_{K=1, K \neq i}^N \left| V_i V_k Y_{ik} \right| \cos(\theta_{ik} + \delta_k - \delta_i)$$
(11)

$$Q_i = \left| V_i V_k Y_{ii} \right| \sin \theta_{ii} + \sum_{K=1, K \neq i}^N \left| V_i V_k Y_{ik} \right| \sin(\theta_{ik} + \delta_k - \delta_i)$$
(12)

Off-diagonal elements of H (i.e. when $i \neq k$) are:

$$H_{ik} = \frac{\partial P_i}{\partial \delta_k} = \left| V_i V_k Y_{ik} \right| \sin(\theta_{ik} + \delta_k - \delta_i)$$
(13)

Expanding by trigonometric function yields,

$$= \left| V_i V_k \right| (Y_{ik}) \sin \theta_{ik} \cos(\delta_k - \delta_i) + \sin \left| Y_{ik} \right| \cos \theta_{ik} \sin(\delta_k - \delta_i)$$
(14)

We know that
$$Y_{ik}sin\theta_{ik} = -B_{ik}$$
 (15)

and
$$Y_{ik}cos\theta_{ik} = -G_{ik}$$
 (16)

then
$$(Y_{ik} = G_{ik} - jB_{ik})$$
 (17)

$$H_{iK} = \left| V_i V_K \right| \left[-B_{iK} \cos(\delta_K - \delta_i) + G_{iK} \sin(\delta_K - \delta_i) \right]$$
(18)

Likewise, the off-diagonal element of L (i.e. normalized form) is

$$L_{ik} = \frac{\partial Q_i}{\partial |V_K|} V_K = |V_i V_K Y_{iK}| \sin(\theta_{iK} + \delta_K - \delta_i)$$
⁽¹⁹⁾

$$L_{ik} = V_i V_k [-B_{ik} \cos(\delta_k - \delta_i) + G_{ik} \sin(\delta_k - \delta_i)]$$
⁽²⁰⁾

From Eqs 3.63 and 3.64b we can see that

.

$$H_{iK} = L_{ik} = \left[V_i V_k \left[-G_{ik} \sin(\delta_k - \delta_i) - B_{ik} \cos(\delta_k - \delta_i) \right] \right]$$
(21)

The diagonal elements of H are given as:

$$H_{i} = \frac{\partial P_{i}}{\partial \delta_{k}} = \sum_{K=1, K \neq i}^{N} \left| V_{i} V_{K} Y_{iK} \right| \sin(\theta_{iK} + \delta_{K} - \delta_{i})$$

$$\tag{22}$$

$$= -\sum_{K=1,K\neq i}^{N} |V_{i}V_{K}Y_{iK}| \sin(\theta_{iK} + \delta_{K} - \delta_{i}) - |V_{i}V_{K}Y_{iK}| \sin\theta_{ik}$$
$$= -\left\{\theta_{ik} + |V_{i}V_{K}Y_{iK}| \sin\theta_{ii}\right\}$$
(23)

$$H_{ii} = -Q_i - V_i^2 B_{ii} \tag{24}$$

Similarly, the diagonal element of L are given as:

$$L_{ii} = \frac{\partial P_i}{\partial V_i} \left| V_i \right| = \left| 2V_i^2 Y_{ii} \right| \sin \theta_{ii} + \sum_{K=1}^N \left| V_i V_K Y_{iK} \right| \sin (\theta_{iK} + \delta_K - \delta_i)$$
(25)

$$L_{ii} = |2V_i^2 Y_{ii}| \sin \theta_{ii} + \sum_{K=1}^{N} |V_i V_K Y_{iK}| \sin(\theta_{iK} + \delta_K - \delta_i) - |V_i V_K Y_{iK}| \sin \theta_{ii}$$

= $|2V_i^2 Y_{ii}| \sin \theta_{ii} + Q_i - |V_i^2 Y_{ii}| \sin \theta_{ii}$ (26)

$$L_{ii} = |V_i^2 Y_{ii}| \sin \theta_{ii} + Q_i, \qquad \text{but } \{Y_{ii} \sin \theta_{ii} = -B_{ii}$$

$$= -V_i^2 B_{ii} + Q_i$$
(27)

$$L_{ii} = Q_i - V_i^2 B_{ii} \tag{28}$$

3. Result and Discussion



Fig. 1. Graph of bus voltage drop (network with a renewable energy)



Fig. 2. Graph of % bus voltage (network with a renewable energy)



Fig. 3. Graph of bus voltage against bus angle (network with a renewable energy)



Fig. 4. Graph of bus voltages (network without a renewable energy)



Fig. 5. Graph of bus voltage drop (network without a renewable energy)



Fig. 6. Graph of bus angle (network without a renewable energy)

Fig.1. is a graph of bus voltage drop on the network with a renewable hybrid system connected. It reveals that, Benin Kebbi has a voltage drops of 3.5 volts. Figure 2. is the graph of % bus voltage, where Adiabo, Eyean and Kanji has 100% voltage level with hybrid energy connected, and Fig. 3. is a bus voltage angle where hybrid renewable is connected, Kanji has angle of 0; being a reference bus. Fig. 4. is a graph of bus voltage without a hybrid renewable energy connected, Benin Kebbi, and Maiduguri buses has a voltage level of 120%. In Fig. 5, voltages drop, Benin Kebbi and Damaturu has a highest of 3.45 and 3.1 volts drops respectively. Fig. 6 has a least bus angle of -18 and 17. The level of penetration of the hybrid energy system helps in determining the level of economic developments of the area.

4. Conclusion

Increasing the share of solar PV and wind energy in Nigeria's energy mix can cut carbon emissions dramatically. Nigeria may be able to fulfill its international climate pledges thanks to this shift to cleaner energy sources, which is consistent with efforts made worldwide to tackle climate change. Nigeria's dependence on fossil fuels, particularly oil and gas, can be reduced by utilizing the country's rich solar and wind resources. This energy security can protect the economy from erratic international

energy markets and improve national security. The frequent power outages and blackouts that have afflicted Nigeria in the past can be lessened with the use of solar and wind energy sources. For economic expansion and development, this increased energy reliability is crucial. Employment opportunities in manufacture, installation, maintenance, and operations are brought about by the development of solar and wind energy infrastructure. This may help to reduce unemployment rates and advance the economy of the nation. Nigeria has a lot of isolated and underdeveloped regions. A decentralized energy system fueled by renewable energy sources can increase access to electricity in these communities, raising living standards and promoting business activity. Nigeria's economy can become more diverse by switching to renewable energy sources. It can boost investment in the field of renewable energy, advance R&D, and foster innovation, resulting in economic growth outside the oil industry. Although there are substantial potential advantages, switching to a high-penetration renewable energy system is not without difficulties. These include the requirement for large investments, grid infrastructure upgrades, regulatory and policy frameworks, as well as resolving logistical and technological difficulties. Solutions for effective energy storage are needed to manage the erratic nature of solar and wind resources. Building storage facilities will be essential for preserving a steady supply of electricity. Collaborations and public-private partnerships are necessary for the successful deployment of a hybrid renewable energy system. Government programs, incentives, and subsidies should encourage private sector investment in the industry.

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Energy Consumption and Carbon Emissions in the Nigeria's Household Sector

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Abstract: In this study, decomposition analysis was carried out on energy consumption in the household sector. The result indicates the changes in the level and structure of energy consumption in Nigeria's household sector between 2000 and 2018, as the total fossil energy consumption grew at an average annual rate of 0.29%. Consequently, the energy consumption increased from $7.55 \times 10-6$ Mt in 2000 to $4.41 \times 10-4$ Mt in 2018 (about 57.4%) with a cumulative average of $1.22 \times 10-4$ Mt. Therefore, fossil energy usage increased. The energy mix (Petrol, Diesel and Kerosene) maintained a stable trend from 2000 to 2009. Still, between 2010 and 2014, diesel utilization increased from $1.13 \times 10-4$ Mt to $1.75 \times 10-4$ Mt (55.35%). Petrol utilization increased by $2.61 \times 10-6$ Mt in 2000 to $1.69 \times 10-4$ Mt in 2018 with an annual growth rate of 63.9%, as kerosene experienced an increase in usage by $1.94 \times 10-6$ Mt in 2000 to $5.65 \times 10-5$ Mt in 2018. Generally, between 2000 and 2018, energy consumption derived from diesel gave the highest share of utilization at 71.10%, followed by petrol and kerosene at 16.74% and 12.16%, respectively. The decomposition results during the time interval (2001-2006) showed negative effects of AHHS and FM on CO2 emissions in 2000-2003, overriding the positive effects of HHS, PCI, EI and CEC.

Keywords: CO2, Energy consumption, Household, Fuels, Nigeria

1. Introduction

Energy availability has continued to be the trajectory upon which economic growth, development and sustainability revolve [1]. Recent years have witnessed increased energy demand occasioned by population growth and industrialization across all sectors of the economy [2]. In Nigeria, with over 200 million people with an annual population growth rate of about 2.5% per annum, there are strong indications of a projection of about 400 million inhabitants by 2050 [3] who will continue to yearn for energy supply.

Energy plays a critical role in enhancing production, competitiveness and incomes through its support of productive activities and the facilitation of investments in industry, commerce and agriculture and used by various sectors [4]. However, the household sector is considered one of the most intensive after transportation and industrial sectors in energy services [5]. Generally, household energy services are required for various purposes, such as lighting, heating, cooking, and electrical appliance use [6]. According to [7], the usage is commonly called household energy consumption. It is defined as the energy consumed in homes to meet the needs of households. Also, [8] identified two household energy classes: solid fuels and non-solid fuels. The solid fuels include fossil fuels (coal and peat) and biomass (wood, dung and agricultural residues). In contrast, in the household sector, non-solid fuels consist of kerosene, liquefied natural gas and electricity, accounting for about 65% of total energy usage [9]. The Energy Commission of Nigeria estimated that over 60% of Nigeria's population in 2003 depended on fuel (wood) for cooking and other domestic uses, with about a 72% rise in 2004. According to World Bank figures, only 40% of Nigeria's out of 200 million population is connected to the national grid. Over 70% of the rural population depend on traditional biomass for cooking [10]. Additionally, the percentage distribution of the various energy carriers in the residential sector is shown in Figure 1.



Fig. 1. Percentage distribution of energy sources for cooking [10]

2. Method

2.1. Estimation of carbon emission in the household sector

2.1.1 Direct carbon dioxide emission estimation

The method employed to estimate the direct CO2 emission was extracted from the National Greenhouse Gas Inventory Guidelines 2006 [11]. Three energy sources (fuel-petrol, diesel and kerosene) were selected for estimating direct carbon emission, and three constant variables were employed. This includes each energy type, the average low calorific value, the carbon emission coefficient, and the carbon oxidation factor. The direct carbon emission was estimated according to [12] in Equation (1).

$$DCO_2 = \sum E_i \times NCV_i \times CEF_i \times COF_i \times \left[\frac{44}{12}\right]$$
(1)

Where: DCO_2 is the direct carbon emission of energy source consumed, E is the amount of energy consumed, NCV is the average low calorific value, CEF is the carbon emission coefficient, COF is the carbon oxidation factor, and 44 is the molecular weight of CO₂, and 12 is the molecular weight of carbon.

Table 1 presents the NCV, CEF and COF values used to compute direct carbon emission for Fuelpetrol, Diesel and Kerosene.

| Energy Source | $NCV (KJ/Kg, KJ/m^3)$ | CEF (KgC/GJ) | COF | |
|---------------|-----------------------|--------------|------|--|
| Fuel-petrol | 43,070 | 18.90 | 0.98 | |
| Diesel | 42,652 | 20.20 | 0.98 | |
| Kerosene | 43,070 | 19.60 | 0.98 | |

Table 1: Constant variables for direct carbon emissions computation for energy mixes [12]

2.1.2 Household Factor Decomposition Analysis of Carbon Emission Change

The traditional factor decomposition method is a distinctive approach to describing population growth's environmental impact [13]. It can suffice in relating the dependence of established indices in an aggregated fashion and is mainly comprised of four factors, namely, carbon emission, total energy consumption, Gross Domestic Product (GDP) and population proposed by (14) in (2).

$$CI = f(CE, EC, GDP, POP)$$

Where the factors *CE*, *EC*, *GDP*, *and POP* denote carbon dioxide emission, total energy consumption, Gross Domestic Product (GDP) and population.

3. Results and discussion

3.1 Carbon emissions change ($\triangle CO_2$)

In evaluating the changes in the CO2 emissions, an analysis showing the periodic trajectory of the effects of changes in the driving factors at different times on the CO2 emissions was determined and presented in Table 1. During 2001-2003, the negative effects of AHHS, especially FM on CO2 emissions, dominated the positive effects of HHS, PCI, EI and CEC. As a result, only in 2001 and 2006 did the overall CO2 emissions from the combustion of fossil fuels decrease by -4.302Mt-CO2, as seen in Figure 1. The increase in CEC, EI, HHS, and PCI factors accounted for 3.599Mt-CO2, 3.107Mt-CO2, 8.247×10-1 Mt-CO2 and 1.743×10-1Mt -CO2, respectively. While FM and AHHS effects accounted for the reduction in CO2 emissions, their contribution was -10.786Mt-CO2 and -1.221Mt-CO2, respectively. The significant factors causing the increase in CO2 emissions in this period were the growth of EI and CEC effects. The energy intensity effect increased by 1.78% from 2000 to 2006. While the carbon emission coefficient increased from 0.43% in 2000 to 0.38% in 2006. Amongst the factors growing emissions in the stated time interval, the household size and per capita income impact is not significant, as seen in Figure 1. Figure 2 presents the carbon emission trajectory from 2007 to 2012. The cumulative change in CO2 emissions was positive, estimated at 3.778Mt-CO2. The effects of HHS, PCI, EI, FM, and CEC contributed to the increase in carbon emission, accounting for 1.099Mt-CO2, 4.029Mt-CO2, 3.184Mt-CO2, 4.901×10-1Mt-CO2, and 3.564×10-1 -CO2 respectively. Furthermore, amongst the drivers promoting CO2 emissions change, the PCI effects accounted for the highest increase of 4.029Mt-CO2 (about 106.65%), followed by EI contributing 3.184Mt-CO2 (84.27%) of total carbon emission increase (2007-2012) respectively. Also, the contributory effects of HHS, FM, and CEC on total carbon emissions were only 29.1%, 12.97% and 9.43%, respectively. On the other hand, AHHS was the only significant driver inhibiting CO2 emission during this time interval. The AHHS effect caused a reduction of about -142.44%, amounting to -5.381Mt-CO2 in total emission. Also, Figure 3 presents the carbon emission trajectory from 2013 to 2018. During the period 2013 to 2018, CO2 emissions increased by 3.667 Mt-CO2. EI and AHHS were the most significant factors causing the increase, contributing 151.58% (5.558 Mt-CO2) and 101.18% (3.71 Mt-CO2). HHS effect was the most negatively related driver to the decrease in CO2 emissions by 4.334 Mt-CO2 (-118.19%). The influence of PCI and FM effects on emission reduction was not significant.



Fig. 2. Carbon emission trajectory from 2001 to 2006



Fig.3. Carbon emission trajectory from 2007 to 2012



Fig. 4. Carbon emission trajectory from 2013 to 2018

| Table 2: Decomposition result |
|--------------------------------------|
|--------------------------------------|

| Year | HHS | AHHS | PCI | EI | FM | CEC | Total Change |
|--------------|----------------------------|----------------------------------|------------------------------|---------------------------|--------------------------|----------------------|---------------------------|
| 2000 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2001 | 33920454.60 | -78068269.55 | 55785455.40 | 492133.04 | -96387237.88 | 197760948.28 | 113505483.89 |
| 2002 | 14440506.93 | - 119552265.21 | 86639770.13 | 77640705.67 | - 333507376.02 | -33094566.22 | - 307431222.73 |
| 2003 | -2536919.71 | 27518174.62 | -27784678.03 | 5010348.15 | 18153.74 | -0.01 | 2227081.77 |
| 2004 | -17692955.89 | 17765518.84 | 3762187.09 | -1953682.66 | -21856.66 | 0.00 | 1861214.72 |
| 2005 | 2842062.77 | -38268815.58 | 39106932.37 | 8682110.06 | 408951.03 | 0.00 | 12773245.63 |
| 2006 | 3553741.60 | 139504737.22 | - 150212605.85 | 40204808.15 | -22105522.69 | -13975738.22 | -3028573.80 |
| 2007 | 3796442.34 | 100321584.36 | 100569382.97 | -30838036.97 | 16348716.19 | 14920407.55 | 4477334.71 |
| 2008 | 3904719.93 | -23123707.86 | 4392105.58 | 17797772.24 | 42099.55 | 0.00 | 3014997.43 |
| 2009 | 4285777.68 | 131961570.20 | - 126920462.78 | 3009489.99 | -33473.59 | 0.00 | 12304910.51 |
| 2010 | 7860054.14 | 237742453.38 | 245875547.59 | 93466823.98 | 4352323.64 | 0.02 | 113814305.98 |
| 2011 | 12976834.95 | -95478237.96 | 30866749.81 | 64246283.80 | -129754.33 | -0.07 | 12483887.21 |
| 2012 | 13210485.05 | 99407617.14 | -86100570.87 | -14383971.56 | -59619.81 | 0.00 | 12075951.96 |
| 2013 | 14971085.71 | -42231630.33 | 56547792.57 | 50523823.34 | -1600362.53 | -8903994.18 | 69308727.57 |
| 2014 2015 | 16376226.02 16498838.60 | - 140362551.75 34470955.54 | 109608517.90 -90373288.33 | 5436749.39 77803052.11 | 2180242.88 -232534.79 | 10266769.08 -0.05 | 3507967.52 38169038.09 |

| 2016 | | 2005401045 | 07001065.00 | 45500550.01 | 2410504 52 | 15106465.05 | 15000110 (5 |
|-------|--------------|--------------|--------------|-----------------|-------------------|--------------|----------------|
| 2016 | 1/316/11.// | 29974919.47 | -87801865.03 | 45530570.21 | -2418/04.73 | 15196465.97 | 17800113.67 |
| 2017 | -6094267.09 | 19311516.61 | -11611848.19 | -4534363.57 | - 287184766.60 | -6083074.38 | - 296194786.23 |
| | - | | | | | | |
| 2018 | 240515324.07 | 254171953.29 | -2579859.56 | 57934232.05 | 251912640.64 | -0.01 | 320925660.33 |
| | | | ъ : | | | | |
| | | | Period | dic change | | | |
| 2001- | | | | | - | | - |
| 2006 | 34526890.30 | -51100919.66 | 7297061.11 | 130076422.41 | 451594888.48 | 150690643.83 | 180104790.49 |
| 2007- | | - | | | | | |
| 2012 | 46034314.09 | 225296796.22 | 168682752.30 | 133298361.48 | 20520291.65 | 14920407.50 | 158171387.80 |
| 2013- | - | | | | | | |
| 2018 | 181446729.06 | 155335162.83 | -26210550.64 | 232694063.53 | -37343485.13 | 10476166.43 | 153516720.95 |
| | | | | | | | |
| | | | Cumulative | contribution (% | b) | | |
| 2001- | | | | | | | |
| 2006 | 19.17 | -28.37 | 4.05 | -2.23 | -250.76 | 83.67 | 100 |
| 2007- | | | | | | | |
| 2012 | 29.10 | -142.44 | 106.65 | 84.27 | 12.97 | 9.43 | 100 |
| 2013- | | | | | | | |
| 2018 | -118.19 | 101.18 | -17.07 | 151.58 | -24.33 | 6.82 | 100 |

4. Conclusion

The study mainly focused on energy consumption and the decomposition of CO2 emissions in the Nigerian household sector. The result indicates the changes in the household sector's level and structure of energy consumption between 2000 and 2018, and the total fossil fuel energy consumption grew at an average annual rate of 0.29% over the study period. Consequently, the energy consumption increased from 7.55×10-6 Mt in 2000 to 4.41×10-4 Mt in 2018 (about 57.4%) with a cumulative average of 1.22×10-4 Mt, thus resulting in an increase in fossil energy usage, which may be attributed to population growth, household disposable income level, lifestyle changes and technological advancements. The effects of HHS, PCI, EI, FM, and CEC contributed to the increase in carbon emission, accounting for 1.099Mt-CO2, 4.029Mt-CO2, 3.184Mt-CO2, 4.901×10-1Mt-CO2, and 3.564×10-1 -CO2 respectively. Furthermore, amongst the drivers promoting CO2 emissions change, the PCI effects accounted for the highest increase of 4.029Mt-CO2 (about 106.65%), followed by EI contributing 3.184Mt-CO2 (84.27%) of total carbon emission increase (2007-2012) respectively.

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Modelling of UNICROSS Calabar campus electricity distribution network for power quality improvement using capacitor bank

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Abstract: The power system networks are experiencing growing pressure due to rapid industrialization and population expansion. This strain on the power infrastructure results in increased reactive power consumption by transmission and distribution lines. The inductive nature of these lines causes voltage to drop at the receiving end, negatively impacting consumers and generator performance. To address this issue, this study proposes the use of capacitor banks to mitigate reactive voltage drops and enhance power quality. Load flow analysis employing the Newton-Raphson method is conducted with and without capacitor banks, using the initial system state, which includes load, generation, and mismatch parameters. A comparative evaluation reveals a significant reduction in Mismatch MW when capacitor banks are added, indicating successful alleviation of excess generation issues. The results show that the capacitor banks effectively remove 156 kVA of reactive power from the system, resulting in cost savings and substantial power quality improvement. These capacitor banks rectify undervoltage conditions, ensuring stable and efficient distribution system operation. In conclusion, this study underscores the pivotal role of capacitor banks in enhancing power quality, reducing excess generation, and maintaining distribution system stability. The findings confirm the effectiveness of deploying capacitor banks as a viable solution for power quality enhancement in the face of mounting stress on power systems.

Keywords: Power system networks, Capacitor banks Power quality, Load flow analysis, Newton-Raphson method.

1. Introduction

Power quality is a crucial aspect of electrical systems, vital for the efficient operation of electrical equipment. It encompasses voltage stability, power factor, and harmonic distortion. Poor power quality can lead to equipment malfunctions, creased energy consumption, and financial losses. To enhance power quality, capacitor banks provide reactive power compensation, voltage support and power factor correction [1-4]. Voltage fluctuations caused by load variations, switching operations, or faults can harm sensitive equipment. Capacitor banks stabilize voltage by injecting reactive power, ensuring a consistent power supply. Harmonic distortions, often caused by nonlinear loads like computers and lighting systems, can lead to equipment overheating and interference with communication systems [4-10]. Capacitor banks mitigate harmonics by absorbing or filtering out unwanted harmonic currents. Implementing capacitor banks offers additional benefits. Improved power factor reduces apparent power demand, potentially resulting in cost savings. They enhance voltage support, minimize voltage drops, and optimize system capacity to effectively enhance power quality, careful sizing and placement of capacitor banks are essential [11-14]. Sizing involves determining reactive power requirements and considering load variations and harmonic profiles. Proper placement within the electrical system ensures maximum compensation and avoids adverse effects such as overvoltage or resonance

2. Method

Data collection and system modeling encompass collecting essential information, including load profiles, system configuration, and equipment ratings. This data is then utilized to construct a detailed power system model within ETAP software, covering generators, transformers, transmission lines, and loads. The collected data is input into the software to faithfully replicate the actual power system. In the load flow analysis phase, ETAP is employed to assess the steady-state behavior of the power

system. Problematic areas with power quality issues, such as low power factor and voltage drops, are pinpointed. These findings guide the optimal placement of capacitor banks based on the load flow analysis results. The sizing and placement of capacitor banks are then determined. This involves calculating the required size and quantity of capacitor banks based on the load flow analysis outcomes. The selection of appropriate capacitor bank configurations, whether fixed, switched, or variable, is made to suit the specific requirements of the power system. Furthermore, the optimal locations for capacitor bank installation are carefully chosen to maximize their effectiveness in improving power quality.

$$S_i = V_i I_i = P_i + j Q_i \tag{1}$$

Where;

 S_i denotes the complex power in bus i

 V_i denotes voltage at bus i, which s expressed as follows

$$V_i = |V_i|e^{j\sigma i}$$

$$V_i = |V_i|e^{-j\sigma i}$$
(2)
(3)

$$v_i = |v_i|e^{-y_i t}$$

 σ_i denotes the bus angle at node i

E denotes Euler's constant

 V_i^* denotes the complex bus voltage at node i

$$V_k = |V_k|e^{j\sigma k} \tag{4}$$

 V_k denotes the voltage at bus k

 σ_k denotes the bus angle at node k

The current injected into bus i, can be given as

$$I_i = \sum_{k=1}^{n} Y_{ik} V_k; i = 1, 2, ..., n$$
(5)

$$Y_{ik} = |Y_{ik}|e^{-j\theta_{ik}} \tag{6}$$

 Y_{ik} denotes the admittance at bus I and k

 θ_{ik} denotes the admittance angle at node I and k

 P_i , Q_i denotes the real and reactive power repectively at bus i

$$S_i^* = V_i^* I_i = P_i - jQ_i = \sum_{k=1}^n |V_i| |V_k| |Y_{ik}| e^{-j(\theta_{ik} + \sigma_i - \sigma_k)}$$
(7)

Separating the conjugate complex power S_i^* , into real and imaginary power

$$P_{i} = V_{i}^{2} Y_{ii} cos \theta_{ii} \sum_{k=1, k \neq 1}^{n} |V_{i}|| V_{k} ||Y_{ik}| \cos(\theta_{ik} + \sigma_{i} - \sigma_{k})$$
(8)

Similarly,

Equations 7 and 8 represent the polar form of the power flow equations, which are used to compute the net real power (*Pi*) and reactive power (*Qi*) injected into the network at bus i. These calculated values of *Pi* and *Qi* are denoted as *Pical* and *Qical*, respectively. This notation establishes the concept of mismatches, symbolized as ΔPi and ΔQi , which quantify the differences between the calculated and actual values

$$\Delta P_i = P_{i\,sch} - P_{i\,cal} \tag{9}$$

$$\Delta Q_i = Q_{i\,sch} - Q_{i\,cal} \tag{10}$$

$$P_{i\,sch} = P_{gi} - P_{di} \tag{11}$$

$$Q_{i\,sch} = Q_{gi} - Q_{di} \tag{12}$$

Pisch and Qisch represent the net real and reactive power scheduled to be injected into bus i.

 P_{gi} and Q_{gi} denote the scheduled real and reactive generated power at bus i.

Similarly, P_{di} and Q_{di} represent the scheduled real and reactive power demand at load bus i. Mismatches occur when P_{ical} and Q_{ical} deviate from their scheduled value. The set of linear equations formed expressing the relationship between changes in real and reactive power components of the bus voltages can be written in compact form as:

$$\begin{bmatrix} \Delta P_i \\ \Delta Q_i \end{bmatrix} = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix} \begin{bmatrix} \Delta \sigma_i \\ \Delta V_i \end{bmatrix}$$
(13)

 J_{11} , J_{12} (Jacobian matrix) is set up as a partitioned matrix by convention in the form

$$\begin{bmatrix} \frac{\partial P}{\partial \sigma} & \frac{\partial P}{\partial |V|} \\ \frac{\partial Q}{\partial \sigma} & \frac{\partial Q}{\partial |V|} \end{bmatrix}$$
(14)

The real values in both the off-diagonal and diagonal terms within the sub-matrices are determined through the process of partial differentiation of equations 7 and 8 concerning σi and |Vi|. This relationship is illustrated by the following equations:

$$J_{11} = \frac{\partial P}{\partial \sigma} = \begin{bmatrix} \frac{\partial P_i}{\partial \sigma_i} & \cdots & \frac{\partial P_i}{\partial \sigma_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n}{\partial \sigma_i} & \cdots & \frac{\partial P_n}{\partial \sigma_n} \end{bmatrix}$$
(15)

$$J_{12} = \frac{\partial P}{\partial |V|} = \begin{bmatrix} \frac{\partial P_i}{\partial |V_i|} & \cdots & \frac{\partial P_i}{\partial |V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n}{\partial |V_i|} & \cdots & \frac{\partial P_n}{\partial |V_n|} \end{bmatrix}$$
(16)

$$J_{21} = \frac{\partial Q}{\partial \sigma} = \begin{bmatrix} \frac{\partial Q_i}{\partial \sigma_i} & \cdots & \frac{\partial Q_i}{\partial \sigma_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n}{\partial \sigma_i} & \cdots & \frac{\partial Q_n}{\partial \sigma_n} \end{bmatrix}$$
(17)

$$J_{22} = \frac{\partial P}{\partial |V|} = \begin{bmatrix} \frac{\partial Q_i}{\partial |V_i|} & \cdots & \frac{\partial Q_i}{\partial |V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n}{\partial |V_i|} & \cdots & \frac{\partial Q_n}{\partial |V_n|} \end{bmatrix}$$
(18)

3. Results and Discussion

Discussion of the results obtained from the simulation is presented. Comparison of result of the distribution system data before the capacitor bank was added and after it has been added, and state the observation are made.



Fig. 1. The distribution system on ETAP software.

| Study ID | UNICROSS Calabar campus |
|------------------|-------------------------|
| Study Case ID | LF |
| Data Revision | Base |
| Configuration | Normal |
| Loading Cat | Design |
| Generation Cat | Design |
| Diversity Factor | Normal Loading |
| Buses | 38 |
| Branches | 37 |
| Generators | 0 |
| Power Grids | 1 |
| Loads | 35 |
| Load-MW | -0.0027 |
| Load-Mvar | 0 |
| Generation-MW | -0.0027 |
| Generation-Mvar | 0 |
| Loss-MW | 0.871 |
| Loss-Mvar | 0 |
| Mismatch-MW | 2.579 |
| Mismatch-Mvar | 0 |
| | |

 Table 1. UNICROSS Calabar campus study data 1

Table 2. UNICROSS Calabar campus study data 2

| Study ID | Untitled |
|---------------|----------|
| Study Case ID | LF |
| Data Revision | Base |
| Configuration | Normal |

| Loading Cat | Design |
|------------------|-----------------|
| Generation Cat | Design |
| Diversity Factor | Maximum Loading |
| Buses | 39 |
| Branches | 38 |
| Generators | 0 |
| Power Grids | 1 |
| Loads | 35 |
| Load-MW | 0.118 |
| Load-Mvar | -0.141 |
| Generation-MW | 0.118 |
| Generation-Mvar | -0.141 |
| Loss-MW | 0.0139 |
| Loss-Mvar | 0.0031 |
| Mismatch-MW | 0.091 |
| Mismatch-Mvar | 0.0431 |

 Table 3. Showing the load data before adding the capacitor bank

| ID | Terminal Bus | Rating/Limit | Rated kV | kW | Amp | % |
|--------|-----------------------------|--------------|----------|-------|---------|---------|
| 12 | 1011111111112115 | | | | · ····p | Loading |
| Lump1 | Old Faculty of Engr | 11 kVA | 0.23 | 1.29 | 3.891 | 14.1 |
| Lump2 | Workshop 1 | 1 kVA | 0.23 | 0.334 | 1.252 | 49.9 |
| Lump3 | Workshop 2 | 10 kVA | 0.23 | 3.27 | 13.68 | 54.5 |
| Lump4 | Workshop 3 | 13 kVA | 0.23 | 2.83 | 11.86 | 36.3 |
| Lump5 | Workshop 4 | 10 kVA | 0.23 | 3.27 | 13.68 | 54.5 |
| Lump6 | Workshop 5 | 10 kVA | 0.23 | 4.9 | 20.52 | 81.8 |
| Lump7 | Ministry of Works | 7 kVA | 0.23 | 1.53 | 6.384 | 36.3 |
| Lump8 | New Sci Block 1 | 1 kVA | 0.23 | 0.436 | 1.824 | 72.7 |
| Lump9 | New Sci Block 2 | 9 kVA | 0.23 | 5.89 | 24.63 | 109 |
| Lump10 | Faculty of Info Tech | 9 kVA | 0.23 | 0 | 0 | 0 |
| Lump11 | Acedemic Block A | 7 kVA | 0.23 | 4.58 | 19.15 | 109 |
| Lump12 | Acedemic Block B | 7 kVA | 0.23 | 3.43 | 14.36 | 81.8 |
| Lump13 | Post Graduate Studies | 8 kVA | 0.23 | 4.36 | 18.24 | 90.8 |
| Lump14 | New Edu Block | 7 kVA | 0.23 | 3.05 | 12.77 | 72.7 |
| Lump15 | Old Edu Block | 5 kVA | 0.23 | 2.18 | 9.12 | 72.7 |
| Lump16 | Hall 4 | 10 kVA | 0.23 | 3.82 | 15.96 | 63.6 |
| Lump17 | Hall 3 | 10 kVA | 0.23 | 4.9 | 20.52 | 81.8 |
| Lump18 | Hall 2 | 10 kVA | 0.23 | 4.9 | 20.52 | 81.8 |
| Lump19 | Hall 1 | 10 kVA | 0.23 | 4.9 | 20.52 | 81.8 |
| Lump20 | Dept, of Human Kinetics | 5 kVA | 0.23 | 1.91 | 7.98 | 63.6 |
| Lump21 | Faculty of Bio Sci. | 9 kVA | 0.23 | 6.87 | 28.73 | 127.2 |
| Lump22 | Infomation Centre | 1 kVA | 0.23 | 0.763 | 3.192 | 127.2 |
| Lump23 | SUG block | 5 kVA | 0.23 | 2.72 | 11.4 | 90.8 |
| Lump24 | Faculty of Environmental | 5 kVA | 0.23 | 2.72 | 11.4 | 90.8 |
| Lump25 | Computer lab | 10 kVA | 0.23 | 8.72 | 36.48 | 145.3 |
| Lump26 | Math Classrooms | 5 kVA | 0.23 | 1.63 | 6.84 | 54.5 |
| Lump27 | Dept. of Stat. | 5 kVA | 0.23 | 2.45 | 10.26 | 81.8 |
| Lump28 | Heritage Bank | 10 kVA | 0.23 | 6.54 | 27.36 | 109 |
| Lump29 | Faculty of Engineering | 7 kVA | 0.23 | 4.58 | 19.15 | 109 |
| Lump30 | Faculty of Physical Sci. | 19 kVA | 0.23 | 10.35 | 43.32 | 90.8 |

| Proceedings of the Internationa | l Conference o | n Engineering, Science | e, & Technology | ' (ICEST, 2023) 2 9 |
|---------------------------------|----------------|------------------------|-----------------|----------------------------|
|---------------------------------|----------------|------------------------|-----------------|----------------------------|

| Lump31 | School Libary | 3 kVA | 0.23 | 1.49 | 3.793 | 50.4 |
|--------|-----------------|--------|------|-------|-------|------|
| Lump32 | Others | 11 kVA | 0.23 | 2.74 | 6.946 | 25.2 |
| Lump33 | Admin Block | 9 kVA | 0.23 | 3.35 | 8.577 | 38 |
| Lump34 | CRUTECH Bank | 11 kVA | 0.23 | 4.11 | 10.42 | 37.7 |
| Lump35 | Chapel of Grace | 1 kVA | 0.23 | 0.375 | 0.942 | 37.5 |

 Table 4 Showing the load data after adding the capacitor bank

| ID | Terminal Bus | Туре | Rating/Limit | kW | kvar | Amp | % Loading |
|--------|--------------------------|-----------|--------------|-------|--------|-------|-----------|
| CAP3 | Workshop 1 | Capacitor | -20 kvar | 0 | -23.51 | 60.85 | 121.2 |
| CAP5 | Hall 4 | Capacitor | -11 kvar | 0 | -5 | 20.82 | 75.4 |
| CAP13 | Power Station | Capacitor | -125 kvar | 0 | -160.2 | 397.2 | 126.6 |
| Lump1 | Old Faculty of Engr | Lumped | 11 kVA | 1.36 | 0 | 3.51 | 12.7 |
| Lump2 | Workshop 1 | Lumped | 1 kVA | 0.369 | 0 | 0.965 | 38.4 |
| Lump3 | Workshop 2 | Lumped | 10 kVA | 3.68 | 0 | 9.722 | 38.7 |
| Lump4 | Workshop 3 | Lumped | 5 kVA | 1.22 | 0 | 3.243 | 25.8 |
| Lump5 | Workshop 4 | Lumped | 1 kVA | 0.367 | 0 | 0.974 | 38.8 |
| Lump6 | Workshop 5 | Lumped | 1 kVA | 0.543 | 0 | 1.499 | 59.7 |
| Lump7 | Ministry of Works | Lumped | 7 kVA | 1.64 | 0 | 5.007 | 28.5 |
| Lump8 | New Sci Block 1 | Lumped | 1 kVA | 0.465 | 0 | 1.445 | 57.6 |
| Lump9 | New Sci Block 2 | Lumped | 2 kVA | 1.38 | 0 | 4.465 | 88.9 |
| Lump10 | Faculty of Info Tech | Lumped | 3 kVA | 0 | 0 | 0 | 0 |
| Lump11 | Acedemic Block A | Lumped | 1.5 kVA | 0.981 | 0 | 4.104 | 109 |
| Lump12 | Acedemic Block B | Lumped | 2 kVA | 0.883 | 0.428 | 4.104 | 81.8 |
| Lump13 | Post Graduate Studies | Lumped | 8 kVA | 4.36 | 0 | 18.24 | 90.8 |
| Lump14 | New Edu Block | Lumped | 7 kVA | 3.05 | 0 | 12.77 | 72.7 |
| Lump15 | Old Edu Block | Lumped | 2 kVA | 0.872 | 0 | 3.648 | 72.7 |
| Lump16 | Hall 4 | Lumped | 10 kVA | 3.82 | 0 | 15.96 | 63.6 |
| Lump17 | Hall 3 | Lumped | 10 kVA | 4.9 | 0 | 20.52 | 81.8 |
| Lump18 | Hall 2 | Lumped | 0.5 kVA | 0.245 | 0 | 1.026 | 81.8 |
| Lump19 | Hall 1 | Lumped | 10 kVA | 4.9 | 0 | 20.52 | 81.8 |
| Lump20 | Dept, of Human Kinetics | Lumped | 2 kVA | 0.763 | 0 | 3.192 | 63.6 |
| Lump21 | Faculty of Bio Sci. | Lumped | 3 kVA | 2.17 | 0.715 | 9.576 | 127.2 |
| Lump22 | Infomation Centre | Lumped | 1 kVA | 0.763 | 0 | 3.192 | 127.2 |
| Lump23 | SUG block | Lumped | 5 kVA | 2.72 | 0 | 11.4 | 90.8 |
| Lump24 | Faculty of Environmental | Lumped | 5 kVA | 2.72 | 0 | 11.4 | 90.8 |
| Lump25 | Computer lab | Lumped | 10 kVA | 8.72 | 0 | 36.48 | 145.3 |
| Lump26 | Math Classrooms | Lumped | 5 kVA | 1.63 | 0 | 6.84 | 54.5 |
| Lump27 | Dept. of Stat. | Lumped | 5 kVA | 2.45 | 0 | 10.26 | 81.8 |
| Lump28 | Heritage Bank | Lumped | 10 kVA | 6.54 | 0 | 27.36 | 109 |
| Lump29 | Faculty of Engineering | Lumped | 7 kVA | 4.58 | 0 | 19.15 | 109 |
| Lump30 | Faculty of Physical Sci. | Lumped | 19 kVA | 10.35 | 0 | 43.32 | 90.8 |
| Lump31 | School Library | Lumped | 3 kVA | 1.5 | 0 | 3.783 | 50.2 |
| Lump32 | Others | Lumped | 2 kVA | 0.5 | 0 | 1.253 | 25 |
| Lump33 | Admin Block | Lumped | 9 kVA | 3.35 | 0 | 8.555 | 37.9 |
| Lump34 | CRUTECH Bank | Lumped | 11 kVA | 4.11 | 0 | 10.39 | 37.6 |
| Lump35 | Chapel of Grace | Lumped | 1 kVA | 0.371 | 0 | 0.957 | 38.1 |

When we compare Table 1 and 2, we could deduce that the 'Mismatch MW' has reduced. The "Mismatch MW" is the difference between the total real power generation and the total real power demand. If the Mismatch MW is positive, it means that there is excess power being generated in the system, which can lead to overvoltage and other issues. If it is negative, it indicates that the power demand exceeds the generation, potentially causing

voltage drops and instability, in this case there was excess generation, the capacitor band was able mitigate the problem.

From the results obtained in Table 3, it could be observed that must buses operate under voltage(most operating at 60% of the nominal voltage), buses such as Dept. of Human Kinetics, Dept. of Stat., ETF BLOCK, Faculty of Bio Sci., Faculty of Engineering, Faculty of Environmental, Faculty of Info Tech, Faculty of Physical Sci., Hall 1,2,3, &4, Heritage Bank, Information Centre, Math Classrooms, Ministry of Works, New Education Block, New Science Block 1, New Science Block 2, Old Education Block etc. From Table 4, we could observe that the capacitor banks added to the distributed system was removing 20 + 11 + 125 = 156 Kvar of the reactive power, thereby saving cost of operation. After the capacitor bank was added, there was significant changes in the system as most buses performing under 60%, where now performing within range.

4. Conclusion

After an in-depth examination of the data and results obtained from the simulation of the distribution system with the integrated capacitor banks, several noteworthy conclusions emerge:

- i. **Enhanced Power Quality:** The incorporation of capacitor banks significantly improved the power quality within the distribution system. Notably, the reduction in the "Mismatch MW" parameter indicates a more balanced power supply and demand relationship. The capacitor banks effectively curbed excess power generation, averting potential overvoltage issues while ensuring stable operations.
- ii. **Voltage Stability:** Prior to the installation of capacitor banks, numerous buses operated below the optimal voltage threshold, posing risks of voltage instability. However, the addition of capacitor banks led to substantial enhancements in voltage levels. This resulted in most buses operating within the desired voltage range, contributing to a more stable and reliable distribution system.
- iii. **Operational Cost Savings:** The capacitor banks proved to be instrumental in optimizing the power factor and reducing the requirement for reactive power within the system. Their cumulative effect resulted in the removal of 156 kVa of apparent power. This not only bolstered system efficiency but also translated into tangible cost savings in terms of operational expenditures.

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Load flow analysis of the University of Cross River State (Calabar campus) for effective planning and energy delivery Ndifreke Okon Udofia ^{a,*}, Asuquo Eke ^b

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Abstract: The electrical power distribution network at the University of Cross River State (UNICROSS) in Calabar, Nigeria, plays a critical role in supporting the diverse academic and administrative activities of the institution. However, with a growing campus and varied energy demands, maintaining voltage stability and ensuring an efficient power supply becomes paramount. This work presents a comprehensive load flow analysis of the UNICROSS Calabar Campus distribution network to address these challenges and optimize its performance. The load flow analysis, also known as power flow analysis, is conducted using the Newton-Raphson method. This iterative technique is employed to approximate the nonlinear power system equations as a set of linear equations, allowing for a detailed examination of voltage profiles, active and reactive power flows, and power losses. The results of the analysis reveal several key findings. Many buses within the campus are operating at voltages well below their nominal values, with a significant portion functioning at only 60% of the nominal voltage. These buses include academic and administrative areas, indicating a potential risk to critical operations. Additionally, certain buses exhibit a marked increase in reactive power, likely due to the presence of inductive loads. In conclusion, this study provides essential insights into the performance and challenges of the UNICROSS Calabar Campus electrical distribution network. Addressing these issues is crucial for maintaining the university's academic excellence and research innovation.

Keywords: Load flow analysis, Newton-Raphson method, electrical power distribution network, voltage stability, University of Cross River State.

1. Introduction

Load flow, also known as power flow analysis, is a fundamental technique in electrical engineering used to study and analyze the steady-state behavior of an electrical power system. It involves calculating the various electrical quantities, such as voltages, currents, and power flows, in all the components of the power network, including generators, transmission lines, transformers, and loads [1-5]. It accounts for the complexities of large interconnected power grids and helps optimize the system's operation to ensure a reliable and efficient supply of electrical energy [2]. The University of Cross River State (UNICROSS), situated at approximately 4°55'33" N latitude and 8°19'56" E longitude, stands as a leading educational institution in Nigeria. With its Calabar Campus nestled in the heart of the vibrant city of Calabar, Cross River State (occupying 178.8 hectares on the South Eastern end of the city of Calabar), the university has established itself as a beacon of academic excellence, research innovation, and cultural diversity. It is home to the following faculties: Faculty of Communication Technology, Faculty of Engineering, Faculty of Environmental Sciences, Faculty of Physical Science, and Faculty of Biological Science [6]. The Calabar Campus serves as a hub for academic and research activities, housing a wide range of faculties, departments, research centers, administrative blocks, student hostels, and recreational facilities, because of the high-power demand, the university distribution networks is consistently under strain, leading to a decrease in voltage levels at the load, thereby impacting the power system's efficiency. As the campus continues to grow and expand its academic offerings, ensuring a stable and efficient electrical power supply becomes increasingly crucial to support the myriad activities taking place within its boundaries.

The power distribution network at the Calabar Campus faces various challenges that warrant careful examination. With a diverse array of buildings and facilities, each with unique energy demands, maintaining voltage stability becomes a primary concern. Voltage instability can lead to fluctuations

and dips in voltage levels, adversely affecting electrical appliances, sensitive research equipment, and other critical infrastructure.

To address these challenges and optimize the power distribution network, a thorough load flow analysis becomes imperative. Some of the significance of load flow studies can be seen in grid stability and security, optimal operation and planning, loss minimization, integration of renewable energy sources, voltage regulation [7], by modeling the power system and analyzing parameters such as voltage profiles, active and reactive power flows, and power losses, load flow analysis, we were able to understand the system's behavior and identify areas for improvement.

2. Method

There are various methods of performing load flow analysis as listed in [8-15], but Newton Raphson method was used because of its convergence speed, robustness, & flexibility. The Newton-Raphson method of load flow analysis is an iterative technique employed in electrical power systems to approximate a set of nonlinear simultaneous equations as a set of linear simultaneous equations. This approximation is achieved through the use of Taylor's series expansion, with the terms being limited to a first-order approximation [1-3,5]. The governing non-linear equations that describe the behavior of a power system network are as follows:

$$S_i = V_i I_i = P_i + j Q_i \tag{1}$$

Where;

 S_i denotes the complex power in bus i

 V_i denotes voltage at bus i, which s expressed as follows

$$V_i = |V_i|e^{j\sigma i} \tag{2}$$

$$V_i = |V_i|e^{-j\sigma i} \tag{3}$$

 σ_i denotes the bus angle at node i

E denotes Euler's constant

 V_i^* denotes the complex bus voltage at node i

$$V_k = |V_k|e^{j\sigma k} \tag{4}$$

 V_k denotes the voltage at bus k

 σ_k denotes the bus angle at node k

The current injected into bus i, can be given as

$$I_{i} = \sum_{k=1}^{n} Y_{ik} V_{k}; i = 1, 2, ..., n$$
(5)

$$Y_{ik} = |Y_{ik}|e^{-j\theta_{ik}} \tag{6}$$

 Y_{ik} denotes the admittance at bus I and k

 θ_{ik} denotes the admittance angle at node I and k

 P_i , Q_i denotes the real and reactive power repecively at bus i

$$S_{i}^{*} = V_{i}^{*}I_{i} = P_{i} - jQ_{i} = \sum_{k=1}^{n} |V_{i}||V_{k}||Y_{ik}|e^{-j(\theta_{ik} + \sigma_{i}} - \sigma_{k})$$
(7)

Separating the conjugate complex power S_i^* , into real and imaginary power

$$P_{i} = V_{i}^{2} Y_{ii} cos \theta_{ii} \sum_{k=1, k \neq 1}^{n} |V_{i}|| V_{k} ||Y_{ik}| \cos(\theta_{ik} + \sigma_{i} - \sigma_{k})$$
(8)

Similarly,

Equations7 and 8 represent the polar form of the power flow equations, which are used to compute the net real power (*Pi*) and reactive power (*Qi*) injected into the network at bus i. These calculated values of *Pi* and *Qi* are denoted as *Pical* and *Qical*, respectively. This notation establishes the concept of mismatches, symbolized as ΔPi and ΔQi , which quantify the differences between the calculated and actual values

$$\Delta P_i = P_{i\,sch} - P_{i\,cal} \tag{9}$$

$$\Delta Q_i = Q_{i\,sch} - Q_{i\,cal} \tag{10}$$

$$P_{i\,sch} = P_{gi} - P_{di} \tag{11}$$

$$Q_{i\,sch} = Q_{gi} - Q_{di} \tag{12}$$

Pisch and Qisch represent the net real and reactive power scheduled to be injected into bus i.

 P_{gi} and Q_{gi} denote the scheduled real and reactive generated power at bus i.

Similarly, P_{di} and Q_{di} represent the scheduled real and reactive power demand at load bus i. Mismatches occur when P_{ical} and Q_{ical} deviate from their scheduled value. The set of linear equations formed expressing the relationship between changes in real and reactive power components of the bus voltages can be written in compact form as:

$$\begin{bmatrix} \Delta P_i \\ \Delta Q_i \end{bmatrix} = \begin{bmatrix} J_{11} & J_{12} \\ J_{21} & J_{22} \end{bmatrix} \begin{bmatrix} \Delta \sigma_i \\ \Delta V_i \end{bmatrix}$$
(13)

 J_{11} , J_{12} (Jacobian matrix) is set up as a partitioned matrix by convention in the form

$$\begin{bmatrix} \frac{\partial P}{\partial \sigma} & \frac{\partial P}{\partial |V|} \\ \frac{\partial Q}{\partial \sigma} & \frac{\partial Q}{\partial |V|} \end{bmatrix}$$
(14)

The real values in both the off-diagonal and diagonal terms within the sub-matrices are determined through the process of partial differentiation of equations 7 and 8 concerning σi and |Vi|. This relationship is illustrated by the following equations:

$$J_{11} = \frac{\partial P}{\partial \sigma} = \begin{bmatrix} \frac{\partial P_i}{\partial \sigma_i} & \cdots & \frac{\partial P_i}{\partial \sigma_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n}{\partial \sigma_i} & \cdots & \frac{\partial P_n}{\partial \sigma_n} \end{bmatrix}$$
(15)

$$J_{12} = \frac{\partial P}{\partial |V|} = \begin{bmatrix} \frac{\partial P_i}{\partial |V_i|} & \cdots & \frac{\partial P_i}{\partial |V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial P_n}{\partial |V_i|} & \cdots & \frac{\partial P_n}{\partial |V_n|} \end{bmatrix}$$
(16)

$$J_{21} = \frac{\partial Q}{\partial \sigma} = \begin{bmatrix} \frac{\partial Q_i}{\partial \sigma_i} & \cdots & \frac{\partial Q_i}{\partial \sigma_n} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n}{\partial \sigma_i} & \cdots & \frac{\partial Q_n}{\partial \sigma_n} \end{bmatrix}$$
(17)
$$J_{22} = \frac{\partial P}{\partial |V|} = \begin{bmatrix} \frac{\partial Q_i}{\partial |V_i|} & \cdots & \frac{\partial Q_i}{\partial |V_n|} \\ \vdots & \ddots & \vdots \\ \frac{\partial Q_n}{\partial |V_i|} & \cdots & \frac{\partial Q_n}{\partial |V_n|} \end{bmatrix}$$
(18)

3. Results and Discussion



Fig. 3. Single Line Diagram of the UNICROSS Calabar Campus Distribution network on ETAP

The input data for this simulation were obtained by physical inspection and estimation. An ETAP model was developed using ETAP 16.0 as shown in Figure 2a when not simulated. After data was feed into the model and analyzed using Newton Raphson iterative algorithm as shown in Figure 2b at simulation mode. The results are as shown below:

| Table | 1. | Bus | data | and | results |
|-------|----|-----|------|-----|---------|
| | | | | | |

| Bus ID | Nominal kV | Туре | Voltage | kW Loading | kvar Loading |
|---------------------------|------------|------|---------|------------|--------------|
| Academic Block A | 0.23 | Load | 60 | 0.378 | 0 |
| Academic Block B | 0.23 | Load | 60 | 0.283 | 0 |
| Admin Block | 0.23 | Load | 97.99 | 3.27 | 0.0124 |
| Bus4 | 11 | SWNG | 100 | 75.2 | 0.0895 |
| Chapel of Grace | 0.23 | Load | 99.83 | 0.374 | 0 |
| Computer lab | 0.23 | Load | 60 | 0.72 | 0 |
| CRUTECH Bank | 0.23 | Load | 98.97 | 4.06 | 0.0004 |
| Dept. of Human | 0.23 | Load | 60 | 0.157 | 0 |
| Kinetics | 0.00 | x 1 | (0) | 0.722 | 2.6 |
| Dept. of Stat. | 0.23 | Load | 60 | 0.732 | 2.6 |
| ETF BLOCK | 0.23 | Load | 60 | 0 | 0 |
| Faculty of Bio. Sci. | 0.23 | Load | 60 | 0.567 | 0 |
| Faculty of Engineering | 0.23 | Load | 60 | 0.503 | 1.36 |

| Faculty of | 0.23 | Load | 60 | 0.225 | 0 | |
|---------------------------------------|------|------|-------|-------|--------|--|
| Environmental Faculty of Info Tech | 0.23 | Load | 60 | 0 | 0 | |
| Faculty of Dhysical | 0.23 | Load | 60 | 0 855 | 0 | |
| Faculty of Filysical Sci | 0.23 | Load | 00 | 0.835 | 0 | |
| Hall 1 | 0.23 | Load | 60 | 0.405 | 0 | |
| Hall 2 | 0.23 | Load | 60 | 0.405 | 0.0628 | |
| Hall 3 | 0.23 | Load | 60 | 0.415 | 0.0628 | |
| Hall 4 | 0.23 | Load | 60 | 0.315 | 0 | |
| Heritage Bank | 0.23 | Load | 60 | 0.54 | 0 | |
| Information Centre | 0.23 | Load | 60 | 0.063 | 0 | |
| Math Classrooms | 0.23 | Load | 60 | 0.135 | 0.082 | |
| Ministry of Works | 0.23 | Load | 60 | 0.178 | 0.476 | |
| New Education Block | 0.23 | Load | 60 | 0.252 | 0 | |
| New Science Block 1 | 0.23 | Load | 60 | 0.036 | 0.0347 | |
| New Science Block 2 | 0.23 | Load | 60 | 0.486 | 0.28 | |
| Old Education Block | 0.23 | Load | 60 | 0.18 | 0 | |
| Old Faculty of Engr. | 0.23 | Load | 83.25 | 52.41 | 3.28 | |
| Others | 0.23 | Load | 98.98 | 2.71 | 0.0001 | |
| Post Graduate Studies | 0.23 | Load | 60 | 0.36 | 0 | |
| Power Station | 0.23 | Load | 99.96 | 75.17 | 2.16 | |
| PREFAB BLOCK | 0.23 | Load | 60 | 0 | 0 | |
| School Library | 0.23 | Load | 98.8 | 4.78 | 0.0232 | |
| SUG block | 0.23 | Load | 60 | 0.225 | 0 | |
| Workshop 1 | 0.23 | Load | 66.88 | 41.01 | 1.6 | |
| Workshop 2 | 0.23 | Load | 60 | 20.8 | 3.74 | |
| Workshop 3 | 0.23 | Load | 60 | 0.355 | 1.15 | |
| Workshop 4 | 0.23 | Load | 60 | 0.424 | 0.777 | |
| Workshop 5 | 0.23 | Load | 60 | 0.5 | 0.777 | |

Table 2. Load data

| ID | Terminal Bus | Rating/Limit | Rated kV | kW | Amp | % | Vtermal |
|--------|-----------------------|---------------------|----------|-------|-------|---------|---------|
| | | | | | | Loading | |
| Lump1 | Old Faculty of Engr. | 11 kVA | 0.23 | 1.29 | 3.891 | 14.1 | 83.25 |
| Lump2 | Workshop 1 | 1 kVA | 0.23 | 0.334 | 1.252 | 49.9 | 66.88 |
| Lump3 | Workshop 2 | 10 kVA | 0.23 | 3.27 | 13.68 | 54.5 | 60 |
| Lump4 | Workshop 3 | 13 kVA | 0.23 | 2.83 | 11.86 | 36.3 | 60 |
| Lump5 | Workshop 4 | 10 kVA | 0.23 | 3.27 | 13.68 | 54.5 | 60 |
| Lump6 | Workshop 5 | 10 kVA | 0.23 | 4.9 | 20.52 | 81.8 | 60 |
| Lump7 | Ministry of Works | 7 kVA | 0.23 | 1.53 | 6.384 | 36.3 | 60 |
| Lump8 | New Science Block 1 | 1 kVA | 0.23 | 0.436 | 1.824 | 72.7 | 60 |
| Lump9 | New Science Block 2 | 9 kVA | 0.23 | 5.89 | 24.63 | 109 | 60 |
| Lump10 | Faculty of Info Tech | 9 kVA | 0.23 | 0 | 0 | 0 | 60 |
| Lump11 | Academic Block A | 7 kVA | 0.23 | 4.58 | 19.15 | 109 | 60 |
| Lump12 | Academic Block B | 7 kVA | 0.23 | 3.43 | 14.36 | 81.8 | 60 |
| Lump13 | Post Graduate Studies | 8 kVA | 0.23 | 4.36 | 18.24 | 90.8 | 60 |
| Lump14 | New Education Block | 7 kVA | 0.23 | 3.05 | 12.77 | 72.7 | 60 |
| Lump15 | Old Education Block | 5 kVA | 0.23 | 2.18 | 9.12 | 72.7 | 60 |
| Lump16 | Hall 4 | 10 kVA | 0.23 | 3.82 | 15.96 | 63.6 | 60 |
| Lump17 | Hall 3 | 10 kVA | 0.23 | 4.9 | 20.52 | 81.8 | 60 |
| Lump18 | Hall 2 | 10 kVA | 0.23 | 4.9 | 20.52 | 81.8 | 60 |
| Lump19 | Hall 1 | 10 kVA | 0.23 | 4.9 | 20.52 | 81.8 | 60 |
| | Proceedings of the International | Conference or | n Engineering, Science, & | technology (ICEST, 2023) 37 کړ |
|--|----------------------------------|---------------|---------------------------|---------------------------------------|
|--|----------------------------------|---------------|---------------------------|---------------------------------------|

| Lump20 | Dept. of Human Kinetics Dept. | 5 kVA | 0.23 | 1.91 | 7.98 | 63.6 | 60 |
|--------|----------------------------------|--------|------|-------|-------|-------|-------|
| Lump21 | Faculty of Bio Sci. | 9 kVA | 0.23 | 6.87 | 28.73 | 127.2 | 60 |
| Lump22 | Information Centre | 1 kVA | 0.23 | 0.763 | 3.192 | 127.2 | 60 |
| Lump23 | SUG block | 5 kVA | 0.23 | 2.72 | 11.4 | 90.8 | 60 |
| Lump24 | Faculty of Environmental | 5 kVA | 0.23 | 2.72 | 11.4 | 90.8 | 60 |
| Lump25 | Computer lab | 10 kVA | 0.23 | 8.72 | 36.48 | 145.3 | 60 |
| Lump26 | Math Classrooms | 5 kVA | 0.23 | 1.63 | 6.84 | 54.5 | 60 |
| Lump27 | Dept. of Stat. | 5 kVA | 0.23 | 2.45 | 10.26 | 81.8 | 60 |
| Lump28 | Heritage Bank | 10 kVA | 0.23 | 6.54 | 27.36 | 109 | 60 |
| Lump29 | Faculty of Engineering | 7 kVA | 0.23 | 4.58 | 19.15 | 109 | 60 |
| Lump30 | Faculty of Physical Sci. | 19 kVA | 0.23 | 10.35 | 43.32 | 90.8 | 60 |
| Lump31 | School Library | 3 kVA | 0.23 | 1.49 | 3.793 | 50.4 | 98.8 |
| Lump32 | Others | 11 kVA | 0.23 | 2.74 | 6.946 | 25.2 | 98.98 |
| Lump33 | Admin Block | 9 kVA | 0.23 | 3.35 | 8.577 | 38 | 97.99 |
| Lump34 | CRUTECH Bank | 11 kVA | 0.23 | 4.11 | 10.42 | 37.7 | 98.97 |
| Lump35 | Chapel of Grace | 1 kVA | 0.23 | 0.375 | 0.942 | 37.5 | 99.83 |

Table 3. Branch data

| ID | Туре | kW Flow | kvar Flow | Amp Flow | % Voltage Drop | kvar Losses |
|-----|-------|---------|-----------|----------|-------------------|-------------|
| C1 | Cable | 2.74 | 0.0042 | 6.874 | 0.98 | 0.0041 |
| C3 | Cable | 50.97 | 3.25 | 154 | 16.37 | 1.96 |
| C4 | Cable | 23.2 | -0.31 | 87.08 | 6.88 | 0.499 |
| C5 | Cable | 0.231 | -1.15 | 4.895 | 0 | 0.002 |
| C6 | Cable | 0.121 | -0.767 | 3.248 | 0 | 0.0009 |
| C7 | Cable | 0.154 | -0.777 | 3.314 | 0 | 0.0001 |
| C8 | Cable | 0.0941 | -0.476 | 2.031 | 0 | 0.0001 |
| С9 | Cable | 0.0092 | -0.0347 | 0.15 | 0 | 0 |
| C10 | Cable | 0.0424 | -0.28 | 1.184 | 0 | 0.0001 |
| C11 | Cable | 0 | 0 | 0 | 0 | 0 |
| C13 | Cable | 3.3 | 0.0226 | 8.387 | 0.81 | 0.0101 |
| C14 | Cable | 4.83 | 0.0205 | 12.14 | 1.17 | 0.0212 |
| C15 | Cable | 0.687 | -2.6 | 11.25 | 0 | 0.0022 |
| C16 | Cable | 4.1 | 0.0149 | 10.31 | 0.99 | 0.0153 |
| C17 | Cable | 0.375 | 0.0001 | 0.941 | 0.13 | 0.0001 |
| C18 | Cable | 0.517 | -1.35 | 6.056 | 0 | 0.0053 |
| C19 | Cable | 0 | 0 | 0 | 0 | 0 |
| C20 | Cable | 0 | 0 | 0 | 0 | 0 |
| C21 | Cable | 0.0126 | -0.082 | 0.347 | 0 | 0 |
| C22 | Cable | 0 | 0 | 0 | 0 | 0 |
| C23 | Cable | 0 | 0 | 0 | 0 | 0 |
| C24 | Cable | 0 | 0 | 0 | 0 | 0 |
| C25 | Cable | 0 | 0 | 0 | 0 | 0 |
| C26 | Cable | 0 | 0 | 0 | 0 | 0 |
| C27 | Cable | 0 | 0 | 0 | 0 | 0 |
| C28 | Cable | 0 | 0 | 0 | 0 | 0 |
| C29 | Cable | 0 | 0 | 0 | 0 | 0 |
| C30 | Cable | 0 | 0 | 0 | 0 | 0 |
| C31 | Cable | 0 | 0 | 0 | 0 | 0 |

| C32 | Cable | 0 | 0 | 0 | 0 | 0 |
|------|------------|--------|---------|-------|-------|-------|
| C33 | Cable | 0 | 0 | 0 | 0 | 0 |
| C34 | Cable | 0.0096 | -0.0628 | 0.266 | 0 | 0 |
| C34a | Cable | 0 | 0 | 0 | 0 | 0 |
| C35 | Cable | 0 | 0 | 0 | 0 | 0 |
| C35a | Cable | 0 | 0 | 0 | 0 | 0 |
| C36 | Cable | 0 | 0 | 0 | 0 | 0 |
| C41 | Cable | 62.89 | 2.04 | 158 | 16.71 | 2.06 |
| T1 | Transf. 2W | 75.2 | 0.0895 | 3.947 | 0.04 | 0.174 |

From the results obtained above, it could be observed that must buses operate under voltage(most operating at 60% of the nominal voltage), buses such as Dept. of Human Kinetics, Dept. of Stat., ETF BLOCK, Faculty of Bio Sci., Faculty of Engineering, Faculty of Environmental, Faculty of Info Tech, Faculty of Physical Sci., Hall 1, 2, 3, & 4, Heritage Bank, Information Centre, Math Classrooms, Ministry of Works, New Edu Block, New Sci Block 1, New Sci Block 2, Old Edu. Block etc. While buses such as Admin block, Chapel of grace, Crutech Bank, School library are operating within the range. Also, we could also detect a critical increase in reactive power in the following buses; Workshop 1,2,3, and Old Faculty of Engineering, this could be cause by the presence of more inductive load.

4. Conclusion

In conclusion, this comprehensive load flow analysis of the power system at the Calabar Campus of the University of Cross River State (UNICROSS) has provided essential insights into the performance and challenges of the campus's electrical distribution network. The findings of this study shed light on critical issues that affect the quality and reliability of electrical power supply to various campus locations. One of the key observations from the analysis is that a significant number of buses within the campus are operating under voltage conditions, with many of them functioning at only 60% of the nominal voltage. Notably, these buses encompass important academic and administrative areas, including the Department of Human Kinetics, Department of Statistics, ETF Block, various faculties, halls, bank, and more. Conversely, certain key locations such as the Administration block, Chapel of Grace, Crutech Bank, and the School library are operating within an acceptable voltage range. Furthermore, the analysis has identified a critical increase in reactive power in specific buses, including Workshop 1, 2, 3, and the Old Faculty of Engineering. This phenomenon can be attributed to the presence of substantial inductive loads in these areas.

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Investigation of electromagnetic radiation from CRUTECH electric power substation

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Received 04 November 2023; Accepted 18 November 2023 Abstract: The aim of this study is to empirically quantify the electric field intensity and the associated magnetic field strength emitted from an injection sub-station and compare results with the generally accepted safety standards such as the International Committee for Non-Ionization Radio Protection (ICNIRP) Standards. For the purpose of this study, We adopted the method of obtaining measurements using appropriate Instrumentation and Employing computational capabilities in order to simulate the propagation environment for easy analysis. MUSTOOL (MT525) Electromagnetic radiation meter a portable field survey instrument that conforms to international standards was used. The switch yard was modelled as a rectangular box, while measurements were taken at specific locations around the box. These locations were sixty in number each having their corresponding x and y axes. At each point, measurements were obtained at three different heights of 1m, 1.5m and 1.75m at each point. But preliminary measurements showed that the Electric field was constant at all these heights. The magnetic field strength measured at a height of 1.5m, 1m, and 1.75m, had a maximum value of 54μ T, 57.699μ T, and 29.93μ T, respectively. The Electric field intensity measured at a height of 1.5m peaked at 0.293kV/m. Contour plots show areas of interest in this investigation. It was noticed that the contour lines increase inwards. This indicates a buildup of magnetic field or electric field at these areas of interest. This was further buttressed by the surface plots, which highlights these areas of interest as elevations on the surface. When compared to the generally acceptable safety standard for public and occupational exposure to power-frequency EMFs. These values were less and within the limit recommended by International Commission on Non-Ionizing Radiation Protection (ICNIRP).

Keywords: Electromagnetic radiation, electric field, magnetic field

1. Introduction

The quantification of electric field strength and its associated magnetic field intensity radiated from injection sub-stations in Calabar, panacea health and environmental effects are subjects of the ongoing research. Radiation is the emission of streams of particles such as electrons, protons, high energy photons or an emission of a combination of these; each particle contains a certain amount of energy, which increases with growing frequency. This energy spreads out as it moves. Instead of producing charged ions when passing through matter, the electromagnetic radiation has sufficient energy only for excitation, the movement of an electron to a higher energy state They include radio waves, microwaves, infrared, visible light and the ultraviolet rays. In a study conducted in the city of Mashhad, Iran by [1], which involved the measurement of ELF-EMF levels at 10 different locations near power substations. The results of the study showed that the ELF-EMF levels at all 10 locations were below the international safety guidelines. The study had a number of merits which are, Firstly, it methodology, which means that the results are more likely to be representative of the ELF-EMF levels that people are exposed to in everyday life and the accuracy of the results. Finally, the study compared the results to international safety guidelines, which provided a context for understanding the significance of the findings. One of the limitations of the study was that it was only conducted in a single city. It is possible that the results would be different in other cities, with different power substations and different environmental conditions. Another limitation of the study was that it did not measure the long-term health effects of ELF-EMF exposure. Overall, the study provided valuable information about the ELF-EMF levels due to power substations in an urban environment. The results of the study suggest that the ELF-EMF levels in Mashhad, Iran, are below the international safety guidelines. Similarly, a study of the electromagnetic environment from a 750 kV transformer substation in Gansu Province, China by [2] involved the measurement of electric field intensity, magnetic field intensity, and noise at different locations around the substation. The results of the study showed that the electric field intensity and magnetic field intensity were highest near the circuit

breaker and switchgear equipment. The noise levels were highest near the reactor and transformer equipment. Consequently, it merits and demerits were similar to that of [1]. Further studies conducted by [3] in Malaysia had a different scope in that the measurement of ELF EMF levels was at various locations in each residence. The results of the study showed that the ELF EMF levels in all three residences were below the international safety guidelines. However, the levels were highest in the owner-occupied house, and lowest in the under-construction condominium. They suggested that it was because the owner-occupied house had more electrical appliances and wiring than the other two residences. Its merits and demerits were similar to studies conducted by [1] and [2]. In a more recent study by [4] in Nigeria, which involved the measurement of magnetic field levels at different locations around common home electrical appliances, such as refrigerators, televisions, and microwave ovens, the results showed that the magnetic field levels from common home electrical appliances can vary significantly depending on the appliance and the distance from the appliance. They used the results of the measurements to assess the exposure of people to magnetic fields from common home electrical appliances. He found that the exposure of people to magnetic fields from common home electrical appliances is generally below the international safety guidelines. However, he also found that some people, such as those who spend a lot of time near electrical appliances, may be exposed to magnetic fields that exceed the safety guidelines. They concluded by discussing the implications of his findings for public health. He notes that the long-term health effects of exposure to magnetic fields are still being studied, but that there is some evidence that exposure to high levels of magnetic fields may be associated with an increased risk of certain health problems, such as cancer. [5] discussed the need for a remote and safe monitoring system for magnetic fields produced by transmission lines in areas of high concentration of lightning strokes. The authors argued that such a system is necessary to protect workers and residents from the potential health risks associated with exposure to magnetic fields. The also described a prototype system that they had developed for remote and safe monitoring of magnetic fields. The system uses a magnetic field sensor to measure the field strength at a safe distance from the transmission lines. The data is then transmitted to a central computer for analysis. They evaluated the performance of their prototype system in a field trial. They found that the system was able to accurately measure magnetic field strength at distances of up to 100 meters from the transmission lines. The system was also able to detect changes in magnetic field strength caused by lightning strikes. A recent study showed that when people used a cell phone for 50 minutes, brain tissues on the same side of the head as the phone 's antenna metabolized more glucose than did tissues on the opposite side of the brain. Inhabitants living near mobile phone base stations suffered from frequent headaches, memory changes, dizziness, tremors, depressive syndrome and sleep disturbance [6]. [7] investigated electromagnetic radiations at high frequencies in order to assess its level of impact on the environment especially as it concerns the pulsed signal at microwave frequencies. They also offered some perspectives on the potential implications for human health exposure on the radiation should it exposure limit exceed the recommended safety zone of about 300 meters away from the base stations. They employed two measurement procedures; one for determining the power density due to the base station of interest, the other for evaluating the total exposure within the university environment. The maximum level recorded at the various sites was 1.3 mW/m² while the total sum of radiation level encountered was about 2 mW/m². The investigated level was compared with the international safety level and was found to be below the recommended safety level as provided by international agencies such as ICNIRP and ANSI as examples.

The proliferation of power transformers on our street is common practice. There are few literatures on the EMR from injection sub-stations in our locality compared to the volumes that exist for Cellular Base station. Thus, this study seeks to bridge this gap by empirically quantifying its characteristics. Also, this study seeks to buttress the need for individuals to adhere to stipulated guidelines or policies while procuring land or properties closed to injection sub-stations by diligently carrying out this study, the gravely effect of these EMR will be highlighted

2. Method

2.1 Study area

The study was carried out in an injection sub-station in Calabar south local government area of cross river state. It is called Crutech injection sub-station rated 33KV/11KV. It comprised of two 7.5MVA power transformers called Anatigha and Crutech feeders. It was constructed with the aim of servicing Anatigha and the state owed University (CRUTECH).



Fig. 1. Study area at CRUTECH injection substation

2.2 Modelling the Study Area

The substation and its environment were modeled as a set concentric rectangle, such that the switch yard was located in the inner rectangle.



Fig. 2. Modelled switchyard

2.3 Objective Measurements

Measurements were taken at specific distances away from the switch yard at three (3) different heights of 1m, 1.5m and 1.75m. These locations were sixty in number each having their corresponding

x and y axes. The methodology adopted was the broadband measurement technique. The MUSTOOL MT525 Electromagnetic radiation meter which is a portable field survey instrument that conforms with international standards such as GB8702-1988 regulation for electromagnetic radiation protection, HJ/T 10.3-1996 Environmental Impact Assessment Methods and Standard on Electromagnetic radiation and GB9175-88 Hygienic Standard for Environmental Electromagnetic waves was used.

3. Results and Discussion

Preliminary measurements showed that the Electric field was constant at all these heights traversing either the X or Y axis, however, the magnetic field strength varies at the different height. Hence, the magnetic field strength was measured at these three (3) heights along the X and Y axis.

| Location | X- A vis(m) | Y- | Magnetic Flux Density (µT) | | | Electric Field | |
|----------|----------------|-----------|----------------------------|--------|--------|------------------|--|
| | AXIS(III) | AXIS(III) | 1.5m | 1m | 1.75m | Intensity (kV/m) | |
| 1. | -1.50 | 0.00 | 54.304 | 31.450 | 29.280 | 0.014 | |
| 2. | - 1.50 | 1.00 | 45.720 | 57.699 | 25.176 | 0.030 | |
| 3. | -1.50 | 2.00 | 34.570 | 42.892 | 20.186 | 0.035 | |
| 4. | 0.00 | 2.00 | 32.376 | 25.996 | 19.950 | 0.043 | |
| 5. | 1.5 | 2.00 | 24.263 | 17.139 | 12.050 | 0.164 | |
| 6. | 3.00 | 2.00 | 14.897 | 12.056 | 8.436 | 0.055 | |
| 7. | 5.00 | 2.00 | 14.613 | 10.391 | 6.990 | 0.043 | |
| 8. | 5.00 | 1.00 | 12.607 | 7.305 | 5.980 | 0.060 | |
| 9. | 5.00 | 0.00 | 10.954 | 5.386 | 5.168 | 0.040 | |
| 10. | 3.00 | 0.00 | 15.492 | 16.120 | 13.824 | 0.035 | |
| 11. | 1.5 | 0.00 | 29.644 | 20.174 | 11.555 | 0.085 | |
| 12. | 0.00 | 0.00 | 42.801 | 23.758 | 16.356 | 0.019 | |
| 13. | -3.00 | 0.00 | 36.464 | 31.247 | 18.128 | 0.010 | |
| 14. | -3 .00 | 1.00 | 23.644 | 27.750 | 14.052 | 0.016 | |
| 15. | -3 .00 | 2.00 | 18.246 | 16.935 | 13.248 | 0.020 | |
| 16. | -3.00 | 3.00 | 12.736 | 9.756 | 8.687 | 0.350 | |
| 17. | -1.50 | 3.00 | 21.256 | 15.777 | 12.698 | 0.352 | |
| 18. | 0.00 | 3.00 | 28.514 | 19.490 | 16.365 | 0.028 | |
| 19. | 1.5 | 3.00 | 16.942 | 12.804 | 7.790 | 0.080 | |
| 20. | 3.00 | 3.00 | 10.087 | 8.865 | 5.242 | 0.035 | |
| 21. | 5.00 | 3.00 | 7.542 | 6.001 | 4.685 | 0.023 | |
| 22. | 6.00 | 3.00 | 5.658 | 4.745 | 3.562 | 0.235 | |
| 23. | 6.00 | 2.00 | 9.565 | 8.029 | 5.775 | 0.028 | |
| 24. | 6.00 | 1.00 | 7.147 | 5.615 | 4.315 | 0.030 | |
| 25. | 6.00 | 0.00 | 5.822 | 3.085 | 3.951 | 0.025 | |
| 26. | 6.00 | -1.00 | 3.000 | 3.908 | 3.756 | 0.026 | |
| 27. | 5.00 | -1.00 | 5.362 | 5.632 | 5.000 | 0.030 | |
| 28. | 3.00 | -1.00 | 12.516 | 13.922 | 10.705 | 0.020 | |

Table 1. Magnetic Flux Density (µT) and Electric Field Intensity (KV/m) at different locations and heights

| 29. | 1.5 | -1.00 | 19.886 | 15.828 | 8.827 | 0.030 |
|-----|-------|-------|--------|--------|--------|-------|
| 30. | 0.00 | -1.00 | 28.296 | 24.655 | 12.920 | 0.010 |
| 31. | -1.50 | -1.00 | 22.758 | 19.653 | 10.956 | 0.015 |
| 32. | -3.00 | -1.00 | 18.652 | 14.563 | 7.845 | 0.012 |
| 33. | -5.00 | -1.00 | 14.65 | 10.654 | 6.564 | 0.012 |
| 34. | -5.00 | 0.00 | 26.731 | 19.381 | 12.185 | 0.011 |
| 35. | -5.00 | 1.00 | 19.980 | 15.350 | 11.910 | 0.010 |
| 36. | -5.00 | 2.00 | 12.378 | 11.274 | 9.460 | 0.001 |
| 37. | -5.00 | 3.00 | 7.652 | 9.685 | 8.897 | 0.001 |
| 38. | -5.00 | 5.00 | 3.333 | 7.666 | 3.265 | 0.001 |
| 39. | -3.00 | 5.00 | 4.854 | 6.859 | 7.596 | 0.001 |
| 40. | -1.5 | 5.00 | 10.444 | 12.458 | 8.152 | 0.001 |
| 41. | 0.00 | 5.00 | 16.125 | 16.143 | 10.628 | 0.020 |
| 42. | 1.5 | 5.00 | 10.777 | 8.286 | 5.125 | 0.047 |
| 43. | 3.00 | 5.00 | 7.826 | 5.842 | 3.850 | 0.035 |
| 44. | 5.00 | 5.00 | 4.156 | 3.865 | 3.215 | 0.030 |
| 45. | 6.00 | 5.00 | 3.768 | 3.665 | 2.879 | 0.025 |
| 46. | 7.00 | 5.00 | 3.200 | 3.497 | 2.126 | 0.022 |
| 47. | 7.00 | 3.00 | 4.258 | 3.263 | 2.664 | 0.022 |
| 48. | 7.00 | 2.00 | 5.895 | 5.148 | 3.011 | 0.020 |
| 49. | 7.00 | 1.00 | 4.158 | 3.397 | 2.276 | 0.020 |
| 50. | 7.00 | 0.00 | 3.028 | 3.189 | 3.095 | 0.014 |
| 51. | 7.00 | -1.00 | 3.264 | 3.258 | 3.542 | 0.012 |
| 52. | 7.00 | -3.00 | 3.011 | 2.895 | 2.658 | 0.012 |
| 53. | 6.00 | -3.00 | 3.276 | 3.158 | 3.565 | 0.011 |
| 54. | 5.00 | -3.00 | 3.095 | 3.028 | 3.542 | 0.010 |
| 55. | 3.00 | -3.00 | 7.386 | 8.090 | 6.005 | 0.015 |
| 56. | 1.5 | -3.00 | 10.013 | 12.072 | 8.493 | 0.020 |
| 57. | 0.00 | -3.00 | 16.802 | 16.652 | 11.515 | 0.010 |
| 58. | -1.50 | -3.00 | 10.542 | 9.658 | 7.095 | 0.012 |
| 59. | -3.00 | -3.00 | 7.542 | 5.565 | 4.542 | 0.012 |
| 60. | -5.00 | -3.00 | 3.658 | 3.542 | 2.658 | 0.011 |

3.1 Surface and contour plots

Figures 3, 4, and 5 shows surface plots of magnetic field strength at a height of 1.5m, 1m and 1.75m respectively. While Figure 3.4 shows the surface plot of the electric field intensity. These plots show areas of interest as elevated pyramids; the spikes show areas of concern which are indications of elevated levels. The flat surfaces show areas of constant radiation. Figures 3.5, 3.6 and 3.7 show contour plots of the magnetic field strength at a height of 1.5m, 1m and 1.75m respectively. While Figure 3.8 shows contour plot of the electric field intensity. These plots show a build-up of magnetic field and electric field in specific areas of interest shown in yellow.



Fig. 3. Surface plot of the magnetic flux density at a height of 1.5m



Fig. 4. Surface plot of the magnetic flux density at a height of 1m



Fig. 5. Surface plot of the magnetic flux density at a height of 1.75m



Fig. 6. Surface plot of the electric field at a height of 1.5m



Fig. 7. Contour plot of the magnetic flux density at a height of 1.5m



Fig. 8. Contour plot of the magnetic flux density at a height of 1m



Fig. 9. Contour plot of the magnetic flux density at a height of 1.75m



Fig. 10. Contour plot of the electric field at a height of 1.5m

3.2 Discussion

It was noticed that all the measurement took the form of a normal curve, the magnetic field strength measured at a height of 1.5m along the y-axis peaked when y was 0m except for values of x greater than 3 that peaked when y was 2m. When x was -5, -3, -1.5, 0, 1.5, 3, 5, 6 and the magnetic field strength measured at a height of 1.5m along the y-axis peaked 26.731µT, 36.464 µT, 54µT, 42.801 μT, 29.644 μT, 28.514 μT, 14.613 μT, 9.565 μT and 5.895 μT respectively. Its highest value was 54μ T at x = -1.5m corresponding to measurement point 1, having a coordinate of x = -1.5 and y =0. The magnetic field strength measured at a height of 1m along the y-axis all peaked when y was 0m except for values of x equal to 5, 6 and 7 that peaked at y equal to 2m and x equal to -1.5 peaked at y =1. When x was -5, -3, -1.5, 0, 1.5, 3, 5,6 and 7 the magnetic field strength measured at a height of 1.5m along the y-axis peaked 19.381µT, 31.247µT, 57.699µT, 23.758µT, 20.174µT, 16.120µT, 10.391 μ T, 8.029 μ T and 5.148 μ T respectively. Its highest value was 57.699 μ T at x = -1.5m corresponding to measurement point 2, having a coordinate of x equal to -1.5 and y equal to 1. The magnetic field strength measured at a height of 1.75m along the y-axis all peaked when y was 0m except for values of x equal to 5, 6 and 7 that peaked at y equal to 2m and x equal to 1.5 peaked at y =1. When x was -5, -3, -1.5, 0, 1.5, 3, 5,6 and 7 the magnetic field strength measured at a height of 1.5m along the y-axis peaked 12.185µT, 18.128µT, 29.280µT, 16.356µT, 12.050µT, 13.824µT, 6.990 μ T, 5.775 μ T and 3.011 μ T respectively. Its highest value was 57.699 μ T at x = -1.5m corresponding to measurement point 1, having a coordinate of x = -1.5 and y = 0.

The magnetic field strength measured at a height of 1.5m along the x-axis peaked when x was either -1.5m (for values of y equal to 0, 1, and 2) or 0m (for values of y equal to -3, -1, 3 and 5). When y was -3, -1, 0, 1, 2, 3, and 5 the magnetic field strength measured at a height of 1.5m along the y-axis peaked 16.802µT, 28.296µT, 54.304µT, 45.720µT, 34.570µT, 18.652 µT, and 14.65µT respectively. Its highest value was 54μ T at x = -1.5m corresponding to measurement point 1, having a coordinate of x = -1.5 and y = 0. The magnetic field strength measured at a height of 1m along the x-axis peaked when x was either -1.5m (for values of y equal to 1, and 2) or 0m (for values of y equal to -3, -1, 0, 3 and 5). When y was -3, -1, 0, 1, 2, 3, and 5 the magnetic field strength measured at a height of 1.5m along the y-axis peaked 16.652µT, 24.655µT, 23.758µT, 57.699µT, 42.892µT, 19.490 µT, and 16.143μ T respectively. Its highest value was 57.699μ T at x = -1.5m corresponding to measurement point 2, having a coordinate of x = -1.5 and y = 1. The magnetic field strength measured at a height of 1.75m along the x-axis peaked when x was either -1.5m (for values of y equal to 0, and 1, 2) or 0m (for values of y equal to -3, -1, 3 and 5). Thus, when y was -3, -1, 0, 1, 2, 3, and 5 the magnetic field strength measured at a height of 1.75m along the y-axis peaked 11.515µT, 12.920µT, 29.280µT, 25.176μ T, 20.186μ T, 16.365μ T, and 10.628μ T respectively. Its highest value was 29.680μ T at x = -1.5m corresponding to measurement point 2, having a coordinate of x = 0 and y = 0.

As stated earlier, the electric field intensity at the three different heights were fairly constant. Hence, the Electric field intensity measured at a height of 1.5m along the y-axis peaked when y was 0m except for values of x equal to -1.5 and 0 that peaked when y was equal to 1m and 2m respectively. When x was -5, -3, -1.5, 0, 1.5, 3, 5, 6 and 7 the electric field intensity measured at a height of 1.5m along the y-axis peaked 0.024kV/m, 0.037kV/m, 0.088kV/m, 0.293kV/m, 0.265kV/m, 0.223 kV/m, 0.145 kV/m, 0.118 kV/m and 0.131 kV/m respectively. Its highest value was 0.293kV/m at x = 0m corresponding to measurement point 4, having a coordinate of x =0 and y =2.

The Electric field intensity measured at a height of 1.5m along the x-axis peaked when x was 0m except for y equal to 1 that peaked when x was equal to 5m respectively. When y was -3, -1, 0, 1, 2, 3, and 5 the electric field intensity measured at a height of 1.5m along the y-axis peaked 0.088kV/m, 0.096kV/m, 0.254kV/m, 0.112kV/m, 0.293kV/m, 0.194kV/m, and 0.073 kV/m respectively. Its highest value was 0.293 kV/m at x = 0m corresponding to measurement point 4, having a coordinate of x =0 and y =2.

The contour plots show areas of interest in these investigations, these areas of are shown in yellow. It is noticed that the contour lines increase inwards. This indicates a buildup of magnetic field or electric field at these areas of interest. These is further buttressed by the surface plots, which highlights these areas of interest as elevations on the surface.

Generally accepted guidelines have been established for safe public and occupational exposure to power-frequency EMFs. The reference levels for general public exposure are, according to the International Commission on Non-Ionizing Radiation Protection (ICNIRP) guidelines for the electric-field strength, magnetic field strength and magnetic flux density at 50Hz are 5kV/m, 100uA/m and 200uT respectively. The measured electric-field strength values are in their entirety below the reference level for safe public and occupational exposure. It can be seen that the measured magnetic field strength values were below the reference level for safe public and occupational exposure. Though significant difference was noted at different heights corresponding to the head, chest and groin areas. So, the measured field values are substantially within recognized guidelines, suggesting that these values are not dangerous and, therefore, are no cause for concern among the public or working personnel.

4. Conclusion

Investigation of low frequency electric and magnetic fields and their interconnectivity are the main problems in transmission and distribution of power energy in terms of standardized electromagnetic radiation permissible and safety limits of human exposure.

This study presents investigation of low frequency electromagnetic radiation from Crutech electric power injection sub-station located in Calabar, Cross River state using a broadband measurement technique and the time average method. MUSTOOL MT525 Electromagnetic radiation meter a portable field survey instrument that conforms to international standards was used. The results presented as contour plots and surface plots shows that there was distinctive difference in the

magnetic flux measurements at different heights of 1m, 1.5m and 1.75m. The electric field measurement was constant at these heights. When comparing the measured values of the magnetic and electric fields to acceptable standard, it was observed that this values very within the acceptable range for occupational safety exposure. Below are some recommendations:

- There should be more advocacies on the effects of EMR.
- Employee with certain medical or physical conditions such as pregnancy should not spend too much time within the substation.
- Employees should be encouraged to wear personal dosimeters to record radiation exposure.
- Government at all levels should ensure that substations are not located in densely populated areas.
- Residents must be discouraged from doing business or residing close to power lines.

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The transformative role of artificial intelligence in smart energy transition for unprecedented energy sustainability in Nigeria

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Abstract: In the face of an impending global energy crisis and the imperative to combat climate change, the integration of artificial intelligence (AI) into the energy sector stands as a seismic shift in the way we approach energy sustainability. This study embarks on a comprehensive journey into the profound and multifaceted role of AI in catalyzing the smart energy transition. Cases studied include; Sustainable buildings and energy consumption, AI-based DSSs for sustainable urban water management, climate artificial intelligence (climate informatics), agriculture 4.0 and sustainable sources of energy, convergence of IoT & AI for sustainable smart cities, AI-based evaluation of renewable energy technologies, and AI for energy optimization. It further delves deep into how AI is revolutionizing renewable energy generation, grid optimization, demand-side management, and carbon emissions reduction, and even envision the path forward, including the ethical and regulatory frameworks that will shape this transformative journey in Nigeria and its environs.

Keywords: Artificial intelligence, smart energy, energy sustainability, energy transition

1. Introduction

The rise of unsustainable practices and procedures co-occurred with the rising urbanization and civilization have driven the emergence of AI-based solutions to assist the path toward energy sustainability [1-3]. Excessive consumption and unsustainable energy sources, which have increased at an unprecedented rate due to factors such as urbanization, improper building construction, transportation, environmental changes, and population growth, have pressured the energy industry to pursue clean energy sources and smart solutions [4]. The deployment of alternative energy sources and access to sustainable energy are pillars of global economic growth [5] and the fight against environmental hazards, in particular climate change [6]. Thus, the energy sector has focused its efforts not only on developing new sources of energy but also on inventing novel technical solutions that increase the efficiency of existing mitigation measures [7]. AI-based interventions, which are available in the form of both hard and soft solutions, such as robot algorithms and models, are one of these solutions that have come to assist humanity [8]. Artificial intelligence can provide a wide range of intelligent solutions, from predictive and prescriptive energy consumption insights to intelligent energy generation and distribution. Parallel to the escalating discussions over sustainable energy and artificial intelligence solutions, the world is now debating the ethics of artificial intelligence and its potentially negative effects on society and the environment. Ethical AI considers not just AI's moral dimensions, but also its epistemic perspectives [9]. While prior studies have urged scholars to focus on the epistemological aspects of sustainable AI and to open the black box of algorithms to develop sustainable models and algorithms [10], other research have concentrated on AI for social good and its favourable societal and environmental circumstances [11,12]; such as the development of sustainable AI. In this paper, the term "sustainable AI" reveals how much artificial intelligence can help society accomplish its sustainability goals [13,14]. The energy industry is one of the core industries that will require the incorporation of sustainable AI, which will aid in the development of energy sustainability [15]. Sustainable energy strives to fulfill today's energy demand without depleting energy supplies or harming the environment. Sustainable energy systems are regarded as a requirement for achieving all the Sustainable Development Goals (SDGs) [16]. Sustainable artificial intelligence can help to expedite the development of sustainable energy [14]. To advance sustainable

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energy, the industry has supplied a wide variety of choices, including wind energy, fossil fuels, solar energy, and bioenergy. It's also vital to recognize how academics have dealt with the confluence of sustainability, artificial intelligence, and energy.

It is worth nothing that the theoretical contribution of this research buttresses the possible solutions integrating AI with energy optimization. This research attempts to enlighten policymakers, the energy sector, engineers, and developers of artificial intelligence about the transformative role of AI in smart energy transition. Additionally, it encourages policymakers to design artificial intelligence regulations that promote the development of sustainable AI in the energy sector while mitigating the unintended consequences of unsustainable energy sources and AI solutions

2. Method

2.1 Overview of key case studies

Many countries especially developing countries like Nigeria are facing energy transformation and sustainability challenges like broach supply-demand gap for electricity and other energy resources, extensive dependence on fossil fuels and low access and penetration of clean energy [21, 17, 18, 19, 20]. It is established globally that these challenges can be addressed and facilitate the transition to smart energy systems from traditional systems using AI, yet the rate of deployment of the AI technologies remains low [21]. By operating the conventional grid, the electricity utility providers have little and at times no insight into how electricity users consume power. Within the traditional grid, the operation by the utilities is purely based on prevailing demand, and in case of a demand uptick, operators simply send more power to the grid [22, 23]. The world has witnessed significant advances in technology which include the development of better electricity carriers, variable electricity pricing, advances in energy storage technologies, decentralization of generation, and increasing contribution of variable renewable sources (VREs) energy to grid electricity as well as the electrification of transport which introduces variable and unpredictable loads which are challenging for the traditional electricity grid [24, 26, 27]. The challenges facing the energy transition are to modernize the grid, innovate, adopt new technologies, develop tomorrow's solutions, and serve local and territorial communities [25, 28]. There is a need to modernize the electricity system to cope with the energy changes and address the limitations of the traditional grid. The integration of new information and communication technologies into the grid makes it communicative allowing for diverse actors' involvement in the electricity system, while at the same time facilitating a more efficient, economically, safe electricity system [27]. Upgrading of the electricity grid is necessary to realise energy-saving schemes which empower users and support and environmental conservation. There is growing demand for sustainable solutions to the electricity-related environmental pollution, high power system losses, high contribution of fossil fuel sources to grid electricity energy mix which is the characteristic of traditional grid systems and hence the need to increase the share of variable renewable energy sources like photovoltaics and wind, use of fuel cells, growing need to integrate storage systems and use of plug-in electric cars as pathways to sustainable energy transition [21, 22]. The world community is increasingly concerned about the looming consequences of greenhouse gas emissions most of which are related to electric power generation and fossil fuel-based transportation [23, 25]. With the ever-growing global electricity demand, the multiple effect is an increase in the cost of energy, diminishing fossil fuel reserves and hence more demand for the widely available variable renewable energy sources like wind and solar. As a move to address the challenge of global warming and limit the temperature rise to less than 2oC, as stated in the Paris Climate Agreement of 2015, the global share of renewable energy in power generation should be increased to 85% in 2050 from 33.3% in 2018 [25].

As a solution renewable energy resource should be used as substitutes for fossil fuels but total replacement may not be feasible in the near future, hence the need for optimum mixing of energy sources and modernisation of the electricity grid to realise this objective [26, 27]. The electrification of industrial domestic energy applications and transport sector are also seen as major pathways in the sustainable energy transition which call for smarter grids for more efficient and effective control of electricity as an energy carrier. There is a need for self-regulation and self-reconfiguration of electric power systems by equipping power systems with the relevant intelligence and technical capabilities to improve the performance quality and efficiency of electric power systems [20, 24].

Renewable energy resources like wind and solar have significant potential in power generation but they face significant challenges in their exploitation due to their intermittence and variability in supply and availability. The main challenges in the sustainable transition to a sustainable grid are limited access to reliable affordable and adequate renewable and continued reliance on fossil fuels in power generation and other energy applications like transport and hence the need to shift to renewable low carbon sources of energy for grid electricity generation [17, 20]. In view of these challenges to the development and consumption of renewable energy resources for electricity generation the use of technology in electricity generation and distribution can go a long way in optimizing renewable energy penetration to the electricity grid [22, 25] as this is where the research draws its focus.

Case 1: Sustainable Buildings and Energy Consumption

One of the primary scholarly interests is the creation of sustainable buildings and smart grids for the purpose of reducing energy consumption. One way to accomplish this aim is to redefine the design and architecture of buildings whether residential public commercial industrial or manufacturing. According to studies the application of automation and intelligent systems in the construction of sustainable buildings will result in sustainable energy usage [29-30]. Several AI-based approaches are proposed to achieve a more sustainable building including building management systems knowledgebased engineering (KBE) fuzzy logic neural networks genetic algorithms and Monte-Carlo simulation [31]. From a broad standpoint sustainable building development fall under the umbrella of sustainable smart cities and reducing building energy consumption [32]. Additionally, scholars have drawn inspiration from nature and advocated regenerative design influenced by nature for pattern detection prediction optimization and planning of buildings [33]. Additionally, scholars discuss the potential of AI in reducing CO2 emissions in buildings suggesting that AI may be used to construct smart multienergy systems such as those found in industrial districts resulting in significant energy savings and CO2 emission reductions. As a result, sustainable building design would be a way to combat climate change. Several additional studies integrate AI solutions with other cutting-edge technologies most notably the Internet of Things and big data to improve not only the design and optimization of sustainable buildings but also the efficiency of their power usage. For instance, one project focused on the application of IoT in public buildings in order to discover and anticipate energy usage trends [34]. A preceding study for illustration outlines the obstacles involved in understanding the semantics of IoT devices using machine learning models. Image Encoded Time Series has been identified as an alternate method to other statistical feature-based inference [35]. Sustainability analysts from [35] and [36] studies have also advocated for continual monitoring of sustainability metrics by integrating AI with DSSs or ambient intelligence. Both residential buildings and plants and commercial buildings and offices have the same issue in regard to energy usage. Previous studies incorporated multiobjective and multi-attribute decision-making modeling as well as impact evaluation of the emission outputs to help designers and manufacturers to make environmentally sustainable decisions about the designs and production of facilities [37]. Researchers also believe that in order to provide bulk energy consumption forecast control and management simulation techniques could be utilized [15] for instance in public buildings offices and factories. Due to new modes of consumption and distributed intelligence the electrical power grids have been also influenced and as a result smart energy grids have been generated to achieve sustainability [38].

Case 2: AI-based DSSs for Sustainable Urban Water Management

Utilizing AI to create DSSs for consumption and water usage enables adequate forecasting realtime monitoring and customized and adjustable pricing and tariffs. AI is used with other sophisticated technologies to assist in the development of a smart city. The previous studies have postulated several approaches such as optimization and AI-based decision support systems for water infrastructure management [39] better delivery of public services of smart cities such as water treatment and supply [40] AI-based water pricing and tariff options [41] and sustainable water consumption [42]. For this goal AI is integrated with recent technological advances in urban life. This includes using open-source data employing deep learning algorithms and developing smart street lighting systems. Such decisions about social impacts of smartphone applications or smart travel behavior are also examined [43]. AI techniques are utilized to anticipate water resource management [44] such as water quality by adopting algorithms such as neuro-fuzzy inference system [45]. Real-time optimization of water resources and cloud technologies are integrated with visual recognition techniques and created to improve efficiency with irrigation systems [46]. A study conducted on ecological water governance implementation using AI found that including algorithms into the system yields higher-quality information and better prediction models for accurate evaluation of water quality [47]. AI may be used for tracking water use and demand as well as forecasting water quality but it can also be used for estimating water infrastructure maintenance monitoring dam conditions water-related diseases and disasters [48] and water reuse [49]. By critiquing conventional decision support systems research offer alternatives based on artificial intelligence such as a systematic decision process [50] sustainability ranking framework based on Mamdani Fuzzy Logic Inference Systems to develop a sustainable desalination plant [51] or a comprehensive and flexible decision-making process fueled by social learning and engagement aimed at ensuring the urban water system's environmental and energy sustainability [52]. One research offers a unique DSS for analyzing the energy effect of each of the urban water cycle's macro-sectors including assessing the system's energy balance and proposing potential energy-efficient solutions [53].

Case 3: Climate Artificial Intelligence (Climate Informatics)

Climate informatics especially climate artificial intelligence as a new field of study is concerned with issues such as AI-based DSSs to reduce greenhouse gas emissions optimizing grid assets enhancing climate resiliency and reliability increasing energy efficiency forecasting energy consumption and modeling earth systems. Moreover, within this topic scholars have addressed the issue of explainable and trustworthy AL models due to the controversial nature of climate change. Climate change has compelled societies to seek alternate energy sources and fuels [54]. Climate informatics [55] such as several AI-based solutions including novel algorithms and DSSs have been hugely beneficial in lowering greenhouse gas emissions in the energy sector. By improving grid assets and strengthening climate adaptability these innovations have greatly contributed to this ultimate goal [15]. Reliable and explainable artificial intelligence models as advocated in prior studies might help stakeholders and decision-makers achieve climate-resilient and sustainable development goals [56]. By integrating advanced machine learning techniques AI can propose fresh insights in complex climate simulations in the field of climate modelling [57]. Energy consumption patterns might undergo considerable changes due to climatic change which means AI forecasts can aid in estimating future energy use for various climate scenarios [58].

Case 4: Agriculture 4.0 and Sustainable Sources of Energy

The fourth area that academics in the field of sustainable AI for energy extensively address is the development of smart agriculture and sustainable energy sources. The primary issue in this subject is how to combine advanced technologies like IoT drones and renewable energy with AI in order to create automated and real-time systems. According to some researchers the agriculture industry is suffering from an insufficient application of responsible innovation [59]. As a result, the researchers are calling for a system referred to as Responsible Agriculture 4.0 which incorporates drones IoT robotics vertical farms AI and solar and wind power linked to microgrids [60–62]. When it comes to the productivity of agriculture factors such as the cost of energy for cultivation are equally significant [63]. Based on the premise that most agricultural machinery operates on fossil fuels it may potentially contribute to climate change. Thus, new energy solutions and AI-based approaches are provided. One way in which bioproduction and renewable energy may positively influence sustainable agriculture and farming is via the development of bioproduction and renewable energy [64]. Proposing new AI methods to forecast agricultural energy use has also been researched [63]. biomass may also be used to provide sustainable energy in agriculture and care should be taken to avoid any injuries [65]. Realtime alerting systems AI-based DSSs real-time DSS forecasting models and alternative energy sources such as solar and wind play a vital role in sustainable agriculture [66]. Maximizing agricultural production and economic stabilization while minimizing the use of natural resources and their harmful environmental consequences may be accomplished using renewable energy and AI [66]. Artificial intelligence enables academics to provide accurate forecasts of agricultural energy use [67]. Especially a drastic shift toward sustainability in agricultural practices has occurred because of its confluence with other cutting-edge technology including sensors DSSs greenhouse monitoring intelligent farm equipment and drone-based crop imaging. [68].

Case 5: Convergence of IoT & AI for Sustainable Smart Cities

A significant step in the implementation of sustainable energy solutions is to implement smart cities and services using internet of things technology. This topic exhibits how AI and IoT operate together to drive environmental progress. Much of this topic focuses on measure such as smart buildings smart grid systems green IoT and smart campuses. AI is used in tandem with a number of

cutting-edge technologies for sustainable energy development such as improved energy conservation [69] and building intelligent energy management [70] such as building management systems [35]. Internet of Things (IoT) is one of the most promising and pervasive technologies [69], whose integration with AI has generated a revolution in the energy sector. There are many functions in creating sustainable energy in the IoT-enabled smart city dubbed City 4.0 [71] such as simulation and optimization of power plant energy sustainability [70]. City systems such as water and electricity as well as other infrastructures such as data analytics will be driven by sensor and data collection in the smart city [71]. A significant use of IoT is in the design of intelligent buildings which with AI included may support a goal of energy or water conservation [39, 72] for instance by educating the citizens on how to use energy more effectively and giving them warnings if they are using excessive amounts of energy. [73]. IoT is integral to modern grid development as well. In particular it seeks to transform the traditional fossil-fuel-based power grids with distributed energy resources and integrate it with cutting-edge technology such as artificial intelligence for improved grid management [74]. In the same manner Blockchain has also been considered to be a viable alternative for smart cities. Fusing blockchain with AI may be leveraged for smart services including energy load forecasting categorizing customers and evaluating energy load [75]. Smart connected devices such as IoT devices have successfully employed blockchain in time to retain these devices safe and secure in a blockchain network [76]. The effect of IoT and AI on agriculture and food sectors is also substantial [7778]. Manufacturing facilities such as food factories and plants may be transformed more intelligent and more environmentally friendly via the use of IoT and AI which merge with nonthermal and advanced thermal technologies [78]. Sustainable and green IoT are other topics covered in this subject. The two main objectives of the literature on green IoT are to increase the recyclability and usefulness of IoT devices as well as to minimize the carbon footprints of such devices. The second objective is to incorporate more effective life cycle assessment (LCA) methods integrating artificial intelligence (AI) in order to cut costs and time [79]. Another of the many topics that apply to IoT is with developing smart campuses which are carbon neutral energy efficient use less water and are laced with various high-quality green energy tools [80] and smart teaching and learning platforms [81]. Researchers have identified the positive traits of IoT devices but they've also forewarned about the possible risks of the devices and proposed various techniques for detecting weaknesses [77] or challenges regarding the heterogeneity of smart devices and their associated meta-data [35].

Case 6: AI-based Evaluation of Renewable Energy Technologies

Scholarly interest has been generated by the discussion of leveraging AI for DSSs to enhance the efficiency of conventional system evaluations for renewable energy technologies. A sustainable future will largely depend on maximizing the use of energy sources that cannot be depleted [82]. Artificial intelligence is important for the survival of the future by leveraging a wide range of renewable energy technologies such as biomass energy wind energy solar energy geothermal energy hydro energy marine energy bioenergy hydrogen energy and hybrid energy [83]. AI is used to evaluate renewable energy solutions based on their cost of energy production carbon footprint affordability of renewable resources and energy conversion efficiency [84]. Artificial intelligence will ensure the most effective use of these resources while also pushing for improved management and distribution systems [14]. Distributed energy management generating forecasting grid health monitoring and fault detection are also made more efficient by using automated AI systems [85]. AI can help disperse the supply and demand of energy in real-time and improve energy consumption and storage allocation.

Case 7: AI for Energy Optimization

Conventional optimization methods may be a roadblock for making progress toward sustainability and AIbased solutions can help eliminate such roadblocks. Whilst renewable energy sources like solar and wind have many merits there are some downsides to consider. They are usually not always available and often rely on the climate which renders employing them complicated [86]. A proper optimization of energy may be utilized to minimize greenhouse gas emissions and cut energy usage. Efforts to reduce costs and side effects of energy consumption are facilitated using optimization models [87]. Computational and intelligent resources have enabled academics to progress with optimization problems by employing advanced AI methods. Manufacturers have developed numerous energy-efficient appliances for this reason. Even if the deployment of digital technologies in buildings will likely lead to improved energy efficiency that is not the sole solution. Studies recommend implementing energy-saving measures that don't just target environmental variables but also include building inhabitants' comfort and preferences which is achievable via the integration of AI-augmented algorithms [88]. For illustration AI algorithms that not only monitor current actions but also give realtime alerts and warnings to users and providers allow optimization to be significantly accelerated. Some approaches such as algorithms that use energy consumption data to lower energy costs in buildings that use advanced AI are only one example of how AI and advanced technology may be used to benefit society [89].

From the aforementioned cases one can infer the abundant research ideas as shown in Figure 1 that can stem from them and how much AI can contribute to ensuring energy efficiency availability sustainability and un-depleted.



Fig. 1. Possible future streams of research pertaining to each topic [19].

2.2 Practical implications

This research provides energy engineers social scientists and policymakers with a variety of insights. Engineers may develop sustainable energy products and services. Energy scientists can also integrate sustainability considerations into their research and development of new energy sources such as renewable energy. In their discussions on AI and energy social scientists may also emphasize ethical problems including sustainability. Additionally, policymakers may create and construct new laws and policy initiatives aimed at mitigating the harmful effects of unsustainable energy on society and the environment.

3. Conclusion

In the intricate dance between humanity and the planet we call home there emerges a profound opportunity to redefine our relationship with energy to rewrite the narrative of our environmental legacy and embark on a journey toward a future that hums with the harmonious synergy of technological prowess and ecological stewardship. Artificial intelligence with its unbounded capacity to learn adapt and innovate has emerged as the maestro of this symphony of change. As we have navigated the labyrinthine challenges of renewable energy AI has been our guiding star illuminating the path to unprecedented energy sustainability.

From the vantage point of resource assessment and site selection AI has scoured the Earth's surface and discerned the most promising locations for our renewable energy aspirations. It has charted the winds and gauged the sun's embrace helping us harness these elemental forces with unrivaled precision. In the realm of energy generation AI has become the luminary in our quest for predictability. It anticipates the capricious moods of the sun and wind endowing us with the foresight to harness their gifts at just the right moment. AI orchestrates the graceful choreography of solar panels and wind turbines conducting them to extract the zenith of energy efficiency. As the electrons embark on their journey from generation to consumption AI's presence is palpable. It manages grids with the poise of a virtuoso balancing the ebb and flow of energy with mathematical precision. It predicts our demands guiding us toward intelligent energy use shaping a future where every watt is cherished. In the realm of energy storage AI optimizes the delicate ballet of charge and discharge breathing life into batteries that store the sun's rays and the wind's caress. It ensures that energy storage systems perform their duty with grace providing us with power when the elements wane. But AI's relevance transcends technology; it extends into the realm of ethics and governance. It guides us in crafting policies that uphold transparency fairness and sustainability. It safeguards our energy infrastructure against the specter of cyber threats and offers a vision of a world where energy is abundant equitable and environmentally benign.

We stand at the nexus of this transformation a transformation where AI and renewable energy converge to illuminate a future we could only dream of a future where carbon emissions dissipate into memory where energy flows seamlessly from sun-soaked deserts and windswept plains where every action we take is infused with the wisdom of sustainability. In this narrative AI is not merely a tool; it is the enabler of a new era. It is the force that pushes the boundaries of what is possible casting aside the shackles of convention and propelling us toward a world where energy is not just a commodity but a force for good. As we march forward on this odyssey let us remember that the true power of AI in renewable energy lies not just in its algorithms but in the spirit of innovation and collaboration it embodies. Together with AI as our ally we have the audacity to dream of a world where renewable energy is not just a choice but a destiny a destiny where the world is powered by the sun's radiance the wind's embrace and the boundless ingenuity of human endeavor.

This is the legacy we seek to create a legacy of harmony resilience and progress. The future of renewable energy guided by AI's transformative touch is not a distant mirage; it is a reality we can shape. The stage is set the audience awaits and the conductor is ready. Let the symphony of sustainable energy begin.

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Speed control of DC motor using PWM technique method for industrial applications

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Abstract: This study aim is to investigate the dynamic performance of a separately excited DC motor fed by Chopper for its efficient Speed control. The study adopts Pulse Width modulation technique. Separately excited DC motor model is modeled using armature control scheme, and the Dc-Dc Buck converter is designed to control the speed of the motor and the model is implemented in MATLAB/SIMULINK software. The speed of the motor is feedback and is compared with the reference speed, PID controller is used to evaluate the error, and the Pulse Width Generator block then converts this signal into trains of pulses which trigger the Chopper (IGBT) of buck converter. The Chopper Switching duration determine output voltage of the Buck converter, which also supply voltage to armature winding of the motor, Since motor speed depends on the armature voltage in armature control scheme. The variable speed operation is implemented and speed of the motor is successfully regulated. The performance of the PWM control method is evaluated using variable load condition, Reference speed tracking is tested with the help of PID controller and transient response to reference speed is evaluated. From the simulation results show that PWM control method provides excellent and efficient control the DC motor and is recommended for Industrial application where variable speed operation is utilized.

Keywords: PID controller, DC-DC Buck converter, DC motor

1. Introduction

DC machines are electromechanical devices that convert electrical energy into mechanical energy or vice versa. The most common varieties rely on magnetic fields to produce forces. Almost all DC motors contain an internal mechanism, either electromechanical or electronic, that changes the direction of current in a section of the motor on a regular basis. The speed of a DC motor can be varied across a large range by varying the supply voltage or adjusting the current intensity in the field windings. Tools, toys, and appliances all employ small DC motors [1]. They are widely used in various applications such as electric vehicles, industrial machinery, and generators. ADC machine consists of two basic parts: the stator (stationary part) and the rotor (rotating part). The stator contains the field winding, which produces a magnetic field that interacts with the armature winding on the rotor [2]. The armature winding is the winding in which the voltage is induced, It is part of the current carrying motor, which interacts with field flux to create torque. The brush is part of the circuit where the electric current flows to the motor from the power supply, brushes is made of graphite or metal [3]. DC machines can be classified into two types based on the type of field winding: (i) separately excited DC machine, and (ii) self-excited DC machine. In a separately excited DC machine, the field winding is supplied with a separate DC source, while in a self-excited DC machine, the field winding is energized by the current produced in the armature winding, the control of DC motors precise and efficient control techniques to achieve optimal performance in some applications. There are several types of applications where the load on the DC motor varies over a wide range. These applications may demand high-speed control accuracy and good dynamic responses. Higher torques can be obtained by using geared motors. The term geared motor is used to define a motor that has a gear reduction system (or gearbox) integrally built into the motor. [4] there are four (4) main types of DC motors: Permanent Magnet DC Motors, Series DC Motors, Shunt DC Motors, and Compound DC Motors. A Dc motor controller is a device that works alongside a microcontroller, the batteries and motors. Most controllers have under-voltage, over-voltage, short circuit protection, current limit protection, thermal protection, and voltage transients. Without these protections, the motor is exposed to threats that can result in permanent electrical or mechanical damage [5][6]. Many control techniques are used in various industrial applications due to efficient and excellent control operation of separately excited DC motors. Pulse Width Modulation (PWM) uses digital signals to control power applications,

as well as being fairly easy to convert back to analog with a minimum of hardware [7][11]. Therefore, the study aims to investigate the dynamic behavior of a separately excited DC motor using Pulse with control scheme. The study shows the efficient performance of DC motors when variable speed operation is utilized.

2. Method

a. Modelling of seperately excited DC motor

The mathematical modeling of the system is done on the actuation model of the SEDC motor shown in Fig.1



Fig. 1. Circuit Diagram of a Separately Excited Direct Current (SEDC) Motor

For the armature control scheme, A fixed voltage Vf is applied to the field and the field current settles down to a constant value. According to the Kirchhoff's voltage law

on the field circuit. The Field voltage is given by:

$$V_f = R_f I_f + L_f \frac{d I_f}{dt}$$
(1)

$$V_a = L_a \frac{dIa}{dt} + R_a I_a + E_g \tag{2}$$

$$E_g = K_b \boldsymbol{\omega} \tag{3}$$

Where, I_a , Ra and La are the armature current, armature resistance and armature inductance respectively. The back electromotive force (emf) or voltage (E_a) is proportional to the angular speed, K_b is the motor voltage constant (in V/A-rad/sec) and ω is the motor angular speed (in rad/sec) I_f , Rf and Lf are the field current, field resistance and field inductance respectively

In addition, the motor generates a torque Td proportional to the armature current,

$$T_d = K_t I_f I_a = K_t I_a \tag{4}$$

Developed Torque is also expressed as:

$$T_d = J \frac{d\omega}{dt} + B\omega + T_L \tag{5}$$

Where, B: Viscous friction constant or frictional coefficient. (N.m/rad/sec), Tl: Load Torque (N.m), J: the rotor moment of inertia

(kg.m²), Kt: Torque constant and If is kept constant.

Equation (2) to equation (5) together makes up the dynamic equations of the direct current motor used for the simulations. If the input voltage Vs(t)=Vs is a constant, the resulted armature current ia(t)=Ia, angular velocity w(t)= and torque T(t)=T are constant in the steady state

Taking Laplace transform, the above equations were formulated as

$$E_{g}(s) = K_{b}\Omega(s)$$
(6)

$$V_{a}(s) = (R_{a} + L_{a}s)I_{a}(s) + E_{g}(s)$$
(7)

$$T_{d}(s) = (Js + B)\Omega(s) + T_{L}(s) = K_{T}I_{a}(s)$$
(8)
All at zero initial conditions, The angular position is given as

$$\theta(s) = \frac{1}{2}\Omega(s) \text{ eqn}$$
(9)

The transfer function of motor speed with respect to input voltage is expressed as:

$$G(s) = \frac{\Omega(s)}{E_a(s)} = \frac{K_T}{(L_a s + R_a)(J s + B) + K_b K_T}$$
(10)

$$G = \frac{K_{\rm T}}{[L_{\rm a}Js^2 + (L_{\rm a}B + R_{\rm a}J)s + (R_{\rm a}B + K_{\rm b}K_{\rm T})]}$$
(11)

The above equations can be represented in block diagram form as shown in Fig. 2



Fig. 2. Block diagram of the armature-controlled DC motor

b. Modelling of seperately excited DC motor



Fig. 3. Block diagram of DC-DC Buck Converter

A buck converter or step-down converter is a DC-DC converter which steps down voltage (while stepping up current) from its input (supply) to its output (load). Its name derives from the inductor that "bucks" or opposes the supply voltage.Buck converters typically operate with a switching frequency range from 100 kHz to a few MHz.Dc-Dc Buck Converter average voltage is equal to the integral of the voltage waveform. The average voltage (V_0) is given by the following equation:

$$V_{o} = DV_{max} + (1 - D)V_{min}$$
(12)

But usually, V_{min} equals to zero and V_{max} is the supply dc voltage (Vs) to Buck converter (Chopper) Thus;

$$V_o = DV_{max} = DV_s \tag{13}$$

Where V_o is the average or equivalent voltage converter output voltage that power the motor V_s is the supply voltage (volts) to converter,D isduty cycle ratio (%), Ton is Pulse duration i, e duration in

which Chopper switch (IGBT or MOSFET) is turn ON, T = is Switching period $(\frac{1}{F_s})$ in seconds. The recommended switching frequency (F_s) is 300 Hz in most practical circuits.



Fig. 4. DC buck converter output voltage waveform based on (PWM)

Duty cycle (*D*) is defined as the percentage of digital 'high' to digital 'low' plus digital 'high' pulsewidth during a PWM period. D describes the proportion of 'ON' time to the regular interval or 'period' (T) of time.

signal information. its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. The average value of voltage (and current) fed to the load is controlled by turning the switch between supply and load on and off at a fast pace. The longer the switch is on compared to the off periods, the higher the power supplied to the load is. The PWM switching frequency has to be much faster than what would affect the load, which is to say the device that uses the power. The term duty cycle describes the proportion of 'on' time to the regular interval or 'period' of time. A low duty cycle corresponds to low power, because the power is off for most of the time. Duty cycle is expressed in percent, 100% being fully on. PWM or duty-cycle variation methods are commonly used in speed control of DC

$$D = \frac{T_{ON}}{T} \tag{14}$$

c. Pulse Width Modulation (PWM)

Pulse-width modulation (PWM), is a modulation technique that conforms the width of the pulse, formally the pulse duration, based on modulator motors. PWM generators include: Microcontroller circuit, Fuzzy logic circuit, 555 Timer circuit etc, these can provide pulse signal trigger Chopper (DC Buck converter) switch like IGBT, GTO, SCR, MOSFET etc. The Pulses (gating signal) control the turning of the switch (Chopper) between Voltage supply (Vs) and the load (DC motor) ON and OFF at a fast pace. The longer the switch is on compared to the off periods (high duty cycle ratio), the higher the output voltage is supplied to the Dc motor. The PWM switching frequency (Fs) has to be much faster. Typically switching is from few kilohertz (kHz) to tens of kHz for a motor drive and well into the tens or hundreds of kHz in audio amplifiers and computer power supplies. In this study, the average value of Dc buck converter voltage (Vo) is fed to the motor. 20KHz is chosen switching frequency.



Fig. 5. Block diagram of DC motor speed control system using PWM

d. Proportional Integral Derivative (PID) Controller

The PID controller is most widely used in industrial applications. It is implemented to control the speed of DC motor. The error between the reference speed and the actual speed is given as input to a PID controller. The PID controller depending on the error changes its output, to control the process input such that the error is minimized. Main purpose of the PID controller is to adjust all the gain values so as to achieve optimum solution for control application. By tuning the PID gains (K_p , Ki and K_d) enable control Engineers to obtain optimum response using trial and error method. proper tuning of these values can be achieved by using Zeigler-Nicholas method.

| Parameters | Values | Units |
|----------------------------|----------|------------------------------|
| Power (Po) | 5 | Нр |
| Armature resistance (Ra) | 11.4 | Ohms (Ω) |
| Armature inductance (La) | 0.1214 | Henry (H) |
| Torque constant (Kt) | 1.28 | N-m/A |
| Back emf constant (Kb) | 0.0045 | V/(rad/sec) |
| Rated speed (N_m) | 1750 | Revolutions per minute (rpm) |
| Moment of inertia (J) | 0.12 | kg.m2 |
| Frictional coefficient (B) | 0.002953 | N-m/(rad/sec) |
| Input Voltage (Va) | 240 | Volts (V) |
| Field voltage (Vf) | 300 | Volts (V) |

Table 1. Paramenters of the PID Controller

The Transfer function of a PID Controller output is given in eqn (15)

$$u(t) = K_p e(t) + K_I \int_0^t e(t) + K_d \frac{de(t)}{dt}$$
(15)
Where u(t) is control signal and e(t) is an error signal of the system to be controlled.

3. Results and Discussion

In order to dynamically predict the control topology, SIMULINK toolbox in MATLAB/SIMULINK software program is used for the simulations to produce a number of results with respect to important variables of the DC motor. The full DC motor speed control scheme was digitally simulated using MATLAB/SIMULINK. motor was fed by Dc-Dc Buck converter (Chopper) as field current is kept constant. the Dc motor operates using negative feedback control strategy as the motor runs to track or match the reference speed of 1146 rpm as it is depicted below. After simulation, plots of speed, current against time when using PWM control technique and plots of the responses are presented.



Fig. 6. Pulse or gating signal from PWM generator with 20KHz switching frequency

Fig. 6 depicts the pulse or gate signal of variable duty cycle that triggers switch of Buck converter, the pulse turn ON durations are greater from 0.5 seconds when load was applied, due to the effect of electromagnetic torque change as the motor draws much power from buck converter at this instant.



Fig. 7. DC Chopper variable output voltage

From the DC buck converter average output voltage depicted in figure 7 shows high voltage level from 0.5 seconds when load torque was applied, this is as a result of high duty cycle (Ton) duration of pulse at this instant shown in Figure 6. this waveform nature of chopper (dc buck converter) makes its mathematical value be calculated as average output voltage value as in equation (13).



Fig. 8. Speed and armature current response for fixed reference speed under variable load condition



Fig. 9. Speed and chopper voltage response for fixed reference speed under variable load condition

Figure 8 and 9 depicts the dc motor responses and response of armature current and that of buck converter voltage supplied to the motor, it could be easily seen that from the start of the motor at zero second, the motor accelerates rapidly to attain reference speed value (1150 rpm), as after 0.3 second, the motor speed oscillates it steady state value around the reference speed value. At this instant, the error being the difference of reference speed and motor speed becomes zero, hence, the pulse signal becomes zero, which consequently turn OFF converter switch, from this duration between 0.4 second to 3 seconds, as far as the speed of motor matches reference speed, the PID controller evaluates the error to be nearly zero, the switching of the chopper has high frequency, from 3 seconds where load is applied. The motor draws more power from the chopper, as a result, torque change causes fall in speed level which affect duty cycle of pulse, the width of the pulse changes to cause higher turn ON time which consequently enable chopper to supply higher voltage to motor as seen in figure 9. also, better speed operation is obtained when dc motor is connected with load. From 6 seconds, the applied load value is reduced to 10Nm, this makes decrease in output voltage waveform, PID controller is characterized by overshoot especially where there are no loads at the start of motor.



Fig. 10. Variable Speed and input voltage response of SEDCM with Load from the starting time

Figure 10 shows similar response of that of figure 9, but in this case the motor rotor is connected to load, the motor speed tracks reference speed of 700 rpm. Motor start at 0.2 second, as the reference speed changes at 2 seconds and at 4 seconds to 1500 rpm and 1000 rpm respectively, since the motor is connected to load the speed response is improved. also output voltage waveform of chopper is high due to effect of load torque on motor. And the motor with applied load torque draws less power (chopper voltage) when reference speed value (1500 rpm) is close to its motor rated speed value (1700 rpm) as it could be seen from 2 seconds to 4 seconds, where Chopper output voltage waveform amplitude decreases until 4 seconds where reference speed decreases to 1000rpm at this instant.

4. Conclusion

This study presents speed control system using pulse width modulation (PWM) technique for industrial application. feedback drive control system technique is employed to control separately excited d motor speed. dc motor speed control system is modeled using PID controller and dc-dc buck converter in MATLAB/SIMULINK environment. the dynamic performance dc motor was evaluated from simulation result. it could be seen that the dynamic response of dc motor speed and the response to change in load condition is very fast and efficient using PWM control strategy. a number of simulation results are presented. based on the simulation results, one can conclude that PWM control scheme of dc motor is suitable for industrial application especially when variable speed operation is utilized as this method offer efficient performance in terms of speed reference tracking as it shows fast operation and robustness.

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Modeling and evaluation of Calabar transmission line network for load flow and transient stability for future grid expansion

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Abstract: The Calabar transmission network, which consists of 41 buses and 56 lines, was subjected to load flow studies and transient stability analyses. During a standard simulation of load flow analysis, buses 9, 50, and 54 had voltages of 66.681%, 66.96%, and 66.655, respectively. However, after compensating the afflicted buses, the voltages on these buses improved by 16.89%, resulting in 96.112%, 98.887%, and 103%, respectively. Without compensators, the total network losses during normal load flow simulation are 16.511MW and 4004.872 mvar. When compensation is applied, the overall network losses increase to 19.211MW and 2348.110 Mvar. Some transient cases were examined; these cases are 3-phase faults on bus 3 at 5 seconds. 50% fault on line 34 cleared after 15 seconds. ETAP 19.0 is utilised as a simulation tool since it has a superior network analysis performance. The purpose of this article is to analyze the Calabar transmission line network, with the results being used for effective planning and extension for energy sustainability. This work is being done in response to the energy issues in the area in order to improve performance and coordination. The Newton Raphson technique of load flow is being investigated for the job because of its advantages of better and shorter iteration to solution

Keywords: transient stability, load flow, power system stability, transient stability methods.

1. Introduction

The power system is divided into three stages: generation, transmission, and distribution. In terms of generation, synchronous generators are used more frequently. The voltage level is then changed by transformers before transmission to decrease currents in the line and thus power losses. Transformers step down voltages for distribution purposes. [1,2,7,9]. Because the system is designed to deliver a constant and consistent power source. However, inevitable events like as lightning and human/animal accidents do occur, resulting in faults of varying magnitude. Generator disturbance produces system in-balance in both generation and distribution due to network problems. However, if these flaws are not corrected within a short period of time, they cause equipment deterioration, which leads to instability. This can be avoided by installing protective equipment in the network for the perfect scheme, which will prevent the spread of fault energy to the rest of the network. Some protective mechanism installations are required for an effective protection system. It is necessary to implement a mechanism. These can be avoided by installing protective equipment in the network for the perfect scheme, which will prevent the spread of fault energy to the rest of the network. Some protective mechanism installations are required for an effective protection system. [3, 4, 5,10] The occurrence of a failure can generates network instability, which can cause a computer to lose synchronism. A load flow analysis is required to assess the power system's transient stability. If the system cannot be sustained until the fault is resolved. The fault then destabilizes the entire system. Demonstrate how transient and load flow can affect the network and how they can be cleared by limiting their impact on the network. Because stability aids in the system's continual generation and transfer. Direct approaches determine stability without having to solve the system differential equations in detail. [3, 11, 14] The early work of Magnusson and Aylett, who employed the energy function to reach stability, sparked substantial interest in this method. The transient energy technique was then represented using a ball rolling on the inner surface of a cylinder formed by the equation describing the system's transient energy, as shown in. The region of stability is represented by the area inside the bowl, while the region of instability is represented by the area outside. The bowl rim symbolizes the highest elevation and thus the most potential energy for the transverse projection induced by the

fault energy. A well-established method for evaluating synchronous machine transient performance and control techniques is mathematical modelling of synchronous machines. [12, 13, 18].

2. Method

2.1 **Developing load flow equation model**

The load flow equation model developed is presented in Eqn. (1) to (8).

$$P_{p} - j Q_{p} = V_{p}^{*} I_{p}$$
(1)
$$=>I_{p} = P_{p} - jQ_{p}$$
(2)

Now the nodal current equations for a n-bus system can be written as

$$I_{p} = \sum_{q=1}^{n} Y_{pq} V_{q}, \quad p = 1, 2, \dots, n;$$
(3)

$$I_{p} = Y_{pp} V_{p} + \sum_{\substack{q=1 \\ q \neq p}}^{n} Y_{pq} V_{q}$$
(4)

$$=> V_{p} = \frac{I_{p}}{Y_{pp}} - \frac{1}{Y_{pp}} \sum_{\substack{q=1 \\ q \neq p}}^{n} Y_{pq} V_{q}$$
(5)
Now,

 $V_p^* \mathbf{I}_p = \mathbf{P}_p - j \mathbf{Q}_p$ (6)

$$=>I_{p} = \frac{P_{p} - jQ_{p}}{V_{p}^{*}}$$

$$\tag{7}$$

Substituting for Ip in the above equation,

$$V_{p} = \frac{1}{Y_{pp}} \left[\frac{P_{p} - jQ_{p}}{V_{p}^{*}} - \sum_{\substack{q=1 \ q \neq p}}^{n} Y_{pq} V_{q} \right], \qquad p=1,2....n$$
(8)

We substitute Ip by active and reactive power, because the quantities are usually specified in a power system.

2.2 Load flow equation solution methods

The final equations derived in the previous section are the load flow equations where bus voltages are the variables. It can be seen that these equations are nonlinear and they can be solved using iterative methods like:

2.3 Newton-Raphson (N-R) method

Consider the solution of a set of simultaneous non-linear equations of the form: [F(x)] = [0]

Where: [F(x)] is a vector of functions: $f_1 - f_n$ in the variables $x_1 - x_n$. (9)

The expression described above will not become equal zero until the N-R process has converged, assuming the initial set of values $x_1, x_2, --- x_n$.

where the x's is voltage magnitude and phase angle for all load buses and voltage phase angles for all generator buses, that is, angles at all buses except slack and |V| for all PQ buses. [4, 8] The equations for load flow problem which can be solved by using N-R method can be derived as:

$$P_{p} - jQ_{p} = V_{p}^{*} I_{P} = V_{p}^{*} \sum_{q=1}^{n} Y_{pq} V_{q}$$
(10)

Let,

$$V_p = e_p + jf_p \quad \text{and} \quad Y_{pq} = G_{pq} - jB_{pq} \tag{11}$$

$$P_{p} - jQ_{p} = (e_{p} + jf_{p})*\sum_{q=1}^{n} (G_{pq} - jB_{pq})(e_{q} + jf_{q})$$
(12)

$$= (e_p - jf_p) \sum_{q=1}^{n} (G_{pq} - jB_{pq}) (e_q + jf_q)$$
(13)

Separating the real and imaginary parts, we have:

$$P_{p} = \sum_{q=1}^{n} [e_{p} (e_{q} G_{pq} + f_{q} B_{pq}) + f_{p} (f_{q} G_{pq} - e_{q} B_{pq})]$$

$$Q_{p} = \sum_{q=1}^{n} [f_{p} (e_{q} G_{pq} + f_{q} B_{pq}) - e_{p} (f_{q} G_{pq} - e_{q} B_{pq})]$$
(14)
(15)

Also,

=

$$|V_p|^2 = e_p^2 + f_p^2 \tag{16}$$

The three sets of equations above are the load flow equations for the N-R method and we can see that they are non-linear in terms of real and imaginary components of nodal voltages. The quantities on the left-hand side i.e., Pp, Qp is for a load bus and Pp and |Vp| is for a generator bus are specified and ep and fp are unknown quantities. [3, 9, 16,]

For an n-bus system, the number of unknowns is (2n-1). Thus, if bus 1 is taken as the slack bus, the unknowns are e_2 , e_3 ,..., e_{n-1} , e_n and f_2 , f_3 ,..., f_{n-1} , f_n .

Thus, to solve all these variables, we need to solve all the 2(n-1) equations.

The Newton-Raphson method helps us to replace a set of nonlinear power-flow equations with a linear set, using Taylor's series expansion.

The mathematical background for this method is as follows:

Let the unknown variables be (x1, x2..., xn) and the quantities specified be y1, y2,..., ynThese are related by the set of non-linear equations

$$Y_1 = f(x_1, x_2, \dots, x_n)$$
 (17)

$$Y_2 = f(x_1, x_2, \dots, x_n)$$
 (18)

$$Y_n = f(x_1, x_2, \dots, x_n)$$
 (19)

To be able to solve the above equations, we apply approximate solution $(x_1^0, x_2^0, \dots, x_n^0)$.

Here, the 0 in the superscript implies the zeroth iteration in the process of solving the above equations. By assuming a flat voltage profile i.e Vp=1.0+j0.0 for P=1,2,3...,n; except the slack bus, which is satisfactory for almost all practical systems.

Linearizing the equation about the initially assumed values. We then expand the first equation $y_1 = f_1$ and the results for the following equations.

Assuming $\Delta x_1^0, \Delta x_2^0, \dots, \Delta x_n^0$ as the corrections required for $x_1^0, x_2^0, \dots, x_n^0$ Respectively for the next better solution. The equation $y_1 = f_1$ will be

$$Y_{1} = f(x_{1}^{0} + \Delta x_{1}^{0}, x_{2}^{0} + \Delta x_{2}^{0}, \dots, x_{n}^{0} + \Delta x_{n}^{0})$$
(20)

$$=\mathbf{f}(x_1^0, x_2^0, \dots, x_n^0) + \Delta x_1^0 \frac{\partial f_1}{\partial x_1} + \Delta x_2^0 \frac{\partial f_1}{\partial x_2} + \dots + \Delta x_n^0 \frac{\partial f_1}{\partial x_n} + \Phi_1$$
(21)

Where Φ_1 is function of higher order of Δx^8 and higher derivatives which are neglected according to N-R method. In fact this is the assumption which needs the initial solution close to the final solution. After all the equations are linearized and arranged in a matrix form, we get:
$$\begin{bmatrix} y_{1} - f_{1}(x_{1}^{0} + \Delta x_{1}^{0}, x_{2}^{0} + \Delta x_{2}^{0}, \dots, x_{n}^{0} + \Delta x_{n}^{0}) \\ y_{2} - f_{2}(x_{1}^{0} + \Delta x_{1}^{0}, x_{2}^{0} + \Delta x_{2}^{0}, \dots, x_{n}^{0} + \Delta x_{n}^{0}) \\ \vdots \\ y_{n} - f_{n}(x_{1}^{0} + \Delta x_{1}^{0}, x_{2}^{0} + \Delta x_{2}^{0}, \dots, x_{n}^{0} + \Delta x_{n}^{0}) \end{bmatrix} = \begin{bmatrix} \frac{\partial f_{1}}{\partial x_{1}} & \frac{\partial f_{1}}{\partial x_{2}} \dots & \frac{\partial f_{1}}{\partial x_{n}} \\ \vdots \\ \frac{\partial f_{2}}{\partial x_{1}} & \frac{\partial f_{2}}{\partial x_{2}} \dots & \frac{\partial f_{2}}{\partial x_{n}} \\ \vdots \\ \vdots \\ \frac{\partial f_{n}}{\partial x_{1}} & \frac{\partial f_{n}}{\partial x_{2}} \dots & \frac{\partial f_{n}}{\partial x_{n}} \end{bmatrix} \begin{bmatrix} \Delta x_{1}^{0} \\ \Delta x_{2}^{0} \\ \vdots \\ \Delta x_{n}^{0} \end{bmatrix}$$

$$B = J.C$$

$$(22)$$

Here the matrix J is called the Jacobian matrix. The solution of the equations requires calculation of the vector B on the left hand side, which is the difference of the specified quantities and calculated quantities at $(x_1^0, x_2^0, ..., x_n^0)$. Similarly the Jacobian is calculated at this assumption. Solution of the matrix equation gives $(\Delta x_1^0, \Delta x_2^0, ..., \Delta x_n^0)$ and the next better solution is obtained as follows:

$$x_1^1 = x_1^0 + \Delta x_1^0$$

$$x_2^1 = x_2^0 + \Delta x_2^0$$

$$x_n^1 = x_n^0 + \Delta x_n^0$$

The better solution is now available and it is $(x_1^1, x_2^1, \dots, x_n^1)$

With these values the iteration process is repeated till:

(1) The largest element in the left column of the equations is less than the assumed value, or

(2) The largest element in the column vector is less than assumed value.

Temporarily assuming that all buses except bus 1, are PQ buses. Thus, the unknown parameters consist of the (n - 1) voltage phasors, V_2, \ldots, V_n . In terms of real variables, these are: Angles $\theta_2, \theta_3, \ldots, \theta_n$ (n - 1) variables

Magnitudes $|V_2|$, $|V_3|$, ..., $|V_n/(n_1)$ variables The linearized equations thus becomes,

$$\begin{bmatrix} \Delta P_2 \\ \Delta P_3 \\ \vdots \\ \Delta P_n \\ \Delta Q_2 \\ \Delta Q_3 \\ \vdots \\ \Delta Q_n \end{bmatrix} = \begin{bmatrix} \frac{\partial P_2}{\partial e_2} & \frac{\partial P_2}{\partial e_3} \cdots & \frac{\partial P_2}{\partial e_n} & \frac{\partial P_2}{\partial f_2} & \frac{\partial P_2}{\partial f_3} \cdots & \frac{\partial P_2}{\partial f_n} \\ \frac{\partial P_3}{\partial e_2} & \frac{\partial P_3}{\partial e_3} \cdots & \frac{\partial P_3}{\partial e_n} & \frac{\partial P_3}{\partial f_2} & \frac{\partial P_3}{\partial f_3} \cdots & \frac{\partial P_3}{\partial f_n} \\ \vdots \\ \frac{\partial P_n}{\partial e_2} & \frac{\partial P_n}{\partial e_3} \cdots & \frac{\partial P_n}{\partial e_n} & \frac{\partial P_n}{\partial f_2} & \frac{\partial P_n}{\partial f_3} \cdots & \frac{\partial P_n}{\partial f_n} \\ \frac{\partial Q_2}{\partial e_2} & \frac{\partial Q_2}{\partial e_2} \cdots & \frac{\partial Q_2}{\partial e_n} & \frac{\partial Q_2}{\partial f_2} & \frac{\partial Q_2}{\partial f_3} \cdots & \frac{\partial Q_2}{\partial f_n} \\ \frac{\partial Q_3}{\partial e_2} & \frac{\partial Q_3}{\partial e_3} \cdots & \frac{\partial Q_3}{\partial e_n} & \frac{\partial Q_3}{\partial f_2} & \frac{\partial Q_3}{\partial f_3} \cdots & \frac{\partial Q_n}{\partial f_n} \end{bmatrix}$$

Let Psp , Qsp and |Vsp| be the specified quantities at the bus p. Now, assuming a flat voltage profile, the value of P,Q and |V| at various buses are calculated.

Then,

$$\Delta P_p = P_{sp} \tag{24}$$

$$\Delta Q_p = Q_{sp} - Q_p^0 \tag{25}$$

(23)

$$|V_p|^2 = |V_{sp}|^2 - |V_p^0|^2$$
 (26)

[7] Where the superscript zero implies that the value calculated corresponding to initial assumption i.e zeroth iteration.

[8]

[9] After calculating the Jacobian matrix and the residual column vector corresponding to the initial solution, the desired increment vector can be calculated by using any standard technique. The next desired solution would be:

$$e_p^1 = e_p^0 + \Delta e_p^0 \tag{27}$$

$$f_p^1 = f_p^0 + \Delta f_p^0 \tag{28}$$

We use these voltage values in the next iteration. This process keeps repeating and the better estimates for the voltages of the buses will be: [1, 12, 21]

$$e_p^{k+1} = e_p^k + \Delta e_p^k \tag{29}$$

$$f_p^{k+1} = f_p^k + \Delta f_p^k \tag{30}$$

3. Results and Discussion

The results of the modelling after evaluating the various parameter are presented the Figure 1 to 13 respectively.



Fig. 1. Generator 2 power angle plot



Fig. 2. Graph of power angle for generator 4.



Fig. 3. Graph of voltage angle, voltage and frequency for bus 3







Fig. 5. graph of voltage angle, voltage and frequency for bus 1



Fig. 6. Graph of voltage angle, voltage and frequency



Fig. 7. graph of line 46, 34 and line 1



Fig. 8. Graph of bus 3 wave forms



Fig. 9. Graph of line 34 wave forms.



Fig. 10. Graph of line 46 wave forms.



Fig. 11. Graph of bus 1 wave forms

Fig. 12. Graph of line 34 wave forms

The load flow analysis was done on the Calabar transmission network which comprises of Adiabo sub station and flour mill injection station. These are the two major transmission networks in the area as shown in the ETAP model Fig. 13. It contains 41 buses, 56 branches, two generators and two grids' lines. These grids lines are Itu line 132KV and Odukpani power plant line 330KV.



Fig. 13. ETAP model of the Calabar transmission and sub-transmission

Setting the simulations time to 20 sec., the ETAP load flow analysis was simulated and the result obtained reveals that at bus 9, bus 54 and bus 50 has a bus voltage below the voltage limit of ± 5 (100V) %. When compensated the buses with static var compensators (SVC), the bus voltages improved to 96.112%, 98.887% and 103% respectively. Thus, increasing the total voltages on the network.

The transient stability analysis conducted on the same network as shown in fig. 4.4 with different faults conditions. The cases are:

- i. 3 phase faults on bus 3 at 5 sec. fault cleared at 15 sec
- ii. 50 % fault on line 34 at 10 sec.
- iii. Generator 4 has voltages impact of 10 % at 10 sec.
- iv. Line to line to ground fault at line 46.

The impact of the three phase faults on the network really affect the currents/voltage waveforms of others line on the network especially those that are closed by.

The line to line to ground faults its impacts on the network are shown in fig 4.15 and 4.16. Its reveals that, at 5sec where faults occur, the plots shows that the MW from the line 46. The wave form returned to zero and lasted for 10sec after which the faults as cleared at 15sec and the system trying

to return back to its normal form but not exact. Its current waveform clearly shows the impact. The faulted waveform returned to normal after which the fault was completely cleared.

4. Conclusion

On transient stability analysis, the impact of the faults on the network was obtained. At the point of faults, the impact generated affects all the lines and some busses, this is depending on the types of faults (3 phase fault) and its locations on the network, its durations also determined its impact on the network and finally when the faults are being cleared. The quicker the responds to fault the better the network. Any fault on the network that lasted for more than a specific period, the effect of the faults can cause a serious damage to the entire network depending on the types and the locations of the faults on the network. Thus, the transient stability analysis reveals the impact of faults on the network.

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Modelling and simulation of an adaptive gain PID controller for a direct torque fuzzy speed-controlled induction machine drive

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Abstract: The ongoing industrial revolution has increased the use of induction motors in various approaches to process control, optimization, and prediction. The direct torque controller (DTC) is an interesting control scheme for induction motor control. It is suitable for variable-frequency drives for torque and its consequent speed control, specifically for the calculation of the estimated Induction motor's magnetic flux and torque based on the motor's measured voltage and current. However, this scheme has a disadvantage in its implementation that makes it unsuitable for high torque applications, resulting in poor drive parameter variation, optimization, and dynamic responses when compared to field-oriented control (FOC). Fuzzy-based DTC is introduced to control. The high torque ripple nature of the direct torque-controlled induction motor, improve drive performance to parameter variation, and improve transient response to step changes in torque during start-up.

Keywords: Direct torque control (DTC), Neural Network (NN), Fuzzy Logic Control (FLC), induction motor

1. Introduction

Motion industries rely on induction motors as their workhorse. Because it is less expensive, more dependable, efficient, and robust than other electrical motors, it is frequently utilized for a variety of drive applications. They are used in hazardous environments because of their robust character, which classifies them as general-purpose machines. The non-linear behavior and sophisticated mathematical model of this concept have certain disadvantages, such as the unpredictability of the real drive operational characteristics and controllability. Induction motor speed management is very difficult, thus some quantitative and intelligent controllers are needed. For reliable and precise results, the exact mathematical model of the machine is needed while designing all of these controls. Non-linear properties are also used in the computation of the accurate mathematical models. These intricate computations demand a controller that is effective, trustworthy, and intelligent. Smart controllers are now in demand as a result of this. The two most popular control strategies in variable speed drive. Applications have been field-oriented control (FOC) and direct torque control (DTC) for a while. By converting the dynamic structure of the AC motor into that of an independently excited DC motor.

The DTC technique is preferably used to drive an appropriate inverter configuration in applications where torque and stator flux must be within a hysteresis band by choosing from the inverter switching table, according to the signs of the errors between the references of the torque, stator flux, and their actual values. This Direct Torque Control (DTC) technology enables fast torque response, low inverter switching frequency, and minimal harmonic losses by allowing direct and independent electromagnetic torque and flux control and optimal switching vector selection. Better transient responsiveness, avoidance of bothersome overcurrent trips, and reduction of load-dependent controller parameters are all feasible using DTC. These dictate that DTC is necessary in applications where torque, flux, and speed regulations are crucial. When compared to Field Oriented Control (FOC), conventional DTC has a significant torque ripple, a delayed transient reaction to step changes in torque during startup, and poor drive parameter variation

In this application such as high-capacity pump and fan drives, wind-energy generation systems, process conveyors, elevators and so on, where low torque ripple, fast transient response to the step changes in starting torque, and improved drive parameters variation, are of great demands, a robust DTC configuration is of increasing worth.

Works related to variable frequency control. [1, 2] presented the Design, Modelling, Simulation and Implementation of Vector Controlled Induction Motor Drive. The performance of the vectorcontrolled scheme was tested on a 40hp prototype drive. The dynamic performance of the drive was extensively tested and the results were presented. And it showed improved flux and torque components control.

Similarly, PID controller, and fuzzy logic controller techniques were simulated and compared in Matlab Simulink by [3, 4]. This work identified strengths and weaknesses of the controllers, and submitted that, the fuzzy controller is better than PID. Both [5, 6] wrote on comparison analysis between fuzzy and fuzzified PID methods on gun-barrel motion control, it was shown that in general the fuzzified PID control method excels the fuzzy-logic control method both in terms of steady-state error and settling-time performance. While, during the control of gun-barrel movement along the elevation direction, the fuzzy logic control performance was better than the fuzzified PID control in terms of settling-time.

[6] Developed a model on space vector modulation direct torque speed control (DTC) of induction motor and concluded that DTC is preferred over other controlling schemes for dynamic applications. Similarly, [6] developed a combined vector and direct torque control methods for two independent Induction Motor Drives. The DTC method produced lower percentage overshoot and faster speed response than the FOC with about 1% to 8% OS respectively. DTC has experienced lower electrical torque response (not beyond 10Nm) compared to the FOC with about 12Nm and 16Nm respectively. It was stated that DTC is unfit for large load torque applications. Also, [8, 9], [10] carried out a review on SERD, compared the indirect vector control and direct torque control of induction motor, and submitted that the speed and torque response of vector control approach gives better responses than the direct torque control.

[11], designed Controller for Direct Torque Controlled Space Vector Modulated (DTC-SVM) Induction Motor Drives. In a DTC-SVM scheme the switching harmonics are neglected in the control algorithm.

[12], presented a direct torque control strategy based on fuzzy logic controller for a doubly fed induction motor in IOP conference series, the controller recorded improve speed control performance and fast response with negligible overshoot. But there was no statistics on the torque performance.

Similarly, [13] presented a fuzzy logic control, via varying the IGBT inverter pulse width to achieve unity power factor. Though this scheme offered an improved unity power factor, but odd harmonics were uncontrolled, perhaps the current/voltage waveforms were obscured. Similarly, performance analysis of doubly inverter fed wound rotor induction motor using fuzzy and PI controller was presented by [14, 15]. It was noted that; the fuzzy logic controller is the best control scheme to envelope challenges arising from using vector control techniques, due to its sensitivity to parameter variation, such as rotor time constant and an incorrect flux estimation at low speed. Sequel to the information disclosed, the Fuzzy control method offers better performance. [16, 17] presented a modified multiband hysteresis controlled director torque controller of induction machine with 27-level asymmetrical CHB-MLI with NVC modulation. There was significant control of the drive hysteresis, but there was no presentation the torque Performance. [18] Modelled a metaheuristics optimization applied to a PI controllers tuning of a DTC-SVM drive for three-phase induction motors using soft computing techniques. It was shown that a PI base DTC controller gives absolute control of the drive speed with moderately improved torque performance.

[19, 20] compared PID and Neural Fuzzy logic control and submitted that FLC has more benefits, such as better static and dynamic performance, higher flexibility, and control, than PID controller.

[21], have made a comparative analysis of different pulse width modulation methods for low-cost induction motor drives, they reported the unbalance three phase output currents due to it the dynamic unbalance between the two capacitors by different pulse width modulation methods. [22] Presented a modified vector controlled DFIG wind energy system based on barrier function adaptive sliding mode control, as a protection and control of modern power systems. The speed control was recorded efficient, but there was no significant analysis of the result.

[23, 24], work on Comparison of output Current Harmonics of Voltage Source Inverter used Different PWM Control Techniques. This paper finds output current harmonics of open loop voltage source inverter for different PWM techniques which are measured by harmonic analyzer. [25] applied

a simple flux regulation strategy (SFRS) for the low-speed operation of DTC of IM for the control and reduction of the torque and flux ripples. The scheme through simulation and experimental and the result showed that the stator flux was regulated, as such a pure sinusoidal current waveform was achieved but the torque performance was not established.

[26] Used a GA optimization control technique with PI controller in combination of the sliding mode control strategy for the control of direct torque control in induction motor drive. The technique was able to control the rapid variation in motor speed to the optimum reference parameter for smooth operations. Also, the drive torque was absolutely controlled scheme. But their drive possessed a complex control scheme, which did not account for the resulting torque steady state response. [27] Introduced a combination of the conventional PI controller with the Type-I Fuzzy Logic control technique, with a sliding mode control strategy for direct torque control in induction motor drive. The model was designed in MATLAB environment, and the result showed that the complex technique was able to controls the rapid variation in motor speed to the optimum reference parameter for smooth operations, and was more effective and faster in variance and stability but the torque performance was not considered. This study aims at modeling and simulating an improved direct torque-controlled induction motor using fuzzy logic and neural network.

2. Method

a. Fuzzy Neural Controller

This is the self-tuned direct torque fuzzy controller for a voltage source PWM inverter fed induction motor. As shown in Fig. 1, in the first layer of the fuzzy structure, sampled flux error $\varepsilon \psi$ and torque error εT , multiplied by respective weights $w\psi$ and wT, are each mapped through two fuzzy logic membership functions which are chosen to be in a triangular shaped. The second layer calculates the minimum of the input signals. [28]. Increment angle. The components of the desired reference voltage vector are added to each other and the result, is delivered to the space vector modulator which calculates the switching states Sa, Sb and Sc according to the generic algorithm. The proposed NF structure is a simplification of the popular ANFIS structure. Where the first layer is composed of three membership functions (NEGATIVE, ZERO and POSITIVE) and is then governed by nine fuzzy rules. To decrease the number of rules used by the NF structure, it is an idea of merging the zero membership function structure. The proposed NF structure is governed by only four fuzzy rules. This results in decreasing the calculation time by more than a half, thereby saving the processing time.



Fig. 1. Neuro Fuzzy controller

This is simulated with the fuzzy Matlab toolbox. Fuzzy linguistic descriptions can be seen as unique depiction of idealization adopting the fuzzy IF-THEN rules. Basically, the fuzzy logic controller comprises four basic components: Fuzzification, knowledge base, inference engine, and a Defuzzification interface. In popular situations, systems with fuzzy outputs are easier to assume a smart (crisp) decision, when their outputs are symbolized as single scalar quantity. However, this simple conversion from fuzzy set to single crisp value is referred to as Defuzzification.

This technical brief described the use of the fuzzy logic toolbox to solve a typical control design problem. Fuzzy logic can make control engineering easier for many types of tasks. It can also add control, where it was previously impracticable. However, fuzzy control needs not be an empirical departure from conventional control techniques such as proportional integral derivative (PID) feedback systems, though it offers better performance.

b. Direct Torque Controller

The output is the switching logic which eliminates hysteresis band and PID and prevents the system from excess losses as shown in Fig. 2 and 3. Hysterics band keeps the system intact in this case.



Fig. 2. Direct Torque Controller system



Fig. 3. The complete system model

c. System model

The complete system model presented in Fig. 4 to 6, comprises of the full designed fuzzy direct torque controller and classical direct torque control. In this case a comparison is needed to demonstrate the conventional method of design and the new model method design.



Fig. 4. Neuro-fuzzy (ANFIS) controller subsystem



Fig. 5. Neuro-fuzzy based DTC, classical DTC and Flux and Torque estimator



Fig. 6. The Flux and the torque estimator

The three-output outlet are designed and come to a conclusion about the neuro-fuzzy model. Simscale is used in the modeling of the inverter machine system. The dc bus voltage parameter are to control the speed. The output of the controller is the torque and enters to the hysteresis band and switches states in the band.

3. Results and Discussion

In Fig. 6, the stator current under no load condition, is displayed using classical Direct Torque Controller, which represents the 40 percent of the full load current under load disturbance as shown in Fig. 7, and this validates the submission that the no-load current is always 20 to 40 percent of the full-load current [1, 8].

Also, within 0.28sec and 0.32sec of the stator current plots against time in Fig. 8 and 9, there is an exponential build-up current which generates the requisite flux to develop the starting torque to constantly increase the drive speed throughout the transient state to the steady state.









In Fig. 8, there is an exponential build-up current which generates the requisite flux to develop the starting torque to constantly increase the drive speed throughout the transient state to the steady state therefore showing the reference speed load track at load conditions and no load conditions within 0.04sec, from 0.28sec to 0.32sec. Hence signifying improved transient response to the step change in starting torque. In Fig. 10, the Stator qd-Flux of an induction motor under No-Load condition shows the constant operational electromagnetic field interaction between the stator and rotor windings, consequent to the application of direct torque control it can be deduced that the starting torque displays high transient response, which implies improvement in step change in starting torque, with respect to swift drive parameter variation from the smooth harmonization of the rotor windings under load conditions. Fig. 11 and 12 shows the high starting torque which displays wonderful characteristics torque performance, similar to excellently performed wound rotor induction motor, whereas the starting torque T-start is greater than T-break, implying that the improved drive is suitable for high inertial application.







Fig. 10. Reference speed tracking under No-load condition



Fig. 11. Stator qd-flux linkage under No-load condition



Fig. 12. Stator qd-flux linkage under load disturbance rejection

4. Conclusion

This analysis was carried out on load and no-load using Simulink, and from the result, the settling time reaches a long time due to drawbacks of classical method. In the neural network, there is a small drawback and a fast transient response reducing the torque ripple effect. The simulation results show the proposed model approach appears to generate and formulate a predictable adaptive gain speed controlled direct torque analysis model.

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Development of cement stabilized interlocking masonry block cubes using aluminum waste and granite powder

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Abstract: Conventional block are the most elementary building materials in building construction and its cost of production has soared. The rapid growth in today's construction industry has prompted the searching for alternative building materials and technique that shall lead towards achieving economical, efficient and durable replacement for these conventional blocks. In this research, quarry dust, Aluminum wastes (AW) and sharp sand were used in various percentages to produce block samples which were tested for compressive strength at age 7, 14, 21 and 28days. Tests on the setting times, particle size distribution, specific gravity and workability were also conducted on the materials and samples respectively. The results showed that Block produced with 78.57 % granite powder, 7.14% aluminum waste materials, 14.29% of cement and 0% of river sand were heavier, denser and 29.73% stronger in compressive strength than the traditional sand blocks. When the percentage of aluminum waste content did not exceed 7.14% AW, the blocks could be classified into medium weight blocks, whereas above 7.14% to 28.57% AW replacement, the blocks produced could be classified as light weight blocks. For the purpose of this study, a block mold of 150 x 150 x 150mm was used under laboratory condition to carry out the research.

Keywords: Cement; mixed; interlocking; gravity; block and aluminum

1. Introduction

The world growing population poses major challenges to the efforts championed by various Governments in facilitating access to affordable and adequate housing for their citizens and this is true in Nigeria. For this reason, there has been need for cheap and appropriate building materials to assist in alleviating the problem of inadequate housing and affordable construction cost. Buildings are made to last for decades. Not only because it shares emotional bonds with its residents, other reasons being the construction cost and time taken [1]. The provision of housing is a challenge faced by countries around the world, especially in developing countries including Nigeria. With the increase of construction materials cost such as cement, steel and timber, contractors are not enthusiastic to build house on tight budget. The alternative method has been explored in order to meet customers demand using low-cost building materials to provide affordable and high-quality housing [2]. Since seventy five percent of concrete is made up of aggregates, its types, quality and general properties determine the quality of concrete. At present, the most commonly used aggregate for mortar/concrete production are obtained from river and crushed aggregate of different sizes [3]. Aggregates (Coarse and fine) are the major constituents of any concrete mixture. It has been established that aggregate grading has a significant impact on the strength of concrete as it can either decrease or increase it, a factor which is as a result of the aggregate sizes, shape, texture etc [4]. In Nigeria, population increase has been tremendous over the years with the 2009 Census results estimated at 154,325,000 (NNBS, 2009) Million people. The continued increase in population size has led to increased housing demand for the low, middle, and high-income groups in the society. Sessional Paper No. 3 of 2004 on National Housing Policy for Nigeria indicates that annual demand for housing in urban areas is 150,000 units while 300,000 units need to be improved in the rural areas annually. The units produced annually, however, are a paltry 20,000-30,000 units which are not enough to meet the housing needs of urban dwellers. The medium term plan (MTP) for the implementation of Vision 2030, however, provides that annual urban housing demand in Nigeria has a projection of about 200,000 against a supply of about 50,000 housing units, thereby leaving a void of about 150,000 units. The population dynamics witnessed in the Country over time has prompted the introduction and adoption of cement stabilized masonry interlocking block (CSMIBs) as an alternative affordable building material and technology to the more commonly used conventional methods in housing construction.

The Growth of population, increasing urbanization, and rising standards of living due to technological innovations in Africa, have contributed to increase the quantity of a variety of solid wastes generated by industrial, mining, domestic and agricultural activities. Disposal of these wastes mostly generated from various industries such as iron slag from steel industries, aluminum hydroxide from aluminum industries is a serious and complicated problem because these wastes requires huge space for its disposal causing harm to the environment. From the perspective of energy saving and conservation of natural resources, the use of alternative ingredient in construction materials is now a global concern hence the research and development works towards exploring new ingredients required for producing sustainable, affordable and environment friendly construction materials. These new ingredients include introducing the utilization of waste materials from manufacturing industries, such as Fly Ash, Blast Furnace Slag, Granite Powder (Slurry), Aluminum Hydroxide, Recycled Aggregates, Red Mud, Burnt Bricks, Kraft Pulp Production Residue etc. thus the possibility of utilizing these wastes for use in construction materials is of great importance. Lots of research works is needed to be carried out to investigate the use of these wastes as construction materials. [5]

Another pressing fact is the introduction of interlocking blocks into Nigeria. Aside from the utilization of waste materials as construction materials, it is important also to note improvement of construction materials in Nigeria particularly the building blocks. Nigeria's history of building blocks, that is, Sandcrete blocks has been in use even throughout West Africa for over 5 decades as a popular building material for preparation of building blocks and bricks. Sandcrete blocks otherwise known as Cement blocks are the most commonly used blocks serving as walling materials in construction of shelter and other infrastructure construction purposes. Although, cement (binder) and natural sand are the most expensive input to the production of this Sandcrete blocks, still the poverty level amongst West African Countries, particularly Nigeria has made these blocks widely acceptable among the populace so as to minimize the cost of construction works. [6] Interlocking masonry blocks on the other hand can be accepted as a new building technique having the disposition to provide safe, sustainable and affordable constructions in Africa and even around the world resulting to a greater economy. Interlocking blocks are unique in relation to regular conventional blocks because of the absence of mortar to be filled between the blocks layers during the construction process [7]. This absence of mortar reduces cost of other construction materials (cement, water and natural sand)

Interlocking blocks is one of the new construction materials using prefabricated components that can interlock with one another. It is improvised from the conventional method which does not require mortar usage during bricklaying work. The amount of cement usage as stabilized agent mixed with quarry dust and aluminum waste in order to increase the strength of masonry interlocking blocks since they do not require mortar, the process of building walls is faster and requires less skilled labour as the block are laid dry and lock into place.

The traditional construction materials such as concrete bricks, hollow blocks, solid blocks, pavement blocks and tiles are being produced from the existing natural resources. Huge quantities of these construction materials are required in today's developing countries due to continued infrastructural growth and in turn large quantities of construction wastes are generated every year. The construction waste damages the environment due to continuous exploration and depletion of natural resources. The emission of toxic matters contaminates air, water, soil, and aquatic life, and thus would influence human health as well as the standard of living. As a result, major changes regarding the conservation of resources and recycling of wastes by proper management are taking place in our ways of living and working. For example, Waste like Fly ash (FA) and bottom ash (BA) are as a by-product from municipal solid waste incinerators and coal fuelled power stations. FA is a highly dispersible powder.

It contains mainly Aluminosilicate and Ferriferrous glassy spherical particles (about 60 - 80%) and irregularly shaped grains of amorphous clay, Mullite quartz and unburned metamorphic fuel. FA obtained from coal combustion is frequently used in concrete as a cost-effective substitute for portland cement. The pozzolanic properties of fly ash improve the strength of concrete. BA consists of irregular particles, which can be up to 10-15 mm in size. The chemical compositions of FA and BA ashes from the same power plant are similar [8]. As a rule, BA is inert and can be used as aggregate for producing construction materials such as mortar and concrete. In addition, BA can be used directly as aggregate in road construction [9]. Therefore from this researched example, the opportunity of reusing the wastes in environmentally and economically sustainable ways will produce an effective result of utilizing solid wastes in construction materials as innovative efforts for saving our environment. [5]

Some of the problems faced in construction today linked to sandcrete blocks include the necessary high cost of materials, Time consumption, and Poor quality of blocks. The poor quality of building materials as a result of unregistered and inadequately trained Block industries spread all over the country is one of the factors responsible for the collapse of buildings [10]. Therefore it is imperative to ensure that the production of interlocking blocks and bricks are not only accepted but regulated and adequately supervised to ensure quality.

Laterite mostly used for interlocking blocks will be replaced with the waste materials, aluminium hydroxide and granite slurry (powder), so research works will be carried out to investigate their use as construction materials and in this case, as cement stabilizers.

This project intends to study the possibility of using Aluminium hydroxide and Granite powder as additives in the development of interlocking blocks, an alternative to the use of sandcrete blocks in Nigeria.

2. Method

There is a variety of materials used and test to be carrying out in this project. These test comprises water absorption test, compressive strength, sieve analysis, slump test and Specific gravity test. The different of cement content, aluminum waste and the mine sand will influence the result of the testing.

The blocks was covered with plastic canvas and water sprinkled in the morning and evening for a total of 14 days to prevent rapid drying of the blocks, which could lead to shrinkage cracking until they were ready for strength and durability tests. The mix proportion 1:3:2:1 of cement-quarry-AW-sand with different ratio of quarry and recycled fine aggregate to be used will influence the testing results. There will be 2 type of curing process which consist of wet in shade, wet expose to direct sunlight. It is conducted to determine suitable curing process to be use. All of the blocks will be tested for compressive strength, water absorption and durability after 7, 14, 21 and 28 days of aged. There are all together 7 batches of the mix with different cement, granite, AW and sand content to be produced.

2.1. Materials Used for the Experiment

Aluminium (AW) used for this study were the industrial waste stockpiled by the aluminum producing firms in the commercial city of Aba, Abia State, Nigerian. Such aluminum production sites served as the source from which the AW used were obtained.

The wastes are irregular in shape, ash in colour and contain lumps and small particles of aluminum produced by burning aluminum scraps (raw material) in a furnace at about 1900°C. The total waste produced per day is approximately 18 tons. Before using the waste with concrete it was ground and sieved using sieve size 150µm. The cement used was Dangote cement, a brand of ordinary Portland cement and conforms to BS 12 (1978). The physical and chemical properties of the AW and OPC are given in Tables 1 and 2. The fine aggregate used is river sand with a specific gravity of 2.62, and a bulk density of 1710 kg/m³. The water used is potable drinkable water.

 Table 1. Physical Properties of Cement and Aluminum Waste

 Property
 Cement
 Aluminum

 Moisture Content (%)
 2

| Tropeny | Cemeni | 211111111111111 | |
|----------------------|--------|-----------------|--|
| Moisture Content (%) | 2 | - | |
| Specific gravity | 3.15 | 3.39 | |
| Bulk density (kg/m3) | 1440 | 776 | |
| Fineness (m2/kg) | 225 | - | |
| Ph | 9 | - | |
| | | | |

Table 2. Chemical Properties of Cement and Aluminum Waste

| Constituent | Cement | Aluminum Waste (AW) |
|-------------|--------|---------------------|
| MgO | 0.09 | 0.50 |
| Fe2O3 | 6.40 | 0.30 |
| CaO | 11.30 | 18.20 |
| Al2O3 | 20.60 | 15.90 |
| SiO2 | 52.40 | 56.60 |
| TiO2 | 0.52 | Trace |
| Na2O | 2.10 | 0.36 |
| K2O | 2.60 | - |
| ZnO | - | 0.80 |
| MnO | - | 0.60 |
| SO4 | - | - |
| CuO | - | Trace |
| CdO | - | Trace |
| LOI | 3.90 | 6.40 |

2.2. Crushed Quarry

Crushed stone or angular rock is a form of construction aggregate, typically produced by mining a suitable rock deposit and breaking the removed rock down to the desired size using crushers. It is distinct from gravel which is produced by natural processes of weathering and erosion, and typically has a more rounded shape.

2.3. Cement

In this study, ordinary Portland cement is chosen in producing interlocking block. The cement is a stabilizer agent. This is because this kind of cement is widely used in construction. Cement is cohesive upon mixing with water. The several of cement content will be mixed with aluminum waste material and quarry dust. This is to determine which proportion can give a better quality of block beside can achieve the requirement strength. The ordinary Portland cement produced by Dangote group of company being Nigerian's largest cement producer and as such readily available in almost every part of Nigeria was used for all the mixes required for this study. This cement also conforms to the requirements of the British Standard Code (BS 12 of 1996). To prevent the cement from being exposed to moisture and hardened before usage, it was kept in air tight packages and stored inside the laboratory.

2.4. Fine Aggregates (Sand)

The sand used was clean, sharp river sand from Onuimo River, it is free from clay, loam, dirt and organic matter of any description. It was obtained by sieving in order to fulfill the requirement of 100% passing through the 4.75mm sieve and 100% retained on the 75µm sieve.

2.5. Portable Water

Water used for the entire experiment was tap water fetched from the University tap. It is fresh, colourless, odourless, tasteless and free from organic matter of any type and its quality satisfies the BS 12 (1996) requirements.

2.6 Sieve Analysis

The aim of this analysis is to determine the various particle size distribution of quarry dust, aluminum waste, and sand. The apparatus used includes; Weighing balance, sets of sieves, weighing pan and oven. Sieve analysis consists of shaking a known weight of dried sample through a set of sieves that have been arranged in descending order of aperture sizes in a mechanical shaker for five minutes or manually for about ten minutes.

2.7 Slump Test

The concrete slump test is an on-the-spot test to determine the consistency as well as workability of fresh concrete. This test plays a vital role in ensuring immediate concrete quality in a construction project. It is used almost in every construction sites.

The slump test is very simple and easy to handle. It also demands comparatively less equipment and can be done in a short period of time. These advantages of slump test have made it very popular all over the world. In the slump test, workability of concrete is not measured directly. Instead, consistency of concrete is measured which gives a general idea about the workability condition of concrete mix.

2.8 Interlocking Block Mix Proportion

The total amount of materials needed for each mix was determined by the assumption of light weight block of density 1500kg/m³. For the purpose of this study, a block of 150 x 150 x 150mm was produced under laboratory condition. The mix ratio used was 1:6 (one part cement to six parts of sand) at constant water cement ratio of 0.5. The sand content was replaced partially and completely with the AW and crushed quarry from 0% to 22.5%. The 0% AW served as the control sample for the study. To prevent shortage as a result of waste, compaction and bulking of aggregates

2.9 Mixing Process

Hand mixing was adopted to produce the samples. According to cement and concrete institute, it is possible to make blocks on a small scale without a concrete mixer. Hand mixing was as well noted to have the advantage of reducing the amount of capital required and providing employment, though it may limit output and not always be thorough. However measures were put in place to control these deficiencies. Prior to mixing, all the components were weighted according to the mix proportions indicated in Table 3 The actual procedure followed is indicated below:

The mixing was done on an impermeable surface made free from all harmful materials which could alter the properties of the mix, by sweeping and brushing or scraping.

The measured aggregates samples was spread using a shovel to a reasonably large surface area.

In the case of both granite powder and AW as the core aggregates, the two materials were first mixed thoroughly until a uniform mix is obtained. Cement was then spread evenly on the aggregates and the composite materials once again thoroughly mixed with the shovel.

The dry mixture was further spread again to receive water which was added gradually while mixing, until the measured water was exhausted

| Mix | W/C ratio | Water (kg) | Cement (kg) | Granite powder (kg) | AW (kg) | Sand (kg) | Design Ratio |
|---------------------------|-----------|---------------|----------------|---------------------------|------------|--------------|-----------------|
| Control mix (0%AW+0%GP | 0.5 | 1.808 | 3.616 | 0.000 | 0.000 | 21.696 | 1:0:0:6 |
| 28.57%AW+ 42.86%GP. A | 0.5 | 1.808 | 3.616 | 10.848 | 7.232 | 3.616 | 1:3:2:1 |
| 7.14% AW + 78.57%GP. B | 0.5 | 1.808 | 3.616 | 19.888 | 1.808 | 0.000 | 1:5.5:0.5:0 |

Table 3. Quantities of materials water cement ratio per mix

| 7.14%AW+ 57.14%GP C | 0.5 | 1.808 | 3.616 | 14.464 | 1.808 | 5.424 | 1:4:0.5:1.5 |
|--------------------------|-----|-------|-------|--------|--------|-------|-------------|
| 28.57%AW + 28.57%GP D | 0.5 | 1.808 | 3.616 | 7.232 | 7.232 | 7.232 | 1:2:2:2 |
| 42.86%AW +42.86%GP. E | 0.5 | 1.808 | 3.616 | 10.848 | 10.848 | 0.000 | 1:3:3:0 |
| 21.43%AW +57.14%.GP F | 0.5 | 1.808 | 3.616 | 14.464 | 5.424 | 1.808 | 1:4:1.5:0.5 |
| 28.57%AW +57.14%GP. G | 0.5 | 1.808 | 3.616 | 14.464 | 7.232 | 0.000 | 1:4:2:0 |

| Mix | W/C | Water | Cement | Granite | AW | Sand | Design |
|---------------------------|-------|--------|--------|---------------|--------|--------|-------------|
| | ratio | (kg) | (kg) | powder | (kg) | (kg) | Ratio |
| | | | | (K <u>g</u>) | | | |
| Control mix (0%AW+0%GP | 0.5 | 3.616 | 7.232 | 0.000 | 0.000 | 21.696 | 1:0:0:6 |
| 28.57%AW+ 42.86%GP. A | 0.5 | 3.616 | 7.232 | 21.696 | 14.464 | 7.232 | 1:3:2:1 |
| 7.14% AW + 78.57%GP. B | 0.5 | 3.616 | 7.232 | 39.776 | 3.616 | 0.000 | 1:5.5:0.5:0 |
| 7.14%AW + 57.14%GP C | 0.5 | 3.616 | 7.232 | 28.928 | 3.616 | 10.848 | 1:4:0.5:1.5 |
| 28.57%AW + 28.57%GP D | 0.5 | 3.616 | 7.232 | 14.464 | 14.464 | 14.464 | 1:2:2:2 |
| 42.86%AW +42.86%GP. E | 0.5 | 3.616 | 7.232 | 21.696 | 21.696 | 0.000 | 1:3:3:0 |
| 21.43%AW +57.14%.GP F | 0.5 | 3.616 | 7.232 | 28.928 | 10.848 | 3.616 | 1:4:1.5:0.5 |
| 28.57%AW +57.14%GP. G | 0.5 | 3.616 | 7.232 | 28.928 | 14.464 | 0.000 | 1:4:2:0 |
| TOTAL (KG) | | 28.928 | 57.856 | 184.416 | 83.168 | 36.16 | |

2.10 Sample Details

Four (4) blocks each was produced from per mix design. This comprises of three (3) number 150 x 150 x 150 mm cube that were crushed later for the strength test and one (1) number of 150 x 150 x 150 mm cube for the water absorption test. In all a total of 64 block samples was mould for the study. The total quantities of materials required for the 64 blocks indicated in Table 4 was obtained from Table 3.1 by multiplying each quantity by two (2).

2.11 Moulding

For casting purposes, the typical steel mould (size: $150 \times 150 \times 150$ mm) were used for all the samples. The interior of the mould was first lubricated with mould oil to prevent the blocks from sticking to the sides so as to give the block a smooth surface and enable easy removal of the mould from the block after casting.

2.12 Block Test

After the stipulated 7, 14, 21, and 28days curing and drying period, the samples were taken to the laboratory for tests on weights, densities, water absorption and strength

2.13 Weight

An electronic weighing scale will be used to weigh the block samples and the result will be recorded on a data sheet. Each sample will be weighed twice; first dry weight and second wet weight (bulk weight) after each sample is immersed in water for 24hours.

2.14 Density

Two densities would be determined thus: dry density and wet (bulk) density. The dry density will indicate the density of the blocks after the 28days curing and drying period whiles the bulk density will refer to the density of the blocks after soaking in water for 24hours. To determine the densities, the volume of block will be calculated. The masses of the blocks obtained from weight test will be used to calculate the densities (p) from based on the Equation 1

$$P = M/V g/cm^3$$
(1)

Where: M = mass (g) and V = volume (cm³) of block sample. (2)

2.15 Water Absorption Test

Water absorption test on bricks are conducted to determine durability property of bricks such as degree of burning, quality and behavior of bricks in weathering. A brick with water absorption of less than 7% provides better resistance to damage by freezing. The degree of compactness of bricks can be obtained by water absorption test, as water is absorbed by pores in bricks. The water absorption by bricks increase with increase in pores. So, the bricks, which have water absorption less than 3 percent can be called as vitrified, the water absorption test will be conducted on the samples after the 28days curing period. This test provides the percentage of water absorption of bricks and procedure of the same is discussed below.

2.16 Compressive Strength Test

The compressive strength test was carried out at 7-days, 14-days, 21-days and 28-day curing age using ELE 2000kN compressive testing machine. All the three specimens for each mix proportion were crushed. The crushing was done on the edge face with a 3mm thick flat steel plate placed at top and bottom of sample for even distribution of load. The compressive strength was then calculated for each block sample using the equation:

Compressive strength =
$$Load/Area N/mm^2$$
 (3)

3. Results and Discussion

In this research work, different proportional substitution of AW aggregates were prepared. The first type of block is the control sample, which consisted of 100% normal fine aggregated (sand) whereas the second type are blocks made with AW aggregates substitution percentages of 2.5%, 7.5%, 10%, and 15% respectively. The results of the aggregates grading for both the sand and AW are discussed in this section. The section also included results and discussions on the strength performance of the different types of blocks produced with the varying AW aggregates of partial and complete replacement for the sand. Furthermore, all the results were obtained from tests conducted according to methods outlined in section 2 above.

3.1 Sieve Analysis

Table 5 to 7 as well as Figure 1 to 3 shows the particle size distribution of the river sand, granite powder and the AW aggregate used for the study. The result from grading tests on the river sand, granite powder and the AW shows that river sand are well graded while both granite powder and AW materials are poorly graded. However, all the aggregates were combined to achieve good results.

| B/S | Sieves | Weight Retained | % Retained | % Cummulative | % Passing |
|-------|--------|-----------------|------------|---------------|-----------|
| 3/8" | 4.76 | - | - | - | 100 |
| 1/4" | 2.00 | 1.2 | 0.46 | 0.46 | 99.54 |
| 3/6 | 1.18 | 0.9 | 0.35 | 0.81 | 99.19 |
| N0 7 | 0.425 | 113.7 | 56.85 | 57.66 | 42.34 |
| 25 | 0.300 | 50.1 | 19.27 | 76.93 | 23.07 |
| 52 | 0.212 | 24.1 | 9.27 | 86.2 | 13.8 |
| 100 | 0.150 | 13.0 | 5 | 91.2 | 8.8 |
| 200 | 0.075 | 17.2 | 6.12 | 97.32 | 2.68 |
| PAN | -0.075 | 5.7 | 2.19 | 100 | 0 |
| TOTAL | | | 100 | 510.58 | |

Table 5. Particle Size Distribution of Sand

Fineness modulus $=\frac{510.58}{100} = 5.1058$



Fig. 2. Particle size distribution for sand

Table 6. Particle Size Distribution of Granite powder

| B/S | Sieves | Weight Retained | Weight Retained % Retained % Cummulativ | | ve % Passing | |
|-------|--------|-----------------|---|--------|--------------|--|
| 3/8" | 4.76 | - | - | - | 100 | |
| 1/4" | 2.00 | 94.1 | 37.64 | 37.64 | 62.36 | |
| 3/6 | 1.18 | 15.9 | 6.36 | 44.00 | 56 | |
| N0 7 | 0.425 | 74.2 | 29.68 | 73.68 | 26.32 | |
| 25 | 0.300 | 12.3 | 5 | 78.68 | 21.32 | |
| 52 | 0.212 | 9.0 | 3.6 | 82.28 | 17.72 | |
| 100 | 0.150 | 11.5 | 4.6 | 86.88 | 13.12 | |
| 200 | 0.075 | 13.3 | 5.32 | 92.2 | 7.8 | |
| PAN | -0.075 | 19.5 | 7.8 | 100 | 0 | |
| TOTAL | | | 100 | 595.36 | | |

$$Fineness\ modulus = \frac{595.36}{100} = 5.9536$$



Fig. 3.Particle size distribution for granite

| B/s | Sieves | Weight retained | % retained | % cummulative | % passing |
|-------|--------|--------------------|------------|---------------|-----------|
| 3/8" | 4.76 | - | - | - | 100 |
| 1/4" | 2.00 | 40.5 | 16.2 | 16.2 | 83.8 |
| 3/6 | 1.18 | 8.7 | 3.48 | 19.68 | 80.32 |
| N0 7 | 0.425 | 164.1 | 65.64 | 85.32 | 14.68 |
| 25 | 0.300 | 32.5 | 13.0 | 98.32 | 1.68 |
| 52 | 0.212 | 20.0 | 0.8 | 99.12 | - |
| 100 | 0.150 | - | - | - | - |
| 200 | 0.075 | - | - | - | 0.88 |
| PAN | -0.075 | 2.2 | 0.88 | 100 | 0 |
| TOTAL | | | 100 | 418.64 | |

Fineness modulus $=\frac{418.64}{100} = 4.1864$



Fig. 4.Particle size distribution for aluminum waste

3.2 Specific gravity

| | Sand | Granite | Aw | Cement |
|------------------|--------|---------|-------|--------|
| $W_{2}(\sigma)$ | 1207.5 | 1253.8 | 996.3 | 1196.2 |
| $W_2(g)$ | 437.2 | 492.7 | 147.6 | 388.2 |
| W_4 (g) | 984.6 | 984.6 | 984.6 | 984.6 |
| $W_1(g)$ | 60.3 | 60.3 | 60.3 | 60.3 |
| Specific gravity | 2.44 | 2.6 | 1.2 | 2.8 |

Table 8. shows the specific gravity of the materials used

The specific gravity of aggregates normally used in construction ranges from around 2.5 to 3.0 with an average value of about 2.68.

Specific gravity of aggregates is considered as an indication of strength. Aggregates having higher specific gravity are generally considered as having higher strength and aggregates having low specific gravity are generally considered as having weaker strength. Hence the sand(2.44) has moderate specific gravity and moderate strength and aluminum waste material (1.2) has low specific gravity and weaker strength and granite powder (2.6) and cement (2.8) have high specific gravity and also high strength.

3.3 Slump test result

Table 9. shows the slump value, setting time and temperature of block

| Block Designation | Ratio (C,G,A,S) | Slump value (mm) | Initial Setting time (minutes) | Final Setting time (minutes) | Setting temperature (°C) |
|-----------------------------|--------------------|------------------------|-----------------------------------|---------------------------------|-----------------------------|
| Control mix (0%AW + 0%GP | 1:0:0:6 | 2 | 30 | 180 | 28 |
| 28.57%AW+ 42.86%GP. A | 1:3:2:1 | 3 | 40 | 568 | 39 – 59 |
| 7.14% AW + 78.57%GP. B | 1:5.5:0.5:0 | 2 | 35 | 280 | 39 - 59 |
| 7.14%AW + 57.14%GP C | 1:4:0.5:1.5 | 3 | 40 | 300 | 39 - 59 |
| 28.57%AW + 28.57%GP D | 1:2:2:2 | 3 | 50 | 520 | 40 - 59 |
| 42.86%AW +42.86%GP. E | 1:3:3:0 | 2 | 60 | 612 | 45 - 59 |
| 21.43%AW +57.14%.GP F | 1:4:1.5:0.5 | 2 | 55 | 470 | 39 - 59 |
| 28.57%AW +57.14%GP. G | 1:4:2:0 | 2 | 50 | 420 | 39 - 59 |



Fig. 5. Relationship between different ratio of AW% replacement and setting time of block

Measurement of workability from slump test is achieved from the slump value, from our result blocks have a very low workability. Aluminum waste material has pozzolanic values and retards the setting times of the blocks and, could be beneficial for hot-weather block moulding.

3.4 Curing of sample

To achieve maximum strength, cement stabilized interlocking blocks need a period of damp curing, where they are kept moist. This is a common requirement for all cementitious materials. What is important is that the moisture of the soil mix is retained within the body of the block for a few days. In practice, two types of curing methods are used to ensure proper curing. Such methods include, wet in shade and wet in direct sunlight to prevent moisture from escaping.

3.5 Compressive test result

Table 10 to 13 shows the compressive strength of the blocks in their respective days of crushing.

Table 10: Showing 7, 14, 21 and 28 days average compressive strength results in N/mm^2

| Block Designation | Cement | Granite Powder (GP) | Aluminum Waste (AW) | Sand | 7 days | 14 days | 21 days | 28 days |
|-----------------------------|--------|---------------------------|------------------------|------|--------|---------|---------|---------|
| Control mix (0%AW + 0%GP | 1 | 0 | 0 | 6 | 1.136 | 1.136 | 1.778 | 2.741 |
| 28.57%AW+ 42.86%GP. A | 1 | 3 | 2 | 1 | 0.000 | 0.000 | 0.000 | 0.222 |
| 7.14% AW + 78.57%GP. B | 1 | 5.5 | 0.5 | 0 | 2.147 | 2.296 | 2.889 | 3.556 |
| 7.14%AW + 57.14%GP C | 1 | 4 | 0.5 | 1.5 | 0.37 | 0.518 | 1.259 | 1.852 |
| 28.57%AW + 28.57%GP D | 1 | 2 | 2 | 2 | 0.222 | 0.296 | 0.37 | 0.518 |
| 42.86%AW +42.86%GP. E | 1 | 3 | 3 | 0 | 0.000 | 0.000 | 0.000 | 0.000 |
| 21.43%AW +57.14%.GP F | 1 | 4 | 1.5 | 0.5 | 0.000 | 0.148 | 0.148 | 0.444 |

| 28.57%AW | 1 | 4 | 2 | 0 | 0.000 | 0.000 | 0.148 | 0.222 |
|--------------|---|---|---|---|-------|-------|-------|-------|
| +57.14%GP. G | | | | | | | | |

100

In this research, Granite powder (GP), Aluminum wastes (AW) and sharp sand were used in various percentages to produce block samples which were tested for compressive strength at age 7, 14, 21 and 28days. Tests on the setting times, particle size distribution, specific gravity and workability were also conducted on the materials and samples respectively. The results of Table 10 and Figure 5 showed that Block produced with 78.57 % granite powder, 7.14% aluminum waste materials, 14.29% of cement and 0% of river sand and ratio (1: 5.5 : 0.5 : 0) (cement : Granite powder : Aluminum Waste : Sand) were heavier, denser and 29.73% stronger in compressive strength than the traditional sand blocks or control sample produced with 0% GP, 0% AW and 85.71% of sharp sand.

When the percentage of aluminum waste content did not exceed 7.14% AW, the blocks could be classified into medium weight blocks, whereas above 7.14% to 28.57% AW replacement as can be seen in samples A, D, F and G, the blocks produced could be classified as light weight blocks. When the percentage of granite powder was reduced to 57.14% and the percentage of sharp sand increased with percentage of AW at the same 7.14% that yielded maximum strength; the compressive strength decreased to 1.852N/mm2. This is an indication that granite powder with high density contribute greater percentage in the strength of the tested samples.



Fig. 5. Relationship between different ratio of AW% replacement and compressive strength of block.

Also, when the percentage of the aluminum waste were increased to 28.57% as can be seen in sample A, D and G, the various compressive strength decreased to 0.222, 0.518 and 0.222 respectively. This is an indication that there is a limit to which one can replace block aggregate with aluminum waste. At 42.86% AW replacement, the sample did not yield any meaningful strength. Hence, it is advised not to exceed replacement of 7.14% AW when high quality blocks are needed. Note also that a block of strength higher than conventional block can be obtained by 7.14% AW replacement.

According to Nigerian standard NS 7.6:1972 / British standard BS 3921:1985 the blocks B and the control block can be categorized as internal walls bearing blocks and can be used for suitable construction purposes.

| Block designation | Initial weight(kg) | Final weight(kg) | Water absorption (%) |
|--------------------------|--------------------|------------------|----------------------|
| Control mix (0%AW+0%GP | 6.736 | 7.002 | 3.964 |
| 28.57%AW+ 42.86%GP. A | 6.477 | 6.823 | 5.342 |
| 7.14% AW + 78.57% GP. B | 6.662 | 7.087 | 6.379 |
| 7.14%AW + 57.14%GP C | 6.635 | 7.202 | 8.546 |
| 28.57%AW + 28.57%GP D | 6.306 | 6.993 | 10.894 |
| 42.86%AW +42.86%GP. E | 5.498 | 5.918 | 7.639 |
| 21.43%AW+57.14%.GP F | 6.003 | 6.757 | 12.560 |
| 28.57%AW+57.14%GP. G | 6.028 | 6.655 | 10.401 |

Table 11. Average Water absorption capacity test results

The blocks (A to G) in which aluminum waste material is added have water absorption value of 5.342% - 12.560%. The control block where aluminum waste material was not added have water absorption value of 3.964%. Hence the addition of aluminum waste material increases the water absorption capacity of the blocks.

A brick with water absorption of less than 7% provides better resistance to damage by freezing, thus the result shows that, the control block, block A and block B will provide better resistance to damage by freezing than the other blocks.

The bricks, when tested in accordance with the procedure laid down in BS 3921:1985, after immersion in water for 24 hours, water absorption shall not be more than 20% by weight up to Class 12.5 and 15% by weight for higher classes. Blocks (B to G) tested fall under Class 5 and have water absorption capacity within 15% satisfying the provision of the code BS 1077:1992, section 7.2. Hence these blocks can be used for construction purpose.

3.6. Weight and Density

Table 12. shows the properties with respect to weights and densities of the block samples produced.

| Designated blocks | Dry density (g/cm ³) | Bulk density (g/cm ³) | Weight (kg) | |
|------------------------|-------------------------------------|-----------------------------------|-------------|--|
| Control mix (0%AW+0%GP | 2.0 | 2.07 | 6.74 | |
| 28.57%AW+ 42.86%GP. A | 1.92 | 2.02 | 6.48 | |
| 7.14% AW + 78.57%GP. B | 1.97 | 2.10 | 6.66 | |
| 7.14%AW + 57.14%GP C | 1.96 | 2.13 | 6.64 | |
| 28.57%AW + 28.57%GP D | 1.97 | 2.07 | 6.31 | |
| 42.86%AW +42.86%GP. E | 1.63 | 1.75 | 5.50 | |
| 21.43%AW +57.14%.GP F | 1.78 | 2.0 | 6.00 | |
| 28.57%AW +57.14%GP. G | 1.79 | 1.97 | 6.03 | |



Fig. 6 shows the properties with respect to weights and densities of the block samples produced

It could be observed from the Figures that, the relationships are the same. This means the higher the weight of a block, the higher the density. Referring to the values on the Figure 5, the block B of 7.14% AW aggregate replacement is found to be heavier and denser (6.66kg and 1.97kg/m³) as compared to the control sample of 0% AW aggregate replacement (6.74kg and 2kg/m³). It could also be noted that, from block C to G the values for both the weights and densities decreases. This indicates that for a better total and partial replacement of granite powder and aluminum waste for sand in block production, block B and C with 7.14% AW is the ultimate if the emphasis is solely on the weight or density.

3.7 Summary of Findings

Quest for strength in masonry block in order to meet present day demands in construction has fostered the utilization of various materials, especially solid waste introduction into aggregate mix. This study considered the 7.14, 21.43, 28.57, and 42.86 % partial and total replacement of natural sand aggregate with aluminum waste material. Blocks with less aluminum waste material and more granite powder have more suitable compressive strength than pure natural sand blocks.

In term of water absorption, A brick with water absorption of less than 7% provides better resistance to damage by freezing, thus the study shows that, the control block, block A and block B will provide better resistance to damage by freezing than the other blocks. It also appeared from the study that the weights and densities of the blocks produced increases in respect to weight. This means the higher the weight of a block, the higher the density. Also the study has reveal that the compressive strength of the block B with 7.14%AW (1:5.5:0.5:0) exceeds the minimum compression strength of 2.8 Mpa required by the BS 6073-1, (1981). However, the blocks with more aluminum waste material tends to have less strength and less weight, these can be used for construction work in high raise building and frame structures. Block (B) showed a very good strength with compressive strength of 3.556 MPa and as such suitable for internal wall bearing block. There was no significant difference among the other aluminum waste material mix ratios utilized in this study compared to strength, however Block (B) masonry unit has the highest potential of being utilized than other grades considered in this study.

Modification of aggregate composition in masonry block production with aluminum waste and granite powder enhanced masonry block quality and this will reduce environmental nuisance resulting from poor management practices of construction and demolition waste.

4. Conclusion

Blocks with aluminum waste and granite powder were found to be more porous than the traditional sand block, however, the resulting porosity do not exceed the minimum acceptable standard. Blocks

produced with granite powder and aluminum waste materials are heavier, denser and stronger than the traditional sand blocks when the aluminum waste content do not exceed 7.14%. At such percentage replacement, the blocks could be classified into medium weight blocks, whereas above 7.14% to 28.57% AW replacement, the blocks produced could be classified as light weight blocks.

Based on the result obtained, the following recommendations were made:

- In terms of water absorption, it is recommended that the use of aluminum waste material in place of sand should not be more than 10% for block production. Furthermore, the AW blocks are strongly recommended not to be used in areas where high moisture penetration is anticipated
- The blocks with percentage AW aggregate replacement not exceeding 7.14% (medium weight blocks) is recommended for load bearing walls such as gravity retaining walls, whereas those produced from 21.43% to 28.57% AW is recommended for areas where light weight blocks are suitable.
- Blocks produced with AW content above 10% (1:3:3:0) was found to be very light, porous and of low compressive strength, hence recommended for non-load bearing partition walls.

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Analysis of rainfall and temperature over a sub-basin of Lake Chad, Nigeria

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Abstract: Rainfall and temperature are two climatic variables that are indispensable for climate variability and change studies. This study aims to examine the trend pattern of rainfall and temperature over a sub-basin of Lake Chad Hydrological Area. To achieve this, rainfall and temperature datasets over 50 years (1970-2020) were analysed for variability and trends using descriptive statistics and Mann Kendal Trend Analysis. The results showed that the area has experienced a mean annual rainfall of 751.13 mm yr⁻¹ with a standard deviation of 136.58 mm yr⁻¹. Rainfall variability was high (CV >30) in the early rainy but less (i.e., CV <20) in the annual and late rainy season. The highest mean value was noted for TMIN, TMAX and TMEAN in the months of April and May and their highest variability was in the months of January and February. Also, an increasing trend in rainfall pattern that is significant (p<0.05) had been recorded in the late rainy season and annual timescale. Except for the TMAX (i.e., the day temperature) that showed an upward but non-significant trend, the remaining temperatures (TMIN and TMEAN) showed upward trends of varying levels of significance on seasonal and annual bases. This implies that the area has been experiencing a warming trend with effects on rainfall that has probably attracted the flood witnessed in part of the Lake Chad Hydrological Area.

Keywords: Rainfall, temperature, trend, variability

1. Introduction

Climate change is a global menace that has posed a serious threat to virtually every nation of the world [1]. Studies have shown that the impact of climate change and environmental crisis has been felt through erosion, drying of the land and prevailing drought [2]. Drought and flood which are the worst climate disasters account for 85% of the world's natural disasters, with drought having more detrimental effects [3]. Rainfall and temperature are the most critical climatic variables influencing climate extreme events. The consequences of their variabilities are evident in Africa, especially Nigeria which is an agrarian hub, with most of its agricultural activities depending on rain. Therefore, understanding the pattern and trends of these climatic variables is essential not only to climate change studies but also for decision-making on adaptation strategies.

Regional-scale analysis of historical climate data is essential for understanding the unique challenges posed by climate change to different parts of Africa. It provides the foundation for developing effective management and mitigation plans to address the impacts of climate change on water resources and agricultural activities, which are critical for the continent's sustainable development and food security [4]. This is so as rainfall and temperature remain better variables for easy understanding of the climatic condition of a place [5]. Several studies have been conducted on changing patterns of rainfall and temperature in Africa. Although most of the studies were carried out separately, either on rainfall or temperature variability. Therefore, there are limited studies conjoining both variables for variability studies. For instance, [6] used Regression and Mann-Kendall trend analysis to study the trend of temperature and rainfall over Guinea during 1960–2016. The results of their study indicated that while trends of temperature had been on the increase, the trends of rainfall had been on the decrease. A study by [5], who observed the rainfall and temperature variability over Nigeria between 1971 and 2000, indicated an increase in precipitation and air temperature in most parts of Nigeria, especially during the last decade (1991–2000) of the study period. The two aforementioned studies showed that though temperature followed a similar trend pattern, the pattern for their rainfall differs. This suggests the uniqueness of each area and a need for each basin or sub-basin to be assesed [4]. Thus, this study aims to analyse the variability and trend of rainfall and temperature over a sub-basin of the Lake Chad hydrological area.

2. Method

2.1. Study area

The Study area is located on latitude 11.8 N and longitude 9.8 E. It is situated within Lake Chad Hydrological Area, which is one of the eight hydrological area in Nigeria (Fig. 1). It falls within Sudano-Sahelian region and characterized with moderate rainfall and tropical climate. It experiences two seasons namely dry and wet season.



2.2. Details of data and data analysis

2.2.1. Dataset

The observation data used for the variability and trend analysis were obtained from the Climate Research Unit (CRU_TS 4.06), University of East Anglia, Norwich, UK. The CRU is a monthly dataset with 0.5 by 0.5 latitude and longitude resolution over the periods 1901–2021. However, this study uses a dataset between 1970 and 2020. The choice of the dataset is due to the unavailability of continuous long-term datasets. In Nigeria, CRU data has gained wide acceptance and its high correlation with Nigeria Meteorological Agency (NiMET) data has been reported by many researchers [8]. The obtained datasets are precipitation, minimum (TMIN) and maximum (TMAX) temperatures and the two were averaged to get the mean (TMEAN) temperature.

2.2.2. Data analysis techniques

In this study, descriptive statistics and Mann Kendall (MK) test have been adopted for the variability and trend studies respectively. The descriptive statistics carried out are the mean, standard deviation, coefficients of skewness (Cs), kurtosis (Ck), and variation (CV). The coefficient of skewness (Cs) is said to be right-skewed, if it has a positive Cs, left-skewed, if its Cs is negative Cs and a time-series is considered normally distributed if it has values of the coefficients of skewness and kurtosis of 0 and 3, respectively [4]. On the other hand, Mann Kendall (MK) and Sen Slope estimator were applied to determine the trend direction and magnitude.

2.2.3. Variability analysis

The CV was computed to evaluate the variability of the rainfall and temperature. The degree of variability is a function of the indicator, which implies that the higher the value of CV, the higher the

variability and vice versa [7]. The value of CV obtained is used to categorize the degree of variability of rainfall events as less (CV < 20), moderate (20 < CV < 30), and high (CV > 30). $CV = (\sigma/\mu) \times 100$ (1)

where CV is the coefficient of variation, σ is standard deviation, and μ is the mean rainfall.

2.2.4. Mann-Kendall trend test

Mann-Kendall (MK) trend test is skillful in detecting the presence, direction (increasing or decreasing) and significance of changes in rainfall and temperature series. The MK. test statistic 'S' is calculated using the equation below

$$S=\sum_{i=1}^{n-1}\sum_{j=i=1}^{n}sign(Xj-Xi)$$

where xi and xj are the sequential data values, n is the data set record length, and

$$\operatorname{Sign}=\begin{cases} +1 & \theta > 1\\ 0 & if \ \theta = 0\\ -1 & \theta < 0 \end{cases}$$
(3)

indicates positive differences, no differences, and negative differences, respectively, and S is computed as the sum of the integers. The expected value of S equals zero (E[S] = 0) for series without trend and the variance is computed as below:

expected value of S equals zero (E[S] = 0) for series without trend and the variance is computed as below:

$$\sigma^{2}(s) = \frac{1}{18} \left[n(n-1)(2n+5) - \sum_{p=1}^{q} t_{p}(t_{p}-1)(2t_{p}+5) \right]$$
(4)

where q is the number of tied groups and tp is the number of data values in pth group. The test statistics Z is then given as:

$$Z = \begin{cases} \frac{s-1}{\sqrt{\sigma 2} (s)} & S > 0\\ 0 & if \ S = 0\\ \frac{s+1}{\sqrt{\sigma 2} (s)} & S < 0 \end{cases}$$
(5)

The Z statistic is used to test the null hypothesis, H0 that the data are randomly ordered in time, with the alternate hypothesis, H1, indicating an increasing or decreasing monotonic trend.

2.2.5. Sen's slope estimator

Sen's Slope Estimator was used along with the MK test to quantify the magnitude of the trend. This provides information about the rate of change in the time series data. Sen's slope estimation test computes both the slope (i.e., change per unit time) and intercepts. A positive value of Z indicates an 'upward trend' (increasing values with time), while a negative value of Z indicates a 'downward trend'. Here, the slope (Q) of all data pairs was computed as presented below. The slope estimates of N pairs of data were first calculated using (6) below:

$$Q = \frac{X_J - X_k}{J - K} \text{ for } i = 1....N$$
(6)

where j > k.

Ranking of N values of Qi was done from the smallest value to the largest, and the Sen's estimator is given as:

$$Q = Q_{[(N+1)/2]} \quad \text{if N is odd} \tag{7}$$

$$Q = \frac{1}{2}(Q_{(N/2)} + Q_{[(N+1)/2]}) \text{ if } N \text{ is even}$$
(8)

For details on the analysis check [8] and [9].

(2)

3. Results and Discussion

3.1. Variability and trend of rainfall

The results of the statistical analyses of seasonal rainfall over the year (1970-2020) under study are presented in Table 1. The mean annual rainfall for the period was 751.13 mmyr⁻¹ having a standard deviation (SD) of 136.58 mmyr⁻¹. The minimum annual rainfall experienced was 425.2 mm while the maximum was 1061.60 mm. The coefficients of skewness and kurtosis were 0.37 and -0.03, respectively, which suggest that the data is right-skewed and not normally distributed. Similar pattern has been reprted by [4] for Niger Central Hydrological Area (NCHA), Nigeria. The temporal variability of annual rainfall was found to be 18.18%. The result of the Mk-test shows that it has an increasing annual trend that is significant (P < 0.05).

Table 1. Descriptive Statistics of monthly (mm/month), seasonal (mm/month), and annual (mm/year) rainfallover the sub-Basin (1970-2020).

| Time series | Min | Max | Mean | SD | CV% | Cs | Ck | Z-value | Q |
|-------------|--------|---------|--------|--------|--------|-------|-------|---------|--------|
| Apr | 0.40 | 31.60 | 8.55 | 8.27 | 96.79 | 0.11 | 0.93 | 0.78 | 0.019 |
| May | 4.50 | 141.80 | 50.23 | 30.49 | 60.70 | 0.09 | 0.78 | -0.19 | -0.039 |
| Jun | 39.20 | 279.70 | 104.78 | 54.13 | 51.66 | 1.60 | 1.36 | 2.13* | 0.986 |
| Jul | 118.00 | 324.70 | 199.97 | 44.99 | 22.50 | 0.32 | 0.34 | 0.90 | 0.459 |
| Aug | 115.00 | 399.40 | 249.68 | 54.11 | 21.67 | 0.69 | 0.02 | 2.75** | 1.233 |
| Sep | 31.70 | 215.10 | 119.31 | 42.60 | 35.71 | -0.60 | 0.09 | 1.66 | 0.771 |
| Oct | 0.60 | 90.70 | 18.16 | 18.45 | 101.63 | 4.17 | 1.80 | 2.14* | 0.306 |
| Early rainy | 59.80 | 362.30 | 163.55 | 68.75 | 42.04 | 0.94 | 0.94 | 1.65 | 1.095 |
| Late rainy | 322.40 | 843.20 | 587.11 | 102.22 | 17.41 | 0.47 | -0.30 | 2.78** | 2.759 |
| Annual | 425.20 | 1061.60 | 751.13 | 136.58 | 18.18 | 0.37 | -0.03 | 3.15** | 4.168 |

The late rainy season was found to have a higher contribution to the total annual rainfall than the early rainy season. While the late rainy season contributed 78.16%, 21.77% was contributed by the early rainy season. This is not unexpected, as most of the rainfall events were recorded in the month of August followed by July with their joint contribution of 76.6% to the average late rainy season rainfall (JASO) and 59.86% to the average annual rainfall. The inter-annual variability was higher in the early rainy season having a CV of 42.04% than in the late rainy season which has a CV of 17.41%. The degree of variability can be classified as high (CV > 30) for the early rainy season, and less (i.e., CV < 20) for the annual and late season rainfall. The less variability for annual time series is in agreement with the finding of [10].

Also, seasonal and annual rainfall have experienced a positive trend which was significant ((P < 0.05) for the annual and late rainy seasons. This evidence indicates that the late rainy season experiences greater fluctuations or variability from one year to the next compared to the early rainy season. This result contradicts what was reported in [4] that inter-annual variability was higher in the early rainy season than in the late rainy season over the NCHA. This variation in results could be attributed to a number of factors, such as climate patterns, weather conditions, or other environmental influences. This variability can have significant implications for agriculture, water resources, and ecosystems, among other things.

The peak of annual rainfall was in the month of August with a mean rainfall of 249.68 mmyr⁻¹, followed by the month of September with a mean rainfall of 119.31 mmyr⁻¹ (Fig. 2). The slope (Q) depicts the same pattern as that of the MK-test (Z-value).



Fig. 2. Monthly and seasonal rainfall (mm)

3.2. Variability and trend of temperature

The results of descriptive statistics of the temperature over the study area is presented in Table 2. The result shows the variability analysis of monthly, seasonal and annual temperature time series (minimum, maximum, and mean) for the period 1970–2020. The mean value of TMIN ranged from 14.03 °C (in January) to 25.06 °C (in May). The coefficient of variation (CV) of the monthly datasets indicated the night temperature varied from 2.24% (in August) to 8.02% (in January). The TMAX showed that the day temperature over the region ranged from 30.29 to 39.36 oC and varied from 2.09 to 5.79%. Also, the mean temperature over the area ranged from 22.14-31.81°C and varied from 1.98-6.16%. It was found that TMIN, TMAX and TMEAN have high mean values in the month of April and May with their highest variability in the month of January and February. Relatively high temperature in the months preceding the onset of the rainy season ascribed to the intensification of convective precipitation at high temperatures and highest variability in January has also been reported in earlier studies [8, 11].

| | TMIN | | TMAX | TMAX | | | N | | |
|--------|-------|------|------|-------|------|------|-------|------|------|
| | Mean | STD | CV | Mean | STD | CV | Mean | STD | CV |
| Jan | 14.03 | 1.13 | 8.02 | 30.25 | 1.75 | 5.79 | 22.14 | 1.36 | 6.16 |
| Feb | 17.01 | 1.35 | 7.93 | 33.47 | 1.83 | 5.46 | 25.24 | 1.55 | 6.13 |
| Mar | 21.26 | 1.28 | 6.00 | 37.18 | 1.41 | 3.80 | 29.22 | 1.26 | 4.30 |
| Apr | 24.25 | 0.90 | 3.73 | 39.36 | 0.90 | 2.29 | 31.81 | 0.82 | 2.57 |
| May | 25.06 | 0.69 | 2.76 | 38.20 | 0.80 | 2.09 | 31.63 | 0.63 | 1.98 |
| Jun | 24.35 | 0.58 | 2.37 | 35.77 | 0.81 | 2.26 | 30.06 | 0.64 | 2.14 |
| Jul | 22.90 | 0.54 | 2.37 | 32.37 | 0.95 | 2.94 | 27.63 | 0.72 | 2.59 |
| Aug | 22.13 | 0.50 | 2.24 | 31.39 | 0.85 | 2.72 | 26.76 | 0.64 | 2.40 |
| Sep | 22.01 | 0.51 | 2.32 | 33.18 | 0.82 | 2.47 | 27.60 | 0.63 | 2.28 |
| Oct | 21.10 | 0.76 | 3.58 | 35.37 | 0.76 | 2.14 | 28.23 | 0.62 | 2.20 |
| Nov | 17.10 | 1.07 | 6.24 | 34.11 | 1.20 | 3.51 | 25.61 | 1.06 | 4.12 |
| Dec | 14.69 | 1.05 | 7.11 | 31.30 | 1.41 | 4.52 | 23.00 | 1.15 | 5.00 |
| NDJFM | 16.82 | 0.66 | 3.95 | 33.26 | 0.84 | 2.53 | 25.04 | 0.72 | 2.87 |
| AMJ | 24.55 | 0.55 | 2.26 | 37.78 | 0.60 | 1.59 | 31.17 | 0.51 | 1.63 |
| JASO | 22.03 | 0.48 | 2.16 | 33.08 | 0.63 | 1.92 | 27.56 | 0.53 | 1.91 |
| Annual | 21.14 | 0.45 | 2.12 | 34.33 | 0.52 | 1.51 | 27.92 | 0.44 | 1.58 |

Table 2. Descriptive statistics of Temperature over the study area (1970–2020) CV in %
More so, on a seasonal basis, all the peak values for TMIN (24.55 °C), TMAX (35.17 °C) and TMEAN (28.03 °C) were recorded in the early rainy season (AMJ). This shows that while the early rainy season was the warmest, the coldest was the late rainy season The high temperature experienced in the early rainy season, despite it being associated with rain, can be attributed to several factors, including intense land preparation activities, increased insolation, moisture levels in the soil, and local climate and geographical features [8]. The activity tends to expose the area to extreme daylight heating and thus increases the temperature [11]. The highest seasonal variability was recorded for the TMIN (3.95%). TMAX (2.53%) and TMEAN (2.97%) in the dry season (NDJFM). The high variance of the temperatures in the dry season indicated a probable extension of the dry season.

The result of the Mann-Kendall trend presented in Table 3 showed the trend of TMIN, TMAX and TMEAN for all the time series. The monthly time series of the TMIN showed that only January and February were insignificant, the remaining months showed increasing trends at various levels of significance. The results for TMAX showed that increasing trend in 50% of the months were not significant, while four months (April, May, July and October) were significant at P < 0.05, the remaining two months (March and November) recorded an increasing trend that significant at P < 0.01. The TMEAN also recorded an increasing trend that were significant in all months, except January, February, August and September which experienced positive but not significant trends. The trend pattern reported for TMEAN in this study is similar with the report of [8].

The trends for annual TMIN, TMAX and TMEAN all showed increasingly significant trends (P < 0.01). On a seasonal scale, both TMIN and TMEAN showed a significant increasing trend (P < 0.01) in both the dry and the rainy seasons, while TMAX showed a significant trend only in the dry (P < 0.01) and early rainy (P < 0.05) seasons. The late rainy season (JASO) was insignificant. In both monthly, seasonal and annual scales, sen's slope showed the same pattern as that of the Men-Kendal estimator in both magnitude and direction. This could be due to the close lag-1 serial correlation observed in the data [12].

TMEAN

| | | | 11011111 | | | BIII | |
|--------|---------|------|----------|-------|----------|-------|--|
| | Test Z | Q | Test Z | Q | Test Z | Q | |
| Jan | 1.29 | 0.01 | 1.00 | 0.017 | 1.210 | 0.015 | |
| Feb | 1.88 | 0.03 | 0.87 | 0.015 | 1.081 | 0.020 | |
| Mar | 3.00** | 0.03 | 2.86** | 0.034 | 3.129** | 0.035 | |
| Apr | 2.47* | 0.02 | 2.54* | 0.023 | 2.936** | 0.023 | |
| May | 2.80** | 0.02 | 2.49* | 0.015 | 3.073** | 0.019 | |
| June | 3.64*** | 0.02 | 1.52 | 0.014 | 2.651** | 0.015 | |
| July | 3.19** | 0.02 | 2.24* | 0.020 | 2.684** | 0.019 | |
| Aug | 2.66** | 0.01 | 0.36 | 0.002 | 1.284 | 0.008 | |
| Sep | 2.08* | 0.01 | 1.20 | 0.011 | 1.577 | 0.012 | |
| Oct | 3.23** | 0.02 | 1.97* | 0.014 | 3.016** | 0.017 | |
| Nov | 3.55*** | 0.04 | 3.17** | 0.035 | 3.690*** | 0.037 | |
| Dec | 2.85** | 0.03 | 1.65 | 0.025 | 2.332* | 0.027 | |
| NDJFM | 4.85*** | 0.03 | 3.42*** | 0.026 | 4.257*** | 0.028 | |
| AMJ | 3.98*** | 0.02 | 2.89** | 0.017 | 4.176*** | 0.020 | |
| JASO | 3.75*** | 0.02 | 1.62 | 0.011 | 2.551* | 0.013 | |
| ANNUAL | 5.43*** | 0.02 | 4.06*** | 0.019 | 5.117*** | 0.022 | |
| | | | | | | | |

ΤΜΔΧ

TMIN

Table 3. MK statistic for monthly and seasonal of temperatures over the area (1970–2020)

In this study, variability and trends of the monthly, seasonal and annual timescale of rainfall and temperature over 50 years (1970 - 2020) were analysed. The peak monthy and seasonal rainfall were in August (249.68 mm) and late rainy season (587.11 mm) and the average annual rainfall over the period was 751.13 mm. The highest monthly and seasonal variability were noted for October (101.63%) and early rainy season (42.04%) respectively. The TMIN and TMAX have high mean values in April and May with their highest variability were in January and February. A significantly positive rainfall had been experienced in the late rainy season and annual timescale. Also, the positive trends for the annual tempertures (TMIN, TMAX and TMEAN) were all significant. On a seasonal timescale, both TMIN and TMEAN showed trends that were positive and significant for both seasons while the trend of TMAX was though positive for both season, the trend was not significant in the late rainy season. This finding suggested that drought resistance growth with a shorter growth period should be planted in the early rainy season and a need for mitigation plan for probable flood as indicated by an increasing trend of the annual and late rainy season.

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Sustainable Materials for Green Economic Advancement with a Focus on Biosynthesized Nanomaterials

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Abstract: The increasing global emphasis on sustainable development and the urgent need to address environmental challenges have led to a growing interest in the search for a solution. The latter has led to a green economy centred on achieving ecological balance and resource efficiency, with green nanomaterials emerging as a transformative solution. These materials are eco-friendly, biodegradable, and possess unique nanoscale properties. They are characterized by environmentally benign synthesis techniques, bioinspired approaches, and diverse industry applications. This work explores the pivotal role of biosynthesized nanomaterials in promoting a green economy. It begins by elucidating the fundamental properties of nanomaterials that confer them with exceptional mechanical, optical, electronic, and catalytic attributes. This paper subsequently explores the diverse applications of nanomaterials across industries while discussing the economic implications. The work underscores the potential of green nanomaterials for achieving a green economy through sustainable energy by enhancing product performance, durability, and energy efficiency. The study addresses safety and ethical considerations and describes the importance of responsible nanomaterial design, risk assessment, and regulatory frameworks. The study concluded that nanomaterials hold immense promise as a cornerstone for driving the green economy.

Keywords: Sustainable development, Green Economy, Nanotechnology, Biosynthesized Industries.

1. Introduction

Sustainable materials play a crucial role in promoting a green economy, which aims to achieve sustainable development by minimizing environmental impact and conserving resources. These materials are designed to be environmentally friendly throughout their entire life cycle, from extraction or production to disposal or recycling [1]. They contribute to the reduction of greenhouse gas emissions, energy consumption, and waste generation. Additionally, sustainable materials often possess properties that enhance energy efficiency and promote the use of renewable resources. In an era marked by pressing environmental concerns and a growing emphasis on sustainable development, the convergence of nanotechnology and biotechnology has given rise to a remarkable solution: Biosynthesized Nanomaterials (NMs). The principles for the green economy are presented in Fig 1.

These innovative materials represent a pivotal step toward achieving a green economy, where resource efficiency, environmental preservation, and economic growth harmoniously coexist. According to the United Nations Environment Programme, "*a green economy is one that results in improved human well-being and social equity while significantly reducing environmental risks and ecological scarcities.*" This is the definition of "green economy" that is both popular and trustworthy. It is socially inclusive, resource-efficient, and low-carbon [2]. The principles of sustainable development serve as the foundation for the green economy. Its definition is rather broad and includes methods based on the concept as presented in Fig. 1. These were the eleven most often used green economic principles that were identified from eight published sets of ideas or characteristics that were looked at by the United Nations Division for Sustainable development, UNDESA [3].



Fig. 1. The 11 Principles (P) for the Green Economy

A "green" economy is not necessarily associated with higher levels of output and employment than a "brown" (or traditional) one. [4]. The notion of a green economy is characterized by either a contribution to reducing risks and inadequacies in environmental sectors or by a significant increase in investments and new initiatives in economic sectors contributing to the improvement and reinforcement of the Earth's natural richness. Sustainable agriculture, green building, clean technology, low-emission transportation methods, and sustainable energy are all receiving special attention. The energy industry unquestionably is pivotal to economic development. All economic growth is based on consumption and management, thus the idea of utilizing sustainable energy is heavily marketed. However, sustainable energy necessitates innovations, acceptance, and marketing of a green economy concept to provide a more comprehensive and integrated approach to the fit-in environment in economic theories and systems of things. It is anticipated that industries and economic sectors will be significantly impacted by nanomaterials [5]. By harnessing the power of nature at the nanoscale (which involves the control, design, or reorganization of matter typically at the strata of L individual atoms and molecules ranging between 1 and 100 nm in size [6]), nanomaterials such as fullerenes, carbon nanotubes, nanowires, quantum dots, and other nanoparticles stand as a beacon of hope for industries seeking to minimize their ecological footprint and embrace a future rooted in sustainability. They offer enormous economic potential, e.g., by substituting for other materials or by making new functionalities available, enabling new products, creating new jobs opening new markets [7].

1.1 Green Nanomaterials

Green nanomaterials offer the prospect of fulfilling a 'two-dimension dream': Sustainable design concepts may be used to create new goods, and 'greener' products can be used to replace older ones that are at least potentially damaging to the environment [8]. Green nanomaterials are in vast demand as natural alternatives to traditional chemical-based, eco-toxic materials in engineering various ecofriendly products that are biodegradable and biocompatible and eco-benign for a variety of applications in agriculture, biomedicine, textiles, and many other industries. Biosynthesized nanomaterials epitomize the fusion of scientific ingenuity and ecological stewardship. They are created by manipulating natural processes and guided by biologically inspired techniques and cutting-edge nanotechnology methodologies. Production involves using biological systems, such as microorganisms, plants, or enzymes, as opposed to traditional chemical synthesis methods. This synthesis approach offers distinct advantages over conventional manufacturing methods (such as easy synthesis and availability, fast, cost-effectiveness, high stability, eco-friendliness, reducing reliance on energy-intensive processes and scarce resources [9], [10]) reducing reliance on energyintensive processes and scarce resources, while simultaneously mitigating the release of harmful pollutants and waste. The inherent biocompatibility of these materials further accentuates their appeal, ensuring they not only adhere to green principles but also find applications across diverse sectors without compromising human health or environmental integrity. This transformative class of materials finds its applications woven seamlessly into the fabric of a Green Economy.

1.2 Benefits of Biosynthesized Nanomaterials

These materials have gained significant attention due to their potential to provide sustainable solutions for various applications in the green economy. Here's an overview of their benefits and applications:

- a) **Environmentally Friendly Production**: Biosynthesis methods often use natural processes and resources, reducing the need for hazardous chemicals and minimizing the generation of harmful byproducts. This aligns well with the principles of green chemistry.
- b) **Reduced Energy Consumption**: Some biosynthesis methods require lower energy inputs compared to conventional chemical methods, contributing to energy conservation and overall sustainability. This energy efficiency contributes to reducing greenhouse gas emissions and overall energy consumption.
- c) **Biodegradability**: Many biosynthesized nanomaterials are biodegradable, which reduces their environmental impact at the end of their lifecycle. This characteristic is particularly important in applications such as drug delivery or environmental remediation, where the nanoparticles need to degrade without leaving harmful residues.
- d) **Renewable Resources**: Biosynthesis can utilize renewable resources such as agricultural waste, microorganisms, and plants, making these methods more sustainable in the long run. By utilizing these resources instead of non-renewable ones, biosynthesis reduces the reliance on fossil fuels and other limited resources.
- e) **Tailored Properties**: Biosynthesized nanomaterials can often be engineered for specific properties, making them suitable for a wide range of applications.
- f) **Waste reduction**: Biosynthesis processes can utilize waste materials as precursors or substrates for nanoparticle production. This approach reduces waste generation and provides a value-added use for these materials.

Although the green chemistry approach offers several benefits over chemical synthesis techniques, some significant issues must be addressed before these technologies can be successfully applied commercially on a substantial industrial scale. The main issues are as follows [9]:

- a) The potential ecological imbalance may result from the overuse of natural bioresources (plants, microorganisms, etc.).
- b) Variations in active biomolecule or phytochemical concentrations brought on by seasonal or climatic fluctuations impact bioactivity or synthesis processes.
- c) Some nanoparticle (NPs) might not be produced using the biosynthetic technique because they require strong reducing agents.
- d) Due to various phytochemicals, it is challenging to recognize and separate bio-active substances for particular applications present in plant leaf extract or other bioresources.
- e) Attaching desirable or selective active molecules to bio-nanoparticles (b-NPs) during synthesis is often impossible.
- f) The synthesis of a good manufacturing practice-grade product requires a detailed study or investigation.

1.3 Comparison between biosynthesize and chemically produced nanomaterial

The choice between biosynthesized and chemically produced nanomaterials depends on factors such as the intended application, desired material properties, environmental concerns, scalability requirements, and available resources. Both approaches have their own merits and limitations, and researchers and industries often make decisions based on a careful assessment of these factors to select the most appropriate method for their specific needs.

Table 1. Comparison between biosynthesize and chemically produced nanomaterial

| S/N | Biosynthesized Nanomaterials: | Chemically synthesized Nanomaterials: |
|-----|--|---|
| 1 | Production Method: | |
| | Produced using biological systems (biologically mediated processes) such as microorganisms, plants, or enzymes. | Synthesized using traditional chemical methods, often involving chemical reactions and the use of chemical precursors. |
| 2 | Environmental Impact: | |
| | Generally considered more environmentally friendly due to the use of natural processes, renewable resources, and reduced reliance on hazardous chemicals. | May involve the use of toxic chemicals, potentially contributing to environmental pollution and waste generation. |
| 3 | Nanomaterial Properties: | |
| | Properties can be influenced by the biological system used for synthesis, leading to unique characteristics. These materials might have specific functional groups or surface modifications. | Precise control over properties such as size, shape, composition, and surface chemistry, allowing customization for intended applications. |
| 4 | Scalability | |
| | Scaling up biosynthesis processes can be challenging due to the variability of biological systems and growth conditions. | Chemical methods can often be scaled up more easily and consistently, allowing for larger production quantities. |
| 5 | Purity and Contaminants | |
| | May contain biological impurities, which could impact material purity and stability. | Can achieve higher levels of purity with careful purification techniques. |
| 6 | Cost | |
| | Initial costs might be lower, as they can utilize natural biological systems and resources. | Initial costs might be higher due to the purchase of chemical reagents and equipment. |
| 7 | Biocompatibility | |

| _ | Could possess inherent biocompatibility due to their biological origin, making them suitable for biomedical and biotechnological applications. | Biocompatibility needs to be evaluated, as some chemical methods might introduce toxic residues. |
|---|---|---|
| 8 | Applications | |
| | Well-suited for applications where specific biological interactions or properties are required, such as in medicine and agriculture. | Versatile and can be tailored for a wide range of applications, including electronics, catalysis, and materials science. |
| 9 | Regulatory Considerations: | |
| | Might encounter less regulatory scrutiny in certain cases due to their biological origin, but potential biohazard risks need to be evaluated. | Must meet established regulatory standards for safety and environmental impact. |

1.4 Classifying Nanomaterials

Nanomaterials can be categorized in a variety of ways and according to a variety of categories. Classification may be based on origin, dimension, structural configuration, composition, etc. Here we look at classifications based on origin [10].

Natural nanomaterials: As the name implies, they are ones that are found naturally in the environment i.e., they exist in nature. These include the tiny pieces that make up smoke and volcanic ash, as well as some of the molecules that make up our bodies, including the hemoglobin in our blood. Other examples include clay, shells, coral, etc. The dazzling colors of a peacock's feathers are the result of the spacing arrangement between nanometer-scale configurations on their surface.

Artificial nanomaterials: The term "artificial nanomaterials" refers to those that result from humanmade processes or products. Intentionally created artificial nanomaterials, such as carbon nanotubes and semiconductor nanoparticles like quantum dots (QDs), are generated using exact mechanical and manufacturing processes.

1.5 Principles of Designing Green Nanomaterials

The principles of green chemistry and engineering governing the design and implementation of green nanomaterials are practiced by designing safer nanomaterials, reducing environmental impact [11], preventing waste, ensuring process safety, enhancing material efficiency, and improving energy efficiency (Table 1, Fig. 2) [12],[13].

The production of the nanomaterials for nanoproducts involves many processes similar to chemical manufacturing processes. As a result, fabricating nanomaterials can produce either harmful contaminants or adverse environmental consequences comparable to those from chemical manufacturing. The opportunity to actively account for and mitigate any negative environmental repercussions occurs at the early design stage of nanomaterial manufacturing. This is in contrast to the chemical sector, where the same processes are firmly ingrained. While prevention has not been a top priority in the present sector, it might become one in the future for those who produce nanomaterials in large quantities commercially. Green nanotechnology becomes the key in this regard [14].



Fig. 2. Design Through the Principles of Green Chemistry and Engineering

1.6 Properties of nanomaterials

Nanomaterials are formed, developed, and dissolved as a result of a sequence of fundamental chemical events that spontaneously redistribute charge and mass at the atomic level [15]. They exhibit distinct, so-called nano-specific principal traits or properties, compared to their equivalent bulk or macro-scale materials, due to their small size, size-dependent functions, high specific surface area, and properties, [16] which result from remarkable surface activity and electrical, magnetic, and optical capabilities. However, materials' properties or characteristics can be distinct on a nanoscale for two significant reasons. First, nanomaterials have a relatively larger surface area than the same mass of the same material produced in a larger form [17]. The surface area-to-volume ratio substantially impacts a material's chemical reactivity. This can make nanomaterials more chemically reactive (in some instances, materials that are inert in their bulkier form become reactive when fashioned in their nanoscale form) and affect their strength or electrical properties [18]. Nanoparticles are crucial in activities like catalysis, pollutant removal, medication release, and wound healing because they have a surface area that is substantially bigger than their unit volume. Second, below 50 nm (the upper limit of the scale range), phenomena not seen in larger structures begin to become apparent. The principles or laws of classical (Newtonian) physics give way to what is best described as quantum mechanical effects, prompting optical, electrical, and magnetic behaviours distinct from those of the same material at a grander scale. Newtonian physics cannot also be used to define the nanomaterials' colour, strength, weight, and chemical characteristics at variable particle sizes [19]. These phenomena can accord materials very wonderful physical properties such as excellent electrical conduction or resistance, or a high capacity for storing or transmitting heat, and can even transform biological properties [15]. Nanomaterials may be coated to display particular qualities, such as hydrophobicity or resistance to the development of microorganisms. As the percentage of atoms at the surface geometry increases, the chemical, mechanical, optical, magnetic, and electrical properties change. Examples include [16],[19],[20], [21]:

• Material properties (such as optical absorption), e.g., for gold (Au), and silver (Ag), experience colour change (a phenomenon called surface plasmon resonance – SPR [22]) with the size of their nanoparticles (Fig. 3).



Fig 3. Optical properties (colour) of gold and silver at the nanoscale

- Bulk silver (Ag), which is non-toxic yet may kill viruses on contact,
- Silver (Ag) becoming a bactericide on a nanoscale,
- Chemically inert gold (Au) can serve as a potent chemical catalyst,
- Brittle ceramics that become more elastic when smaller,
- Graphite (Gr), and diamond, which are formed of carbon components with various atomic configurations, and
- Carbon nanotubes are more flexible than rubber and stronger than steel,
- Opaque copper (Cu), becomes transparent
- Silicon (Si) insulators become conductors
- A white pigment, titanium dioxide (TiO₂), suddenly becomes transparent, etc.

Another important element of quantum physics is the capability of nanotechnology to produce materials in all three dimensions (nanoparticles), two dimensions (nanotubes), or one dimension (nanowires), which are highly sought-after in items connected to industrial applications [20]. These characteristics, however, can be quite challenging to manage. For instance, if two nanoparticles come into contact, they may fuse and lose their structure and any unique qualities, like magnetism, that researchers hope to employ to create a new generation of microelectronic devices and sensors.

2. Green Industry, Manufacturing and Sustainability

The green industry and green manufacturing are two distinct concepts that are often used interchangeably but have different meanings and implications. While both are focused on promoting sustainability and environmental responsibility, they operate in different sectors and have different objectives. The primary goal of the green industry is to develop and promote environmentally friendly practices that minimize negative impacts on the planet. [23]. An economy that is capable of sustainability needs manufacturing. It serves as the prime engine for innovation and the creation of higher-value jobs [24]. However, industrial manufacturing is saddled with a substantial environmental footprint in two forms. First, it requires an enormous amount of resources, such as materials, water, and power.

Additionally, it generates a significant amount of waste (gaseous, liquid, and solid) and hazardous by-products. One of the key principles of green manufacturing is resource efficiency. This involves optimizing the use of energy, water, and raw materials to reduce waste and minimize environmental pollution [25]. Green manufacturing also emphasizes the reduction of greenhouse gas emissions and other pollutants. This can be achieved by implementing cleaner production technologies, reducing transportation-related emissions through efficient logistics planning, or adopting carbon capture and storage techniques. To this end, nanomaterials have become indispensable in the green industry and green manufacturing sectors due to their unique properties and potential for enhancing sustainability.



Fig. 4. Contribution of nanomaterials to green economy by enabling innovative solutions in various sectors

From renewable energy technologies to water treatment processes and lightweight materials in manufacturing, nanotechnology offers numerous opportunities for improving energy efficiency, environmental friendliness, and overall sustainability. Governments and organizations have also developed various initiatives and certifications to support green manufacturing and sustainability. For example, the Leadership in Energy and Environmental Design (LEED) certification provides a framework for designing, constructing, and operating green buildings [26]. The ISO standard sets out criteria for an environmental management system that helps organizations minimize their environmental impact [27]. Additionally, there are industry-specific certifications, such as the Forest Stewardship Council (FSC) certification for sustainable forestry practices [28].

2.1. Applications of nanomaterials across industries

Green nanomaterials have the potential to revolutionize various industries, including energy, healthcare, pharmaceuticals, environmental remediation, electronics, textiles, packaging, and more [29], (Fig. 4). They can improve energy efficiency, reduce material usage, and enhance product performance. In the automotive industry, they can improve fuel efficiency, emission reduction, and food preservation. In the agriculture and food industry, they can improve crop yield, food safety, and packaging. In construction and building materials, they can enhance durability and energy efficiency. Cosmetics and personal care can lead to safer and more effective products. Nanomaterials can contribute to more efficient waste treatment and recycling in waste management. In the cosmetics and personal care sector, they can improve sunscreen effectiveness and anti-ageing products. They can contribute to more efficient waste treatment and recycling in the waste management sector. In environmental control, green nanomaterials can lead to resource efficiency, extended product lifespan, market differentiation, export opportunities, investment in research, and regulatory compliance. Collaboration between industries, researchers, and policymakers is crucial to maximize these materials' positive economic and environmental impacts.

3. Nanomaterial for Achieving Green-Economy Through Sustainable Energy

One of the key areas where nanomaterials play a significant role is in renewable energy generation. The present pace of energy consumption is putting additional strain on natural resources and fossil fuels. By 2050, annual energy consumption will double compared to current demand [5]. Even though most of the world's energy needs are met by fossil fuels, which release harmful gases into the atmosphere and cause severe natural disasters and climatic changes, researchers from all over the globe are working to identify secure and environmentally friendly replacements for non-renewable fossil fuels. Globally, solar energy is an abundant and cost-free resource. Finding and developing practically efficient technologies to harness and store solar energy is challenging. One such means is the use of solar cells and solar panels to produce, store, and convert solar energy [5]. Solar cells, for instance, can benefit from the integration of nanomaterials to enhance their efficiency and reduce costs. Nanomaterials such as quantum dots, nanowires, and perovskites have shown great promise in improving light absorption and charge transport within solar cells. Nanomaterials such as graphene and carbon nanotubes are promising in enhancing electrode conductivity and surface area within batteries, leading to higher energy storage capabilities. Biosynthesize Nanomaterials have also been incorporated into solar cells to improve their performance.

According to research, nanotechnology can be used as a substitute for non-renewable traditional energy sources and to achieve the objective of a hydrogen economy. For example, researchers have developed bio-inspired nanomaterials for water splitting, which is a key process for producing hydrogen as a clean fuel. However, these turbines employ generators to transform mechanical energy into electrical energy. These turbines can become more affordable and lightweight thanks to nanotechnology. Using carbon nanotubes in turbines results in lighter rotor blades with improved conductivity and robustness. The application of nanotechnology to the energy sector offers a path for developing energy sources that are more efficient, economically viable, and environmentally

responsible. The energy of the future will be produced by using nanostructures to build lightweight, low-fuel hybrid cars.

3.1 Risk assessment, and regulatory frameworks

Nanomaterials have sparked considerable interest in several industrial applications because of their distinct, nano-specific characteristics. The benefits of nanostructures for sustainable growth must compete with unknowns regarding market and industrial acceptance, competition from current conventional technologies, certain issues with environmental safety, and health risks. Concerns concerning the safety of their usage have been raised since the interactions of nanomaterials with their biological environment are not completely recognized or understood. Additionally, due to a lack of law due to the rapid advancement of technology, there are presently no enforceable rules governing the safety evaluation of nanoparticles. However, a number of authorities and organizations from around the world have released opinions and recommendations on how to ensure the safe production and use of nanomaterials. According to the safe-by-design philosophy, these suggestions encourage and advise manufacturers to evaluate safety first, or before the commencement of industrial production [16]. Because the features of the various nanomaterials vary greatly from one another, a case-by-case examination is frequently suggested [30]. But read-across data can offer a plethora of knowledge. The risk assessment procedure released by the European Commission (EC) [16]. seems to offer a useful tool for evaluating the risk connected with the production of nanomaterials and their byproducts. However, it shares with other risk assessment plans the problem of a lack of knowledge on the dangers and exposure of nanomaterials [31].

The Toxic Substances Control Act, often known as TSCA, is a law from the United States passed in 1976 that provides the U.S. Environmental Protection Agency the power to impose reporting, record-keeping, testing, and usage limits on chemical compounds. For instance, under the TSCA, the EPA is required to analyze substances like lead and asbestos that are known to pose a risk to human health. In addition, nanomaterials are governed under the TSCA as "chemical substances". "Control of Nanoscale Materials under the Toxic Substances Control Act". Environmental Protection Agency of the United States the EPA has just lately started exercising its control over nanotechnology, though. All businesses who produced or processed nanomaterials between 2014 and 2017 were obliged by the EPA to submit data on the kind and amount of nanotechnology they had utilized, [32]. The EPA must now be consulted before any new applications of nanotechnology may be put on the market [33]. The Environmental Protection Agency (EPA) makes use of this data to evaluate the possible environmental impacts of nanotechnology and control the discharge of nanomaterials into the environment.

4. Conclusion

In conclusion, nanomaterials hold immense potential for achieving a green economy through sustainable energy. Their unique properties and versatility make them valuable in various energy-related applications, including renewable energy generation, energy storage, energy conservation, and efficient lighting technologies. Nanomanufacturing has been described as an up-and-coming set of trends that will ultimately develop into a global megatrend: a technological reform still in its infancy but that many knowledgeable individuals—in science, commerce, and government, worldwide—expect to bloom in the years to come, bringing about "disruptive game-changing breakthroughs and innovation," new opportunities, job creation, and sundry societal benefits. As can be seen in figure 3, many schools of thought opine that, in terms of economic relevance and societal impact, nanomanufacturing may one day equal or perhaps surpass the digital revolution [34]. By harnessing the capabilities of nanomaterials, we can pave the way towards a more sustainable and environmentally friendly future. As we embark on this journey toward a more equitable and sustainable future, it is imperative to explore the realm of biosynthesized nanomaterials. This paradigm shift in material science reflects a technological evolution and a revolution in perspective.

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Flood inundation mapping of Calabar river using Hec-Ras and QGIS

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Abstract: Floods pose significant challenges worldwide, affecting communities, ecosystems, and economies. In Cross River State, Nigeria, the Calabar River, with its complex river network and climate conditions, is particularly vulnerable to recurrent floods. Recent events, such as the destructive flood in Cross river Local Government Areas highlight the urgent need for comprehensive flood management in the region. This study addresses the ongoing flood problem by utilizing a combination of HEC-RAS and QGIS for detailed flood mapping. Geospatial data extraction from Google Earth Pro, Digital Elevation Model (DEM) development in QGIS, and high-precision floodplain mapping using HEC-RAS form the core of the research scope. Three simulation Profiles with varying discharges of 1189.31, 1727.33 and 2491.88 cubic meters per second were used. The study found that the flow in the channel is subcritical, with a Froude number between 0.2 and 0.72. The results revealed that Profile 1, 2 and 3 resulted in an inundation area of 3365733.24, 3770894.64 and 3994215.90 square meters respectively with Profile 3 resulting in the highest flooding area. The findings reveal subcritical flow in the Calabar River, indicating slow and calm flow conditions. The study's key contribution lies in providing a detailed Flood map, offering crucial insights for disaster preparedness and risk mitigation. These findings highlight the importance of comprehensive flood mapping and robust risk assessment in flood-prone regions provides practical tools for enhancing flood resilience in the Calabar River region and beyond.

Keywords: QGIS, HEC-RAS, Discharge, Calabar River, Nigeria.

1. Introduction

Floods are recurrent natural disasters with significant effects on human populations and the environment. Flooding has had a profound and wide-ranging effect on communities, ecosystems, and the economy in the Nigerian state of Cross River. Using both local and worldwide viewpoints, this section gives a general overview of floods and their effects on the region. A naturally occurring hydrological phenomenon, floods are defined as the flooding of normally dry areas. Numerous things can cause them, such as excessive rain, snowmelt, storms, river overflows, and coastal locations [1]. Floods are a major obstacle to sustainable development in areas like Cross River State, where a complicated network of rivers and climate conditions are prevalent. With so many rivers, notably the Calabar River, Cross River State is especially prone to floods [2]. Floods in the state have an effect that goes beyond only immediate property destruction; they also interfere with livelihoods, infrastructure, and agriculture, which feeds a vicious cycle of social and economic problems [3].

HEC-RAS, the Hydrologic Engineering Center's River Analysis System is a crucial instrument in hydraulic modelling for risk assessment and flood mapping in the Calabar River region. This specialist program was developed by the U.S. Army Corps of Engineers [4] and enables a thorough study of river systems under various situations. Its features, which include sediment transport modelling, one-dimensional steady and unsteady flow, and water quality analysis, make it adaptable and ideal for intricate situations such as flood mapping. With its tools for modelling infrastructure like Flood Inundations, culverts, bridges, and channel alterations, HEC-RAS allows for a comprehensive knowledge of river dynamics. The program uses crucial data, such as topography, bathymetric, and cross-sectional information, to generate accurate hydraulic models. Flood mapping is made possible by HEC-RAS, which simulates how rivers react to various flow circumstances. This allows for the prediction of inundation extents, water velocities, and depths during flood occurrences. Because of the integration of data from many sources, such as GIS and cross-sectional surveys, HEC-RAS can provide crucial insights for the region's flood risk assessment. Flood analysis may be approached more effectively with the combined use of HEC-RAS and QGIS, two crucial tools for flood mapping. The U.S. Army Corps of Engineers created HEC-RAS, a hydraulic modelling tool that is used to properly simulate the characteristics of flood occurrences as well as model river systems, bridges, culverts, and Flood Inundations. However, data integration, visualization, and analysis are areas where QGIS, an adaptable open-source GIS program, shines [5] These two instruments work together to offer a holistic approach to comprehending and controlling flood occurrences in the Calabar River basin.

Floodplain mapping in Pakistan's Kabul River, providing a valuable tool for policymakers and urban planners in the region to identify and mitigate flood risks. Using the model, the study generates floodplain maps that delineate vulnerable areas, enabling informed decision-making for flood preparedness and disaster prevention. Radar Topography Mission digital elevation model and flood frequency analysis techniques was used to calculate extreme flows, revealing a significant 400% increase in flood risk, particularly in agricultural areas [6].

The application of HEC-RAS and ArcGIS for floodplain mapping in Segamat Town, Malaysia, emphasizing a risk-based approach to flood mitigation was carried out using Interferometric Synthetic Aperture Radar (IFSAR) data to analyze flood frequency and employed five distribution models to calculate extreme flows [7]. The Generalized Pareto distribution was found to best represent the flood characteristics of the Segamat River. Peak flood data from frequency analysis was used as input for the HEC-RAS model to determine corresponding flood levels, and ArcGIS was used to create floodplain maps for different return periods.

Comprehensive approach to flood modelling on a regional scale can be developed by combining Geographic Information Systems (GIS) with a rainfall-runoff model (HEC-HMS) and a hydrologic model (HEC-RAS) [8]. HEC-RAS produces Flood inundation maps that highlight areas at risk and delineate regions prone to flooding. It emphasizes 2D modelling of flood problems and demonstrates the significance of employing flood risk reduction measures to prepare for and manage future flood events.

This research aims to generate a flood inundation map of the Calabar River using QGIS and HEC-RAS. The research helps to enhance disaster preparedness, promote climate resilience, and engage local communities in flood mapping and management efforts.

2. Method

The geospatial coordinates of the stretch of Calabar River, spanning from Ikot Okon to Ikot Ekpene, were extracted using Google Earth Pro. Subsequently, QGIS was employed to generate a Digital Elevation Model (DEM) for the study area through interpolation methods. The DEM served as a crucial foundation for understanding terrain variations. Leveraging HEC-RAS, steady flow simulations were conducted, allowing the delineation of essential hydraulic parameters such as discharge, velocity, and water rating curves. The flood mapping process involved the use of three profiles, contributing to a comprehensive understanding of the river's behaviour.

2.1. Study Area

The geographic coordinates of Calabar River are around 04°54'15"N to 08°16'08"E in latitude and 04°56'40"N to 08°18'14"E in longitude. This region is in South Eastern Nigeria, inside the Cross River system. Fig. 1 shows the map containing the Calabar River, in Cross River State, Nigeria. According to [9], the Calabar River rises in the Oban Hills in Akamkpa, Nigeria, and runs south through the verdant rainforest of the country's southeast coast before joining the Cross River Estuary at Calabar. There are distinct rainy and dry seasons in this area, which is part of the humid tropical rainforest belt. Generally speaking, the dry season runs from December to March, while the wet season lasts from April to November.

Dense vegetation characterizes the coastal shoreline along the Calabar River, which eventually transitions to mangrove swamps close to the estuary from freshwater to swamp environment. The

nipa palm (Nypa fruticans), a member of the Arecaceae family, is the predominant vegetation along the riverbanks [10].



Fig. 1. Calabar River, Cross River State, Nigeria [11]

2.2. QGIS Data Preparation and Processing

In the Calabar River flood mapping research, QGIS plays a pivotal role in data preparation and processing. QGIS centralizes data integration, harmonizing various types of data like topographic, hydrological, meteorological, remote sensing, and GIS data. Georeferencing assigns spatial coordinates to non-spatial data, facilitating accurate overlay with GIS layers. QGIS ensures data cleanliness and validation through cleaning processes, enhancing the accuracy of Flood Inundation maps. Supporting both raster and vector data, QGIS is essential for tasks like terrain analysis and river network definition. Spatial analysis tools identify flood-vulnerable areas, overlay layers, and assess patterns. QGIS allows flexible data conversion and export for enhanced accessibility and compatibility. The software also designs the final Flood Inundation maps to effectively communicate results and integrates seamlessly with HEC-RAS for efficient data transfer.

2.3. Setting Up HEC-RAS Models and Key Parameters

HEC-RAS, a versatile hydraulic modelling software developed by the U.S. Army Corps of Engineers, is vital for simulating flood events. The process involves the following key steps:

HEC-RAS Overview: The software aids in the river and flood inundation hydraulics modelling, conducting hydrological and hydraulic simulations to understand Calabar River's behaviour during floods.

2.3.1 Key Parameters and Steps

River Geometry: Defining river geometry involves inputting cross-sections, banks, and channel data obtained from surveys, maps, or remote sensing.

Terrain Data: Detailed terrain data, including DEMs, is processed in QGIS for accuracy in understanding floodwater propagation.

Flow Data: Flow data, including rates, hydrographs, and boundary conditions, is derived from historical records, rainfall data, or simulated scenarios.

Hydraulic Structures: Integration of relevant hydraulic structures, like bridges, considers dimensions and characteristics.

Initial Conditions: Setting initial conditions establishes water surface elevation, velocity, and flow direction under normal conditions.

Boundary Conditions: Boundary conditions, such as downstream water levels, mimic river behaviour during floods.

Hydraulic Computations: HEC-RAS computes water surface elevations, flow velocities, and flood extents, considering terrain, river geometry, flow data, and boundaries.

Model Calibration and Validation: Model accuracy is validated by comparing simulated results with observed or historical data, adjusting as needed.

Simulation Scenarios: Multiple scenarios examine the river's response to different floods, evaluating various return periods and generating Flood Inundation maps.

3. Results and Discussion

3.1. River Geometry

The geometry of the river, the selected study area which is the Calabar River from Ikot Okon to Ikot Ekpene has been delineated and shown in Fig. 2. This was obtained using DEM generated from QGIS using EPSG 4326 W84 and the coordinates of the Minna/ Nigeria Middle Belt. The DEM is shown in Fig. 3.



Fig. 2. River geometry



Fig. 3. DEM for study area

3.2. Steady Flow Simulation

Steady flow analysis was carried out for the simulation of flood occurrence according to the documentation of HEC-RAS Software. Three profiles were used for the simulation to visualize the flood extents of the river in an increased flow The parameters used for simulation are shown in Table 1.

| S/N | Parameters | Value |
|-----|--|----------------|
| 1 | Flow for Profile 1 | 1189.31 cumecs |
| 2 | Flow for Profile 2 | 1727.33 cumecs |
| 3 | Flow for Profile 3 | 2491.88 cumecs |
| 4 | Manning coefficient at River Bed | 0.03 |
| 5 | Manning coefficient at River Bank (left and right) | 0.05 |
| 7 | Downstream Slope at normal depth | 0.0003 |

Table 1. Input variables for HEC-RAS Steady Flow Simulation

3.3. Cross Section for Study Area

Delineating cross sections have been delineated at the river centerline in HEC-RAS software which is essential for creating a hydraulic model that closely represents the real-world river behavior. It ensures that the model considers variations in channel geometry, flow distribution, and the impact of hydraulic structures, all of which are critical for accurate flood simulations and Flood Inundation mapping. The cross-section used for the Calabar River study area is shown in Fig. 4.



Fig. 4. Cross section used for Calabar river study area

Blue line denotes the River Centerline while the green line is the cross-section line. The numbers labelled at the green lines are the river stations of the cross-sections. The Cross-section values from the resulting simulations for Each of these stations are shown in Table 2.

| Reach | River Sta | Profile | Q Total | Min Ch El | W.S. Elev | Crit W.S. | E.G. Elev | E.G. Slope | Channel Vel | Flow Area | Top Width | Froude # Chl |
|----------|--------------|---------|---------------------|--------------|--------------|--------------|--------------|---------------|----------------|-------------------|--------------|-----------------|
| | | | (m ³ /s) | (m) | (m) | (m) | (m) | (m/m) | (m/s) | (m ²) | (m) | |
| Reach 1 | 22424 | PF 1 | 1189.31 | 2.12 | 6.29 | | 6.38 | 0.000308 | 1.40 | 973.68 | 343.06 | 0.23 |
| Reach 1 | 22424 | PF 2 | 1727.33 | 2.12 | 6.98 | | 7.11 | 0.000348 | 1.66 | 1219.53 | 366.40 | 0.25 |
| Reach 1 | 22424 | PF 3 | 2491.88 | 2.12 | 7.79 | | 7.96 | 0.000387 | 1.96 | 1515.50 | 366.40 | 0.28 |
| Reach 1 | 22029 | PF 1 | 1189.31 | 2.08 | 6.23 | | 6.34 | 0.000426 | 1.46 | 871.41 | 309.88 | 0.26 |
| Reach 1 | 22029 | PF 2 | 1727.33 | 2.08 | 6.92 | | 7.06 | 0.000450 | 1.71 | 1085.64 | 318.02 | 0.28 |
| Reach 1 | 22029 | PF 3 | 2491.88 | 2.08 | 7.71 | | 7.91 | 0.000484 | 2.02 | 1342.34 | 327.72 | 0.30 |
| Reach 1 | 21572 | PF 1 | 1189.31 | 2.15 | 6.06 | | 6.24 | 0.001005 | 1.88 | 632.38 | 275.24 | 0.39 |
| Reach 1 | 21572 | PF 2 | 1727.33 | 2.15 | 6.74 | | 6.96 | 0.000941 | 2.12 | 826.27 | 301.24 | 0.39 |
| Reach 1 | 21572 | PF 3 | 2491.88 | 2.15 | 7.52 | | 7.81 | 0.000901 | 2.39 | 1086.23 | 352.49 | 0.40 |
| Reach 1 | 21120 | PF 1 | 1189.31 | 2.07 | 6.08 | | 6.14 | 0.000283 | 1.13 | 1102.80 | 449.76 | 0.21 |
| Reach 1 | 21120 | PF 2 | 1727.33 | 2.07 | 6.77 | | 6.86 | 0.000281 | 1.30 | 1414.51 | 449.76 | 0.22 |
| Reach 1 | 21120 | PF 3 | 2491.88 | 2.07 | 7.58 | | 7.69 | 0.000287 | 1.51 | 1778.44 | 449.76 | 0.23 |
| Reach 1 | 20665 | PF 1 | 1189.31 | 2.11 | 6.03 | | 6.10 | 0.000342 | 1.28 | 1078.84 | 378.02 | 0.24 |
| Reach 1 | 20665 | PF 2 | 1727.33 | 2.11 | 6.71 | | 6.81 | 0.000358 | 1.50 | 1340.15 | 384.91 | 0.25 |
| Reach 1 | 20665 | PF 3 | 2491.88 | 2.11 | 7.51 | | 7.64 | 0.000382 | 1.77 | 1649.59 | 392.42 | 0.27 |
| Reach 1 | 20199 | PF 1 | 1189.31 | 2.07 | 6.00 | | 6.06 | 0.000215 | 1.12 | 1216.47 | 392.36 | 0.19 |
| Reach 1 | 20199 | PF 2 | 1727.33 | 2.07 | 6.68 | | 6.76 | 0.000242 | 1.34 | 1490.15 | 408.77 | 0.21 |
| Reach 1 | 20199 | PF 3 | 2491.88 | 2.07 | 7.48 | | 7.59 | 0.000272 | 1.59 | 1826.09 | 438.19 | 0.23 |
| D | 10.5.0 | | 1100.01 | • • • • | | | | | | 101016 | 10.000 | 0.15 |
| Reach I | 19562 | PF 1 | 1189.31 | 2.06 | 5.97 | | 6.01 | 0.000181 | 0.94 | 1313.16 | 496.92 | 0.17 |
| Reach I | 19562 | PF 2 | 1/2/.33 | 2.06 | 6.65 | | 6.71 | 0.000189 | 1.11 | 1656.36 | 504.40 | 0.18 |
| Keach 1 | 19562 | PF 3 | 2491.88 | 2.06 | 7.45 | | 7.54 | 0.000201 | 1.30 | 2062.73 | 512.98 | 0.19 |
| Reach 1 | 19029 | PF 1 | 1189.31 | 2.06 | 5.91 | | 5.98 | 0.000275 | 1.18 | 1048.25 | 374.97 | 0.21 |

 Table 2. Cross-section output of the three profiles

| Reach 1 | 19029 | PF 2 | 1727.33 | 2.06 | 6.58 | 6.67 | 0.000300 | 1.39 | 1301.37 | 379.16 | 0.23 |
|---------|-------|------|---------|------|------|------|----------|------|---------|--------|------|
| Reach 1 | 19029 | PF 3 | 2491.88 | 2.06 | 7.36 | 7.49 | 0.000331 | 1.64 | 1598.75 | 384.03 | 0.25 |
| Reach 1 | 18456 | PF 1 | 1189.31 | 2.14 | 5.83 | 5.92 | 0.000358 | 1.35 | 993.49 | 369.76 | 0.24 |
| Reach 1 | 18456 | PF 2 | 1727.33 | 2.14 | 6.50 | 6.61 | 0.000386 | 1.58 | 1239.55 | 373.10 | 0.26 |
| Reach 1 | 18456 | PF 3 | 2491.88 | 2.14 | 7.26 | 7.42 | 0.000423 | 1.85 | 1527.38 | 376.97 | 0.28 |
| | | | | | | | | | | | |
| Reach 1 | 17905 | PF 1 | 1189.31 | 2.14 | 5.77 | 5.86 | 0.000373 | 1.35 | 956.61 | 352.02 | 0.25 |
| Reach 1 | 17905 | PF 2 | 1727.33 | 2.14 | 6.42 | 6.54 | 0.000404 | 1.59 | 1188.53 | 356.12 | 0.27 |
| Reach 1 | 17905 | PF 3 | 2491.88 | 2.14 | 7.18 | 7.35 | 0.000445 | 1.87 | 1460.09 | 360.86 | 0.29 |
| | | | | | | | | | | | |
| Reach 1 | 17506 | PF 1 | 1189.31 | 1.91 | 5.74 | 5.81 | 0.000347 | 1.19 | 1198.34 | 539.71 | 0.23 |
| Reach 1 | 17506 | PF 2 | 1727.33 | 1.91 | 6.41 | 6.49 | 0.000326 | 1.34 | 1563.40 | 554.19 | 0.23 |
| Reach 1 | 17506 | PF 3 | 2491.88 | 1.91 | 7.18 | 7.28 | 0.000321 | 1.53 | 1997.36 | 568.84 | 0.24 |
| Reach 1 | 16871 | PF 1 | 1189.31 | 2.05 | 5.70 | 5.75 | 0.000235 | 1.05 | 1263.89 | 474.71 | 0.20 |
| Reach 1 | 16871 | PF 2 | 1727.33 | 2.05 | 6.36 | 6.43 | 0.000246 | 1.23 | 1585.50 | 493.71 | 0.21 |
| Reach 1 | 16871 | PF 3 | 2491.88 | 2.05 | 7.13 | 7.23 | 0.000263 | 1.45 | 1970.97 | 510.78 | 0.22 |
| | | | | | | | | | | | |
| Reach 1 | 16273 | PF 1 | 1189.31 | 2.34 | 5.64 | 5.70 | 0.000319 | 1.10 | 1100.47 | 501.41 | 0.22 |
| Reach 1 | 16273 | PF 2 | 1727.33 | 2.34 | 6.30 | 6.38 | 0.000300 | 1.25 | 1442.21 | 526.54 | 0.22 |
| Reach 1 | 16273 | PF 3 | 2491.88 | 2.34 | 7.07 | 7.17 | 0.000294 | 1.43 | 1857.96 | 553.45 | 0.23 |
| Reach 1 | 15384 | PF 1 | 1189.31 | 2.07 | 5.47 | 5.59 | 0.000487 | 1.50 | 851.48 | 351.04 | 0.28 |
| Reach 1 | 15384 | PF 2 | 1727.33 | 2.07 | 6.12 | 6.27 | 0.000515 | 1.76 | 1091.54 | 436.05 | 0.30 |
| Reach 1 | 15384 | PF 3 | 2491.88 | 2.07 | 6.86 | 7.06 | 0.000533 | 2.04 | 1416.07 | 436.05 | 0.31 |
| | | | | | | | | | | | |
| Reach 1 | 14324 | PF 1 | 1189.31 | 2.18 | 5.32 | 5.41 | 0.000498 | 1.38 | 971.81 | 419.86 | 0.28 |
| Reach 1 | 14324 | PF 2 | 1727.33 | 2.18 | 5.97 | 6.09 | 0.000480 | 1.58 | 1255.15 | 451.65 | 0.28 |
| Reach 1 | 14324 | PF 3 | 2491.88 | 2.18 | 6.72 | 6.87 | 0.000478 | 1.82 | 1593.91 | 451.65 | 0.29 |
| Reach 1 | 13452 | PF 1 | 1189.31 | 1.47 | 5.23 | 5.30 | 0.000320 | 1.33 | 1220.80 | 522.84 | 0.23 |

| Reach 1 | 13452 | PF 2 | 1727.33 | 1.47 | 5.88 | | 5.97 | 0.000331 | 1.52 | 1576.32 | 545.81 | 0.24 |
|---|---|--|---|---|---|-------------|---|--|--|---|--|---|
| Reach 1 | 13452 | PF 3 | 2491.88 | 1.47 | 6.64 | | 6.75 | 0.000346 | 1.75 | 1988.19 | 545.81 | 0.26 |
| | | | | | | | | | | | | |
| Reach 1 | 12971 | PF 1 | 1189.31 | 1.23 | 5.15 | | 5.24 | 0.000415 | 1.51 | 1097.33 | 482.33 | 0.26 |
| Reach 1 | 12971 | PF 2 | 1727.33 | 1.23 | 5.79 | | 5.91 | 0.000447 | 1.76 | 1416.54 | 542.97 | 0.28 |
| Reach 1 | 12971 | PF 3 | 2491.88 | 1.23 | 6.54 | | 6.69 | 0.000450 | 1.98 | 1825.16 | 542.97 | 0.29 |
| Reach 1 | 12537 | DF 1 | 1180 31 | 1 / 3 | 5 12 | | 5 18 | 0.0003/3 | 1 37 | 1377 34 | 6/3 83 | 0.24 |
| | 12537 | | 1707.00 | 1.43 | 5.12 | | 5.10 | 0.000341 | 1.57 | 1012 (0 | (07.() | 0.24 |
| Reach I | 12537 | PF 2 | 1/2/.33 | 1.43 | 5.77 | | 5.84 | 0.000341 | 1.54 | 1813.69 | 687.63 | 0.25 |
| Reach 1 | 12537 | PF 3 | 2491.88 | 1.43 | 6.53 | | 6.62 | 0.000331 | 1.71 | 2337.24 | 687.63 | 0.25 |
| Reach 1 | 11472 | PF 1 | 1189.31 | 1.23 | 5.01 | | 5.08 | 0.000295 | 1.19 | 1030.97 | 389.18 | 0.22 |
| Reach 1 | 11472 | PF 2 | 1727.33 | 1.23 | 5.63 | | 5.73 | 0.000325 | 1.41 | 1284.25 | 422.18 | 0.24 |
| Reach 1 | 11472 | PF 3 | 2491.88 | 1.23 | 6.36 | | 6.50 | 0.000355 | 1.67 | 1607.08 | 448.91 | 0.26 |
| | River | Profile | O Total | Min | W.S. | Crit | E.G. | E.G. | Vel | Flow | Тор | Froude # |
| D | | 1101110 | • | | EI. | MIC | T. | C1 | | | **** 1.1 | CLI |
| Rea | ach Sta | | (m3/s) | Ch El (m) | Elev (m) | W.S. (m) | Elev (m) | Slope (m/m) | Chnl (m/s) | Area (m2) | Width (m) | Chl |
| Reach 1 | ach Sta 10226 | PF 1 | (m3/s) 1189.31 | Ch El (m) 1.23 | Elev (m) 4.80 | W.S. (m) | Elev (m) 4.92 | Slope (m/m) 0.000562 | Chnl (m/s) 1.53 | Area (m2) 806.17 | Width (m) 358.31 | Chl 0.30 |
| Reach 1 Reach 1 | Interference 10226 10226 | PF 1 PF 2 | (m3/s) 1189.31 1727.33 | Ch El (m) 1.23 1.23 | Elev (m) 4.80 5.40 | W.S. (m) | Elev (m) 4.92 5.56 | Slope (m/m) 0.000562 0.000589 | Chnl (m/s) 1.53 1.79 | Area (m2) 806.17 1041.72 | Width (m) 358.31 406.79 | Chl 0.30 0.32 |
| Reach 1 Reach 1 Reach 1 Reach 1 | Interference Sta 10226 10226 10226 10226 | PF 1 PF 2 PF 3 | (m3/s) 1189.31 1727.33 2491.88 | Ch El (m) 1.23 1.23 1.23 | Elev (m) 4.80 5.40 6.10 | W.S. (m) | Elev (m) 4.92 5.56 6.32 | Slope (m/m) 0.000562 0.000589 0.000615 | Chnl (m/s) 1.53 1.79 2.09 | Area (m2) 806.17 1041.72 1332.00 | Width (m) 358.31 406.79 417.77 | Chl 0.30 0.32 0.33 |
| Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 | Internation Sta 10226 10226 10226 10226 10226 9783 | PF 1 PF 2 PF 3 PF 1 | (m3/s) 1189.31 1727.33 2491.88 1189.31 | Ch El (m) 1.23 1.23 1.23 2.09 | Elev (m) 4.80 5.40 6.10 4.23 | W.S. (m) | Elev (m) 4.92 5.56 6.32 4.72 | Slope (m/m) 0.000562 0.000589 0.000615 0.0003905 | Chnl (m/s) 1.53 1.79 2.09 3.11 | Area (m2) 806.17 1041.72 1332.00 394.58 | Width (m) 358.31 406.79 417.77 248.32 | Chl 0.30 0.32 0.33 0.33 0.73 |
| Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 | Instance Sta 10226 10226 10226 10226 10226 9783 9783 9783 | PF 1 PF 2 PF 3 PF 1 PF 2 | (m3/s) 1189.31 1727.33 2491.88 1189.31 1727.33 | Ch El (m) 1.23 1.23 1.23 2.09 2.09 2.09 | Elev (m) 4.80 5.40 6.10 4.23 4.78 | W.S. (m) | Elev (m) 4.92 5.56 6.32 4.72 5.36 | Slope (m/m) 0.000562 0.000589 0.000615 0.0003905 0.003401 | Chnl (m/s) 1.53 1.79 2.09 3.11 3.40 | Area (m2) 806.17 1041.72 1332.00 394.58 536.03 | Width (m) 358.31 406.79 417.77 248.32 261.94 | Chl 0.30 0.32 0.33 0.73 0.71 |
| Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 | Arch Sta 10226 10226 10226 10226 9783 9783 9783 9783 | PF 1 PF 2 PF 3 PF 1 PF 2 PF 2 PF 3 | (m3/s) 1189.31 1727.33 2491.88 1189.31 1727.33 2491.88 | Ch El (m) 1.23 1.23 1.23 2.09 2.09 | Elev (m) 4.80 5.40 6.10 4.23 4.78 5.38 | W.S. (m) | Elev (m) 4.92 5.56 6.32 4.72 5.36 6.10 | Slope (m/m) 0.000562 0.000589 0.000615 0.0003905 0.003401 0.003250 | Chnl (m/s) 1.53 1.79 2.09 3.11 3.40 3.83 | Area (m2) 806.17 1041.72 1332.00 394.58 536.03 694.85 | Width (m) 358.31 406.79 417.77 248.32 261.94 266.89 | Chl 0.30 0.32 0.33 0.73 0.71 0.72 |
| Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 | Arch Sta 10226 10226 10226 10226 9783 9783 9783 9783 | PF 1 PF 2 PF 3 PF 1 PF 2 PF 2 PF 3 | (m3/s) 1189.31 1727.33 2491.88 1189.31 1727.33 2491.88 | Ch El (m) 1.23 1.23 1.23 2.09 2.09 | Elev (m) 4.80 5.40 6.10 4.23 4.78 5.38 | W.S. (m) | Elev (m) 4.92 5.56 6.32 4.72 5.36 6.10 | Slope (m/m) 0.000562 0.000589 0.000615 0.0003905 0.003401 0.003250 | Chnl (m/s) 1.53 1.79 2.09 3.11 3.40 3.83 | Area (m2) 806.17 1041.72 1332.00 394.58 536.03 694.85 | Width (m) 358.31 406.79 417.77 248.32 261.94 266.89 | Chl 0.30 0.32 0.33 0.73 0.71 0.72 |
| Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 | Arch Sta 10226 10226 10226 10226 9783 9783 9783 9783 9783 9783 9094 9094 | PF 1 PF 2 PF 3 PF 1 PF 2 PF 2 PF 3 PF 3 | (m3/s) 1189.31 1727.33 2491.88 1189.31 1727.33 2491.88 1189.31 | Ch El (m) 1.23 1.23 1.23 2.09 2.09 2.09 1.04 | Elev (m) 4.80 5.40 6.10 4.23 4.78 5.38 4.16 | W.S. (m) | Elev (m) 4.92 5.56 6.32 4.72 5.36 6.10 4.30 | Slope (m/m) 0.000562 0.000589 0.000615 0.0003905 0.003401 0.003250 0.000802 | Chnl (m/s) 1.53 1.79 2.09 3.11 3.40 3.83 1.68 | Area (m2) 806.17 1041.72 1332.00 394.58 536.03 694.85 706.09 | Width (m) 358.31 406.79 417.77 248.32 261.94 266.89 296.21 | Chl 0.30 0.32 0.33 0.73 0.71 0.72 0.35 |
| Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 | Arch Sta 10226 10226 10226 10226 9783 9783 9783 9783 9783 9783 9094 9094 | PF 1 PF 2 PF 3 PF 1 PF 2 PF 2 PF 3 PF 1 PF 1 PF 2 | (m3/s) 1189.31 1727.33 2491.88 1189.31 1727.33 2491.88 1189.31 1727.33 | Ch El (m) 1.23 1.23 1.23 2.09 2.09 2.09 1.04 | Elev (m) 4.80 5.40 6.10 4.23 4.78 5.38 4.16 4.73 | W.S. (m) | Elev (m) 4.92 5.56 6.32 4.72 5.36 6.10 4.30 4.93 | Slope (m/m) 0.000562 0.000589 0.000615 0.0003905 0.003905 0.003250 0.000802 0.000842 | Chnl (m/s) 1.53 1.79 2.09 3.11 3.40 3.83 1.68 1.96 | Area (m2) 806.17 1041.72 1332.00 394.58 536.03 694.85 706.09 892.44 | Width (m) 358.31 406.79 417.77 248.32 261.94 266.89 296.21 344.81 | Chl 0.30 0.32 0.33 0.73 0.71 0.72 0.35 0.37 |
| Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 Reach 1 | Internation Sta 10226 10226 10226 10226 10226 9783 9783 9783 9783 9783 9794 9094 9094 9094 | PF 1 PF 2 PF 3 PF 1 PF 2 PF 3 PF 1 PF 2 PF 2 PF 3 | (m3/s) 1189.31 1727.33 2491.88 1189.31 1727.33 2491.88 1189.31 1727.33 2491.88 | Ch El (m) 1.23 1.23 1.23 2.09 2.09 2.09 1.04 1.04 | Elev (m) 4.80 5.40 6.10 4.23 4.78 5.38 4.16 4.73 5.37 | W.S. (m) | Elev (m) 4.92 5.56 6.32 4.72 5.36 6.10 4.30 4.93 5.64 | Slope (m/m) 0.000562 0.000589 0.000615 0.0003005 0.003401 0.003250 0.000802 0.000842 0.000911 | Chnl (m/s) 1.53 1.79 2.09 3.11 3.40 3.83 1.68 1.96 2.29 | Area (m2) 806.17 1041.72 1332.00 394.58 536.03 694.85 694.85 706.09 892.44 1115.12 | Width (m) 358.31 406.79 417.77 248.32 261.94 266.89 296.21 344.81 352.68 | Chl 0.30 0.32 0.33 0.33 0.73 0.71 0.72 0.35 0.37 0.39 |
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| | | | | | | | | | 1 | | 1 |
|---------|------|------|---------|-------|------|------|----------|------|---------|---------|------|
| | | | | | | | | | | | |
| Reach 1 | 8069 | PF 1 | 1189.31 | 0.87 | 4.01 | 4.09 | 0.000448 | 1.27 | 945.31 | 429.69 | 0.26 |
| Reach 1 | 8069 | PF 2 | 1727.33 | 0.87 | 4.59 | 4.70 | 0.000456 | 1.48 | 1209.60 | 478.91 | 0.27 |
| Reach 1 | 8069 | PF 3 | 2491.88 | 0.87 | 5.23 | 5.38 | 0.000486 | 1.74 | 1530.44 | 521.95 | 0.29 |
| | | | | | | | | | | | |
| Reach 1 | 7631 | PF 1 | 1189.31 | 0.79 | 3.85 | 4.00 | 0.000930 | 1.75 | 680.76 | 313.26 | 0.37 |
| Reach 1 | 7631 | PF 2 | 1727.33 | 0.79 | 4.39 | 4.61 | 0.000962 | 2.04 | 862.34 | 348.00 | 0.39 |
| Reach 1 | 7631 | PF 3 | 2491.88 | 0.79 | 4.98 | 5.27 | 0.001060 | 2.40 | 1077.02 | 385.45 | 0.42 |
| | | | | | | | | | | | |
| Reach 1 | 6865 | PF 1 | 1189.31 | 0.58 | 3.80 | 3.86 | 0.000304 | 1.10 | 1094.59 | 531.11 | 0.22 |
| Reach 1 | 6865 | PF 2 | 1727.33 | 0.58 | 4.36 | 4.45 | 0.000329 | 1.29 | 1432.34 | 607.46 | 0.23 |
| Reach 1 | 6865 | PF 3 | 2491.88 | 0.58 | 4.97 | 5.08 | 0.000369 | 1.52 | 1804.08 | 615.58 | 0.25 |
| | | | | | | | | | | | |
| Reach 1 | 6040 | PF 1 | 1189.31 | 0.59 | 3.74 | 3.79 | 0.000213 | 0.98 | 1422.97 | 736.20 | 0.18 |
| Reach 1 | 6040 | PF 2 | 1727.33 | 0.59 | 4.30 | 4.36 | 0.000228 | 1.14 | 1869.07 | 823.28 | 0.20 |
| Reach 1 | 6040 | PF 3 | 2491.88 | 0.59 | 4.91 | 4.99 | 0.000255 | 1.35 | 2386.17 | 885.35 | 0.21 |
| | | | | | | | | | | | |
| Reach 1 | 4841 | PF 1 | 1189.31 | 0.60 | 3.63 | 3.69 | 0.000329 | 1.14 | 1407.79 | 925.51 | 0.23 |
| Reach 1 | 4841 | PF 2 | 1727.33 | 0.60 | 4.20 | 4.27 | 0.000301 | 1.25 | 1942.58 | 948.53 | 0.22 |
| Reach 1 | 4841 | PF 3 | 2491.88 | 0.60 | 4.80 | 4.88 | 0.000306 | 1.41 | 2520.12 | 974.75 | 0.23 |
| | | | | | | | | | | | |
| Reach 1 | 3341 | PF 1 | 1189.31 | 0.57 | 3.41 | 3.48 | 0.000607 | 1.31 | 1158.90 | 719.02 | 0.29 |
| Reach 1 | 3341 | PF 2 | 1727.33 | 0.57 | 4.01 | 4.08 | 0.000489 | 1.34 | 1774.12 | 1200.70 | 0.27 |
| Reach 1 | 3341 | PF 3 | 2491.88 | 0.57 | 4.63 | 4.71 | 0.000403 | 1.42 | 2522.42 | 1200.70 | 0.26 |
| | | | | | | | | | | | |
| Reach 1 | 2211 | PF 1 | 1189.31 | 0.60 | 3.18 | 3.26 | 0.000615 | 1.30 | 1031.43 | 652.68 | 0.30 |
| Reach 1 | 2211 | PF 2 | 1727.33 | 0.60 | 3.81 | 3.90 | 0.000540 | 1.34 | 1496.44 | 831.84 | 0.28 |
| Reach 1 | 2211 | PF 3 | 2491.88 | 0.60 | 4.46 | 4.55 | 0.000459 | 1.44 | 2122.86 | 1035.92 | 0.27 |
| | | | | | | | | | | | |
| Reach 1 | 1422 | PF 1 | 1189.31 | -0.12 | 3.11 | 3.16 | 0.000270 | 1.01 | 1242.78 | 610.77 | 0.20 |
| Reach 1 | 1422 | PF 2 | 1727.33 | -0.12 | 3.73 | 3.80 | 0.000292 | 1.13 | 1685.16 | 821.93 | 0.22 |
| Reach 1 | 1422 | PF 3 | 2491.88 | -0.12 | 4.38 | 4.46 | 0.000298 | 1.27 | 2258.31 | 980.14 | 0.22 |
| t | | 1 | 1 | | | | | | | | |

| Reach 1 | 828 | PF 1 | 1189.31 | 0.21 | 3.05 | 1.32 | 3.11 | 0.000300 | 1.03 | 1189.34 | 593.10 | 0.21 |
|---------|-----|------|---------|------|------|------|------|----------|------|---------|--------|------|
| Reach 1 | 828 | PF 2 | 1727.33 | 0.21 | 3.68 | 1.61 | 3.74 | 0.000300 | 1.15 | 1610.15 | 718.26 | 0.22 |
| Reach 1 | 828 | PF 3 | 2491.88 | 0.21 | 4.32 | 1.96 | 4.40 | 0.000300 | 1.32 | 2093.33 | 817.66 | 0.23 |

The discharge of water for the three simulations is shown in Fig. 5 where the water surface elevation and the energy radiant line are plotted against the main channel distance.



Fig. 5. Profile plot of study area

3.4. General Velocity

The water velocity in the river is influenced by three primary factors: discharge, depth, and location within the river channel. The velocity increases with discharge due to the larger volume of water flowing, resulting in faster-moving water molecules. Conversely, velocity decreases with depth as frictional forces between water molecules and the riverbed become more pronounced. Additionally, velocity is highest around the center of the river, gradually decreasing towards the banks, where frictional forces from the riverbed and banks impede water flow. The general velocity plot from the simulation is shown in Fig. 6



Fig. 6. General Velocity Plot for the Study Area

3.5. Water Rating Curve

The water rating curve plot provided by HEC-RAS is a graphical representation of the relationship between the depth (water level) and discharge (flow rate) of a river or stream. The water rating curve plot typically shows depth on the y-axis and discharge on the x-axis. The curve itself is usually a smooth, upward-sloping line, indicating that discharge increases as stage increases. This is because when the water level rises, more water is able to flow through the river channel. There are several factors that can affect the shape of the water rating curve, including the geometry of the river channel, the roughness of the channel bed and banks, and the presence of any obstructions in the channel. It is a valuable tool for hydrologists and water resource managers, who use it to monitor and predict streamflow, forecast floods and droughts, and design water control structures. The water rating curve for river station 22424 is shown in Fig. 7.



Fig. 7. Water rating curve for Station 22424

3.6. Flood inundation map

The flood inundation map is a map that shows the areas that would be flooded under different flood scenarios. The Flood inundation maps for our study area are created using a DEM from QGIS and HEC-RAS software. Fig. 8, 9, and 10 shows the Flood Inundation Map for profile 1, 2 and 3 respectively



Fig. 8. Flood Inundation Map of Profile 1



Fig. 9. Flood Inundation Map of Profile 2



Fig. 10. Flood Inundation Map of Profile 3

The inundation area of a profile is the area of land that would be flooded at a given water level. It is calculated by integrating the water depth over the area of the profile. The inundation area of Profile 1 is 3365733.24 square metres, the inundation area of Profile 2 is 3770894.62 square metres, and the inundation area of Profile 3 is 3994215.89 square metres.

4. Conclusion

The study's foremost accomplishment lies in its ability to provide a detailed and data-driven Flood Inundation map for the Calabar River, a region grappling with recurrent flood events. By combining HEC-RAS (Hydrologic Engineering Center's River Analysis System) and QGIS (Quantum Geographic Information System), the research has successfully portrayed the dynamic interaction between the river's geomorphology and hydrodynamics. The high-precision Flood Inundation maps offer valuable insights into the potential extent of flooding under varying conditions, crucial for disaster preparedness and risk mitigation.

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Analysis of geotechnical properties of solid waste and natural soil site for structural foundation F. C. Onyeka^a, T. E. Okeke^{b,*}

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Abstract: Optimization of landfills as a result of increasing population and demand for infrastructural development has necessitated intensified investigation among engineers. Examining the engineering properties of soils from these landfills is of great concern. This paper presented the bearing capacity of soils from dump sites of municipal solid wastes and natural soil using their shear strength parameters obtained from direct shear tests, after preliminary tests had been carried out to determine index properties of the soil samples. Samples were obtained at 1m, 1.5m, 2m, 2.5m and 3m depth from Jettu site in Edo State, Nigeria. The maximum and least cohesion values were observed to be 24 kN/m² and 17 kN/m², 15 kN/m² and 5 kN/m²; and the maximum angles of internal-friction were 22 °C and 24 °C, while the least internal friction angles were 6 °C and 9 °C for NS and SWSS samples respectively, which denotes that the samples are fine soils with good shear strength and can serve as reliable structural foundation materials.

Keywords: Solid-waste-site soil (SWSS), natural soil (NS), shear strength, bearing capacity

1. Introduction

Solid wastes consist of both biodegradable and non-biodegradable waste materials [1]. These materials have harmful impact on both soil and groundwater [2]. To ensure healthy and safe environment, solid waste management techniques is adopted. Solid waste management activities include; waste segregation, collection, transportation, treatment and disposal [3-5]. The various waste disposal methods used are composting, recycling, landfilling and incinerating. Wastes found in open dump sites often results to scavengers retrieving items and reusing, leading to serious health implications due to the transmission of infectious disease [6-7]. In this study area, landfills are the most preferred method of waste disposal. These include sanitary, engineered, controlled and uncontrolled landfills (open dumping). The occurrence of numerous biochemical reactions within the waste body in the landfills produce biogas and leachates which contribute to air, water and soil pollution [8].

The system of open dumping of solid wastes attracts varying environmental and health concerns [9, 10]. Solid waste disposal sites have, to a great extent, managed this challenge over time. Solid waste disposal site is a type of landfill site that collects municipal solid waste from homes, businesses, and institutions. The growing population and demand for infrastructural development have led to optimization of all lands, both old and new landfills [11, 12]. The need to determine the safety of structural foundation soils have made engineers to focus on investigating the properties of soils from solid waste sites [13]. The component of a structure that conveys the loads precisely to the underlying soil is regarded as a foundation [14, 15]. The choice of foundation type depends on the nature and strength of soil. Foundation soil is meant to sustain the loads from any engineered structure placed upon it without a shear failure and with the resulting settlements being tolerable for that structure, to ensure satisfactory performance [16]. The shearing-resistance offered by the foundation-soil determines the stability and integrity of engineering structures erected on any soil [17]. Strength evaluation of foundation soils is very critical in design of foundations. Owoyemi and Awojobi [18], considers constituent study of foundation-soil as a preventive approach for foundation failure.

To overcome the collapse of structures, detailed Geotechnical investigation of the foundation soils is needed [19, 20] and this validates the essence of this study. Municipal solid waste is frequently generated at Jattu-Uzairue, Edo State as it is occupied with human settlements, commercial activities and small industries. Economic development and the population growth promotes the production of these solid waste. Approaching the challenges linked with improper waste management and disposal in this area is a non-negotiable alternative for a sustainable environment and a heathy living. Various soil geotechnical properties are affected by indiscriminate disposal of waste and citation of open dumpsites. Beneath dumpsites, different contaminants are trapped in the soil, results in long term contamination of the underlying soil in terms of geotechnical characteristics [20]. Alignment of structural foundation with the engineering characteristics of available soil in the construction site is a matter of concern for engineers and builders [21].

The primary aim of this study is to assess the geotechnical properties of the soil at the dumpsite at Jattu, Edo State, Nigeria. The geotechnical properties like particle size distribution and shear strength were carried out for samples from dump site and natural soil. Shear strength parameters such as angle of internal friction ϕ and cohesion C were used to estimate the bearing capacity of the soil. The potential of municipal-solid-waste finer-fraction as sustainable structural fill material was evaluated by Dalal et al., [22]. The authors examined in details the bearing capacity, settlement and modulus of subgrade-reaction for the shallow-foundation of different sizes and shapes resting on soil with low subgrade modulus and the soil improved with a layer of MSW-FF as structural fill. To understand the upshot of soil and foundation stiffness on the foundation design parameters, STAAD Pro. Software was employed for a soil-structure interaction analysis.

Thakur et al., [10] presented the impact of open-dumping on soil behavior and degradationsettlement-analysis of soil in non-engineered-landfill. Their study considered settlement analysis and the investigation of Geotechnical features of waste-soil and its comparison was done with naturalsoil. Energy Dispersive X- Ray Spectroscopy and Scanning-Electron-Microscopy (SEM) were employed for geochemical analysis. Tests carried out on samples of waste and natural site includes particle size distribution, specific gravity, compaction, maximum dry density (MDD), permeability, California bearing ratio (CBR) and shear strength.

Preferred location in Port-Harcourt was studied by Nwankwoala and Warmate [23]. They investigated the geotechnical behaviour of the soil-sample and recommended the use of pile foundation in order to carry the imposed load from the cellar to the underlying sand stratum during structural constructions. Alawode et al., [24] assessed the suitability of soils as foundation materials. Their focus was on selected soils in Ile-Ife, Osun State, Southwestern Nigeria. The authors analyzed the carrying capacity of collected soil samples and characterized them. Ige and Ogunsanwo [25] also evaluated the geotechnical properties of foundation soils in Ilorin, Southwestern, Nigeria. Investigations on shear strength parameters employing triaxial and direct-shear-box methods, were carried out by Oluwapelumi [26], Otuaga [27], and Egbe et al., [28]. They addressed soils in Akure, Owo Local Government Area of Ondo, and Calabar South, Nigeria respectively. A safe-bearing-strength of 139.01 kN/m2 was recommended in [27] for adoption in foundation design.

This work intends to fix the gap in previous works as there is no documentation pertaining to soil characterization and bearing capacity assessment of dumpsite soils at Jattu, Edo State, Nigeria. The population of the residents in this area and the demand for infrastructural development amplifies the necessity of this research. This is because, lack of waste management in the area has resulted to lack of available natural site for building construction thereby posing the danger of shortage of houses to service the in-flux of resident which increase on the daily basis.

The outcome of this study will be of great assistance to engineers and contractors in the study area and will add to the body-of-knowledge on bearing strength in relation to the behavior of the natural soil, compared to the municipal solid waste soils in order to achieve the suitability of the later for foundation engineering. In this study, engineering properties of the selected-soil is evaluated, strength parameters and carrying strength of the soil is determined. The studied soil is characterized and suitable foundation type corresponding to the bearing-strength of the soil is recommended.

2. Method

2.1 Location of the study area

Soil samples were collected from municipal solid waste dumpsite located at Jattu Uzairue in Edo State, Nigeria. Jattu is a town in Edo state Nigeria. It is the headquarters of the Uzairue - Clan in Etsako-West Council of Edo State, Uzairue Clan consist of twenty-one villages which comprises of Jattu and others. It is geographically located within the coordinates N 7° 5' 31" Latitude and E 6° 17' 47" Longitude. Figure 1 shows the township map of Jattu and neighboring communities, highlighting

settlements and road networks. Figure 2 depicts the site considered in this study. The samples used were gotten from the site at depths of 1m, 1.5m, 2m, 2.5m and 3m. The materials excavated from the study site are solid wastes from homes, industries, institutions, and farms. The major-components of studied-soil sample are biodegradable materials such as food waste, paper waste, spoiled food grains, biodegradable plastics, agricultural remains and ashes.



Fig. 1. Map Showing Location of Jattu in Etsako West Council of Edo State Source: Ministry of lands, surveying and housing, Edo State, 2008



Fig 2. The Study Site at Jattu Uzairue, Edo Nigeria

2.2 Experimental Procedure

Preliminary tests were conducted on the soil samples (natural soil and solid waste site soil) to examine their index properties for proper identification and to determine their suitability for foundation works. The soil tests were carried-out in accordance to the specifications of British Standard BS 1377 [29]. The tests include; Sieve Analysis, Atterberg Limits, Specific Gravity, and Moisture Content. The shear-strength parameters of the soils were also evaluated and presented.

2.2.1 Sieve Analysis

The test was carried out in the laboratory in conformity to British Standard (BS 1377) using BS sieve sizes of 4.75mm, 2.36mm, 1.18mm, 600µm, 425µm, 300µm, 150µm, 75µm, and a pan. The weight of the materials retained on each sieve size was recorded and employed during computations for plotting the grain size distribution curve.

Percentage passing = 100% cumulative – percent retained (4)

2.2.2 Atterberg Limits

In accordance with the specification of British Standard (BS 1377) and using the Cassagrande apparatus, the liquid-limit, plastic-limit and plasticity index were determined in the laboratory and computed. The water-content at which the soil transforms from semisolid to plastic-state is regarded as the plastic limit (PL) whereas the water content at which soil changes from plastic to a liquid state is called the liquid limit (LL). The plasticity-index (PI) is given by;

$$PI = LL - PL$$
⁽⁵⁾

2.2.3 Moisture content

Moisture content is the ratio of the weight of water to the weight of the solids in a given mass of soil or the percentage of water present in a soil mass by its weight [30]. This test was carried out in accordance with British Standard (BS 1377).

Moisture content (%) =
$$W_w/W_s \ge 100\%$$
 (6)

Where; $W_w = weight \ of \ water$

 $W_{\rm s} = W eight \ or \ dry \ soil$

2.2.5 Shear Strength

Soil shear-strength is the extent of shear stress that will result in yielding a soil-mass under load which exist due to interaction of particles brought about by cohesive and frictional forces [31]. The soil-shear-strength is evaluated in terms of cohesion and angle of internal-friction of the soil particles. Shear strength determines the capacity of a soil to support a loading from a structure. The cohesion property of the soil, angle of internal-friction and shear-strength of the individual soils was determined using the direct shear box apparatus.

2.2.6 Bearing Capacity

The maximum-pressure the soil can sustain without shear failure is termed as an ultimate - bearing-capacity of the soil [32]. The parameters obtained from direct-shear-test were applied in Terzaghi's bearing capacity equations (7) to (9) to obtain the ultimate-bearing-capacity of the soils for different types of footing-circular footing, square footing, and strip footing respectively. The corresponding values of the bearing-capacity-factors were derived from Das [33]. For each of the footings, safety factor of 3.0, unit width and unit depth were adopted.

$$Q_U = 1.3cN_c + \gamma DN_q + 0.3\gamma BN_\gamma \tag{7}$$

$$Q_U = 1.3cN_c + \gamma DN_a + 0.4\gamma BN_{\gamma} \tag{8}$$

$$Q_U = cN_c + \gamma DN_q + 0.5\gamma BN_\gamma \tag{9}$$

Where Q_U = Ultimate bearing capacity (kN/m3)

C = Cohesion (kN/m^3)

 γ = bulk unit weight of soil (kN/m3)

D = depth of footing (m)

B = width of footing (m)

 N_c , N_q , N_γ are bearing capacity factors which depend on the values of angle of internal friction φ .

Allowable bearing capacity of soils q_{allow} was determined using;

$$q_{allow} = \frac{Q_u}{F_s}$$

Where F_s is the factor of safety.

3. Results and Discussion

3.1 Sieve Analysis

The percentages of fine in the soil particles collected from the dumpsite in the present study was between 12.15 to 15.35 % for SWSS sample as shown in Table 1 while that of NS sample ranged from 10.75 to 14.36 %. The contaminated soil samples had higher percentages of fine content when compared to that of the uncontaminated soil used as the control due to fine particles arising from the decayed municipal solid waste which dominates the soil. This aligns to similar work carried out by Krishna et al. [34] and Estabragh et al. [35]. Soils can be categorized as coarse grained (sand or gravel), fine-grained (clay or silt) and highly organic soils, according to USCS system of classification. According to Unified Soil Classification System (USCS), NS sample is made of sand-silt mixtures, while SWSS sample consists of sand-clay mixtures.

Table 1. Results of Particle size distribution of the contaminated and uncontaminated soil samples

| | | | | | % Pa | issing | | | | |
|-------|-------|-------|-------|-------|-------|--------|-------|-------|-------|-------|
| Sieve | 1.0m | 1.5m | 2.0m | 2.5m | 3.0m | 1.0m | 1.5m | 2.0m | 2.5m | 3.0m |
| (mm) | SWSS | NS | SWSS | NS | SWSS | SWSS | NS | SWSS | NS | SWSS |
| 4.75 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| 2.36 | 80.36 | 93.75 | 85.70 | 95.93 | 86.62 | 96.54 | 90.20 | 94.66 | 90.15 | 92.64 |
| 1.18 | 73.12 | 81.56 | 77.32 | 87.76 | 79.46 | 85.45 | 84.12 | 83.56 | 86.36 | 86.4 |
| 0.6 | 66.35 | 62.48 | 69.80 | 72.60 | 72.58 | 76.40 | 76.30 | 60.72 | 78.45 | 64.15 |
| 0.425 | 47.50 | 52.42 | 42.52 | 44.34 | 50.50 | 53.74 | 52.32 | 56.40 | 53.64 | 54.35 |
| 0.3 | 31.04 | 36.46 | 33.08 | 58.36 | 36.76 | 56.55 | 45.65 | 42.56 | 46.90 | 36.90 |
| 0.15 | 15.24 | 17.24 | 17.44 | 24.19 | 18.65 | 22.16 | 35.72 | 25.80 | 37.21 | 28.86 |
| 0.075 | 12.15 | 10.75 | 13.28 | 12.36 | 14.10 | 13.48 | 13.70 | 13.42 | 15.35 | 14.36 |
| | | | | | | | | | | |

3.2 Atterberg Limits

From Table 2, it was observed that there were low PI values for uncontaminated soil sample as a result of the paltry quantity of clay existing in among the soil particles. The contained soil samples had high PI values due to decrease in the effective porosity rising from the clogging impact of pore space because of the increased number of microorganisms in the leachate. The Atterberg limits provides a quantitative description on the effect of varying water content on the consistency of fine-grained soils. Generally, they are used in classification of soils and assessment for engineering purposes. The Atterberg limits of NS and SWSS samples were presented in Table 2. The liquid limit for the SWSS sample varied from 32.50 % to 39.50 %, while that of NS sample varied from 36.80 % to 41.70 %. The plastic limit and the plasticity index varied from 19.10 % to 25.10 % and 27.30 to 33.40 %, 13.40 to 14.50 and 7.60 to 9.50 for SWSS and NS samples respectively. The reduction in the plastic limit of the SWSS samples is attributed to the increase in cohesion of the soil particles including its resistance to cracking.

(10)

| Sample | S | WSS Samp | ole | ľ | NS Sample | |
|--------|--------|----------|--------|--------|-----------|--------|
| (m) | LL (%) | PL (%) | PI (%) | LL (%) | PL (%) | PI (%) |
| 1.0 | 32.50 | 19.10 | 13.40 | 36.80 | 27.30 | 9.50 |
| 1.5 | 34.00 | 20.50 | 13.50 | 37.60 | 28.80 | 8.80 |
| 2.0 | 35.70 | 21.20 | 14.50 | 38.20 | 30.60 | 7.60 |
| 2.5 | 37.70 | 23.50 | 13.60 | 40.10 | 31.30 | 8.80 |
| 3.0 | 39.50 | 25.10 | 14.40 | 41.70 | 33.40 | 8.30 |

Table 2. Results of Particle Atterberg limits for NS and SWSS samples

3.3 Specific Gravity Test

In Figure 3, the result of the specific-gravity of both soil samples were tabulated. The specificgravity of the NS - sample increased from 2.60 at 1m depth to 2.75 at 3m depth. For SWSS specimen, it increased from 2.45 at 1m depth to 2.52 at 2m and reduced to 2.40 at 2.5m with a rise of 3m. The least value of specific-gravity (2.40) recorded at 2.5m depth is due to the dominance of clay-sized particles at this depth. The specific-gravity of clayey and silty soils varies from 2.6 to 2.9, according to Das [33]. This implies that most of the soil samples collected were silty-clayey in nature.



Fig 3. Variation of specific gravity with depth for NS and SWSS specimens

The specific gravity of NS is larger compared to that of SWSS with a maximum and a minimum percentage variation of 7.84% and 4.84% respectively. This implies that both soil samples are suitable for construction although Prakash and Jain [36] confirms that the higher the value of specific-gravity of a sample, the more strength it has for the foundations and roads. The attenuation of SWSS values is due to the decomposition of particles of the organic content present in the soil [37]. The behavior of these soils was in conformity with the studies carried out by [10, 38, 39].

3.4. Shear Strength

Table 3 captured the values of shear-strength parameters (c and ϕ) obtained from direct-shear-test. The maximum and least cohesion values were observed to be 24 kN/m2 and 17 kN/m2, 15 kN/m2 and 5 kN/m2 for NS and SWSS samples at 1m and 3m depth respectively. The highest internal friction angle was 22° and 24°, while the lowest internal friction angle was 6 o and 9 o for NS and SWSS samples respectively. The internal friction angle lies within 260 and 48 o for granular soils, while internal friction angle less than 26 o is for fine soils [40, 41]. The results obtained as the angles of internal-friction indicates that the samples are fine soils [42]. Both NS and SWSS possess good shear-strength and can serve as good foundation materials for structures.

| Soil Type | Depth (m) | Cohesion C (kN/m²) | Angle of Internal Friction (φ) |
|--------------|--------------|-----------------------|--------------------------------|
| | 1.0 | 24 | 6 |
| | 1.5 | 22 | 10 |
| Natural soil | 2.0 | 20 | 12 |
| | 2.5 | 19 | 15 |
| | 3.0 | 17 | 22 |
| | 1.0 | 15 | 9 |
| | 1.5 | 12 | 11 |
| Solid waste | 2.0 | 10 | 13 |
| site soil | 2.5 | 7 | 17 |
| | 3.0 | 5 | 24 |
| | | | |

Table 3. Shear strength parameters for NS and SWSS samples

3.5 Bearing Capacity of soil

The results of bearing capacity evaluation were presented in Table 4 (a, b, and c). The shape of the footing determines the variation in the bearing-strength of soil samples. The square-footing was found to have the greatest bearing capacity for each of the soil samples, followed by circular footing while strip footing has the least bearing capacity. The coefficients applied in the bearing capacity equations and the varying values of the bearing-capacity-factors contributed to these observations. The samples were $c-\phi$ soils and are good foundation materials.

| Soil Type | Depth (m) | Ultimate Bearing Capacity Q _u (kN/m ²) | Safe Bearing Capacity Q _{safe} (kN/m ²) |
|--------------------------|--------------|--|--|
| | 1.0 | 215.74 | 71.91 |
| Natural Soil | 1.5 | 258.41 | 86.14 |
| | 2.0 | 273.97 | 91.32 |
| | 2.5 | 326.76 | 108.92 |
| | 3.0 | 373.08 | 124.36 |
| | 1.0 | 161.20 | 53.73 |
| Solid waste site soil | 1.5 | 166.81 | 55.60 |
| Site Soli | 2.0 | 170.13 | 56.71 |
| | 2.5 | 190.51 | 63.50 |
| | 3.0 | 213.46 | 71.15 |

Table 4(a). Bearing capacities of the soils at varying depths for strip footing

| Soil Type | Depth (m) | Ultimate Bearing Capacity Q _u (kN/m ²) | Safe Bearing Capacity Q _{safe} (kN/m ²) |
|--------------------------|--------------|--|---|
| Natural Soil | 1.0 | 270.76 | 90.25 |
| | 1.5 | 320.06 | 106.69 |
| | 2.0 | 335.84 | 111.95 |
| | 2.5 | 395.25 | 131.75 |
| | 3.0 | 442.00 | 147.33 |
| Solid waste site soil | 1.0 | 198.95 | 66.32 |
| | 1.5 | 201.52 | 67.17 |
| | 2.0 | 201.55 | 67.18 |
| | 2.5 | 215.26 | 71.75 |
| | 3.0 | 230.17 | 76.72 |

Table 4(b). Bearing capacities of the soils at varying depths for circular footing

Table 4(c). Bearing capacities of the soils at varying depths for square footing

| Soil Type | Depth (m) | Ultimate Bearing Capacity Q _u (kN/m ²) | Safe Bearing Capacity Q _{safe} (kN/m ²) |
|--------------------------|--------------|--|---|
| Natural Soil | 1.0 | 271.08 | 90.36 |
| | 1.5 | 320.95 | 106.98 |
| | 2.0 | 337.19 | 112.40 |
| | 2.5 | 414.38 | 138.13 |
| | 3.0 | 505.06 | 168.35 |
| Solid waste site soil | 1.0 | 199.43 | 66.48 |
| | 1.5 | 202.45 | 67.48 |
| | 2.0 | 232.62 | 77.54 |
| | 2.5 | 313.11 | 104.37 |
| | 3.0 | 396.06 | 132.02 |
| | | | |

4. Conclusion

From the observations and findings made, the following conclusions were deduced; the uncontaminated soil within and around the waste site is relatively consistent, though there are few divergences. The contaminated soil has lower specific gravity and this indicates the presence of organic content in the soil.

According to Unified Soil Classification System (USCS), the uncontaminated soil sample is made of sand-silt mixtures, while sample from the dumpsite consists of sand-clay mixtures. Soils from this dumpsite should be stabilized using additives in order to enhance its engineering properties and its suitability to serve as a good foundation material. Utilization of the soil for construction largely solves the problem of groundwater pollution and release of hazardous gases to the atmosphere.

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Mathematical modeling of seasonal rainfall prediction and climate change impact in Cross River State: A case study Calabar metropolis

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Abstract: In this study, mathematical modeling of Seasonal rainfall and climate change impact in Calabar, annual rainfall was analyzed for trend and climate variability events from three input parameters, Rainfall, maximum temperature, and relative humidity with a focus on seasonal variability for Calabar. Monthly rainfall data from in-situ measurements over a period of 31 years (1991 - 2020) was used for the study and were obtained from archives of the Nigerian Meteorological Agency (NIMET) Calabar Center. Rainfall variability was examined as standardized rainfall departures used to identify and delineate the extent to which the input parameters impact the climate of Calabar. For the rainfall services, we use a seasonal Autoregressive Integrated Moving Average (SAEIMA) model with mini tab programming software. From the least square regression equations, and plots, the average annual rainfall for Calabar is 348mm/year recorded in 2012, trend (MAPE) mean absolute percentage error 26690.0, (MADE) mean absolute deviation error 156.0, (MASD) mean absolute standard deviation 35479.7, The temporal statistical equations indicates that there is an increase in rainfall, temperature (MAPE) 4.82570,(MADE) 1.48176, (MASD) 3.22941and relative humidity of 0.0832 mm/yr,0.002oc and 0, respectively, (MAPE) 4.5431,(MADE) 3.7450, (MASD) 25.2547. This result underscores the need for effective monitoring of Calabar rainfall for prompt warnings and responses that would guarantee effective risk reduction and management in the run -into the occurrences of extreme events, that might hinder engineering practices since building and construction works are not favorable to rainy season.

Keywords: Climate change, rainfall prediction, mathematical modelling, Calabar

1. Introduction

Rainfall is a sporadic hydrologic event whose occurrence cannot be predicted with the distribution of the rainfall over time as well as over distance which is very complex and irregular, such irregularity is especially pronounced with respect to the occurrence of exceptional heat by storms. However, it is possible by the use of rainfall data spanning a long period of time, to estimate the likelihood of the rainfall of a particular magnitude or more occurring within a specified period of time referred to as return period or recurrence interval. The ability to predict the possibility of the occurrence of rainfall of a particulate magnitude or more can help water resources experts, individual authorities and engineers to plan for such extreme eventualities as floods, drought, land use, thunderstorms, etc.

Nigerian coastal cities are daily inundated with flood waters, and millions of properties have been destroyed and lives lost. Similarly, poor drainage systems are often associated with street flooding, and this has become a critical environmental problem in coastal cities of Nigeria cities, such as Calabar, Uyo, Warri, Port Harcourt, and Lagos. These towns are quite close to the Atlantic Ocean which experiences heavy flooding, especially during the rainy season. Moreso, flooding may follow heavy rainfall, although flooding can also follow from tidal surges and rapid snow melt. Nevertheless, flooding of low-lying lands caused by the rise in sea level secondary to melting of the ice caps is also likely to happen in all types of natural disaster worldwide, flooding is the commonest and can cause enormous damage and financial and structural loss, no one in Nigeria will be unaware of the floods of recent years and the suggestion that flood events are likely to increase in future [1].

This research is restricted to the city of Calabar which is made up of Calabar South local government and Calabar Municipality areas.

The analysis is restricted to 31 years (1990-2021) of annual rainfall data drawn from archives of NIMET Calabar.

This rainfall seasonal study of Calabar involved the analysis and determination of the series, average deviation from averages, extremities, probability, probability assessment, as well as relationship. The relevance of the study will expose the trend in rainfall behavior in the area by the mathematical model.

The phenomenon of intense rainfall increases surface run-off which results in gully erosion one of the largest ecological problems of the world. Likewise, data records published between 1989 and 1996 by the National Meteorological Services (NIMET) show that of all the state capitals in Nigeria calabar has rainfall is highest in Calabar (NIMET 2006).

Floods are amongst the most prevalent natural disasters, and the frequency with which floods occur, their magnitude, extent, and cost of damage are escalating all around the globe. Accordingly, [1] describe flooding as a general impermanent condition of incomplete or complete inundation of normally dry areas from the overspill of inland or tidal waters or unusual and rapid buildup or runoff. [2].

There are different types of floods these include coastal flooding [3] flash Flooding [4], flooding due to rising of groundwater [4], and flooding due to the opening of a dam.

Flooding may follow heavy rainfall, although flooding can also follow from tidal surges and rapid snow melt. Flooding of low-lying lands caused by the rise in sea level secondary to melting of the ice caps is also likely to happen in all types of natural disaster worldwide, flooding is the commonest and can cause enormous damage and financial and structural loss, no one in Nigeria will be unaware of the floods of recent years and the suggestion that flood events are likely to increase in future [4,5]. The health effects of flooding can be divided into those associated with the acute event and those arising from the floods. A high number of people are killed each year by floods [5].

Similarly, between 80-90% of all documented disasters from natural hazards during the past 10 years have resulted from floods, droughts, tropical cyclones, heat waves, and severe storms. Floods are also increasing in frequency and intensity, and the frequency and intensity of extreme precipitation are expected to continue to increase due to climate change [6].

1.1. Remote Sensing for Flood Damage Assessment

During floods, decision-makers and rescue workers require detailed status reports to identify areas affected by the floods, direct rescue missions and implement mitigation measures. It is imperative that the status reports contain accurate and up-to-the-minute information. Remote sensing helps in the quick assessment of flood damage through the provision of comprehensive, rapid, synoptic, and real-time multi-temporal imagery with information on what is actually happening on the ground.

Remote sensing is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object, area, or phenomenon under investigation. By utilizing sensors operating in the visible and microwave spectral bands, remote sensing techniques, combined with topographical or hydrological data in a GIS environment, enable the rapid acquisition and dissemination of quantitative information over large areas. Information gleaned from the application of remote sensing techniques can be used to assess and model the present damage situation, evaluate processes and trends, and provide direction for the rehabilitation of flood-affected areas.

Similarly, [6,7], used change detection and thresholding (CDAT) with synthetic aperture radar (SAR) imagery to delineate the extent of flooding for the Chobe floodplain in the Caprivi region of Namibia. Change detection and thresholding methods which include image subtraction, and decision-based classification with threshold values, in coordination with adaptive filtering and segmentation, were

used to determine the extent of inundation during seasonal flood events using ENVISAT/ASAR and Radarsat-2 satellite images.

The modeling approach is generally used for detailed flood assessment. To accurately determine and model flood-prone areas for an entire series of flood events (for 20,30 or 100 years), mathematical applications are essentially required. The modeling approach employs geographic data such as topography, land use, and land cover, bathymetry; Hydrological/hydraulic data such as river discharge, rainfall, peak discharge, water velocity, and elevation; soil geology, etcetera, to develop flood hazard maps. Currently, there are a number of software that can model flood plains in one and two dimensions and generate maps. Given that the modeling approach uses satellite imagery together with software and given the synoptic nature of satellite imagery, the modeling approach has the advantage that it can be applied over a large area in a comparatively short period of time. It enables direct observations of flood events and prediction of flood events and their behavior. The disadvantage of optical satellite imagery is that it requires cloud-free conditions, is acquired only during the daytime, and is unable to penetrate flooded areas under canopies formed by trees. Microwave satellite imagery does not have this problem.

Different authors use a combination of GIS with remote sensing or GIS with Hydrological/hydraulic data to undertake flood models. The GIS - Hydrological/hydraulic combination is somewhat more intensive and expensive as compared to the GIS–remote sensing combination as it involves a lot more calculation but if part of the objective is to determine the rate of flow, discharge, and depth of flood waters, then the GIS - Hydrological/hydraulic combination is the best option.

1.2. Climate change

One of the main causes of climate change is changes in Earth's atmosphere due to changes in the amounts of greenhouse gases, aerosols, and cloudiness. The anthropogenic increase in greenhouse gas emissions, not natural variability, is responsible for most of the warming in recent decades. Since the start of the industrial era, the overall effect of human activities on climate has been one of warming. The major greenhouse gases, for example, carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), and halocarbons are the result of human activities and accumulate in the atmosphere, and their concentration increases with time.

The ongoing search for technologies, policies, treaties, and other measures to sustainably limit worldwide carbon emission flows, reduce atmospheric carbon stocks, and reduce temperature elevation remains an important issue of our time. Climate mitigation has proven an elusive goal to date and will likely remain so unless something like climate clubs with sanctions for non-members is implemented internationally [7]. Technical and policy scholars have developed an extensive understanding of the science, technologies, institutions, and policies to control flows of carbon emissions and stocks of atmospheric carbon. Several analyses of national and international policy proposals like carbon taxes, cap-and-trade, various regulatory measures, climate clubs, and integrated roadmaps have been undertaken. Yet neither of the most important international climate treaties to date, the Kyoto Protocol of 2005 or the Paris Accords of 2016 has reduced carbon emissions significantly. Climate mitigation still has a long way to go, so this paper's objective is to address the more modest aim of HEA to address climate adaptation. Water is a big part of the climate story, so this work turns to water systems analysis in the search for better methods to support integrated assessments.

Water has many complexities. Growing demands for water combined with increased variability of climate-induced water supplies in many parts of the world is leading to an increasing array of challenges faced to supply adequate levels of water's six important dimensions: quantity, quality, timing, location, price, and cost. These challenges need to address water's four important characteristics, namely that it leaks, seeps, evaporates, and transpires, all of which experience impacts from climate change and policies to deal with it [8].

2. Method

The present work consists of materials used and the methodology adopted for forecasting, selection of Study Area, Meteorological Data Extraction and verification for the selected, statistical methodologies compiled, and the use of auto-regressive integrated moving average (ARIMA). This study aims at examining the nature of rainfall in Calabar over a 31 years (1990-2021) period in order to any evidence of climate changes the study of rainfall seasonal prediction is also important in architectural designs, building and construction field work, and planting of crops, rainfall strength has a transparent bearing on flooding. Calabar is a city in southern Nigeria with latitude 40 53' 41.10" to 50 7' 37.57" North and longitude 80 14' 14.90" to 80 25' 14.03" East, occupying an approximate area of 158 km².

2.1. Seasonal ARIMA Modeling (the Box-Jenkins Method)

Box–Jenkins modeling method, named after the statisticians Box and Jenkins (1970), describes stationary time series and applies autoregressive moving average ARMA or autoregressive integrated moving average ARIMA models to find the best fit of a time series to past values of this time series in order to make forecasts. The methodology involves three steps and these are;

- a. The first step is model identification- Identification of the model consists of specifying the appropriate structure (AR, MA, or ARMA) and order of the model. Models can also be identified by looking at plots of the autocorrelation function (ACF) and partial autocorrelation function (PACF). Thus, making sure that the variables are stationary, identifying seasonality in the dependent series, and using plots of the ACF and PACF of the dependent time series to decide which (if any) autoregressive or moving average component should be used in the model.
- b. The second step is to estimate the parameters of the model- The coefficients of the models can be estimated by maximum likelihood estimation or non-linear least-squares estimation methods. Estimation of parameters of MA and ARMA models usually requires a more complicated iteration procedure.
- c. The third step is model checking and Forecasting- Two important elements of checking are to ensure that the residuals of the model are random and to ensure that the estimated parameters are statistically significant. Usually, the fitting process is guided by the principle of parsimony, by which the best model is the simplest possible model. The seasonal ARIMA model incorporates both non-seasonal and seasonal factors in a multiplicative model. The model is given as

| ARIMA | (p, d, q) | $(P, D, Q)_m$ |
|-------|--------------|---------------|
| | Non seasonal | Seasonal part |

part of the model of the model

Where;

p = Non-seasonal AR order

- d = Non-seasonal differencing
- q = Non-seasonal *MA* order
- P = Seasonal AR order
- D = Seasonal differencing
- Q = Seasonal *MA* order

m = Time span of repeating seasonal pattern

Without differencing operators, the model could be written more formally as

$$\Phi(B^m)\phi(B)(y_t - \mu) = \Theta(B^m)\theta(B)u$$

The non-seasonal components are

$$MA \,\phi(B) = 1 - \phi_1 B - \phi_2 B^2 - \Lambda - \phi_p B^p \tag{1}$$

$$\theta(B) = 1 + \theta_1 B + \theta_2 B^2 + \Lambda + \theta_q B^q \tag{2}$$

The seasonal components are

Seasonal AR $\Phi(B^{m}) = 1 - \Phi_{1}B^{m} - \Phi_{2}B^{2m} - \Lambda - \Phi_{P}B^{Pm}$ (3) Seasonal MA

$$\Theta(B^m) = 1 + \Theta_1 B^m + \Theta_2 B^{2m} + \Lambda + \Theta_Q B^{Qm}$$
⁽⁴⁾

ARIMA Model for Rainfall in Calabar metropolis

$$\Phi(B^{m})\phi(B)(1-B^{m})^{D}(1-B)^{d}(y_{t}-\mu) = \Theta(B^{m})\theta(B)u_{t}$$

$$D = 1, d = 1, \quad m = 12 \text{ and } \quad x_{t} = y_{t} - \mu$$

$$\Phi(B^{12})\phi(B)(1-B^{12})(1-B)x_{t} = \Theta(B^{12})\theta(B)u_{t}$$
(5)

$$(1+0.121B^{12})(1-0.043B)(1-B)(1-B^{12})x_t = (1+0.90B^{12})(1+0.94B)u_t$$
(6)

ARIMA Model for Relativ Humidity

Estimates at each iteration

$$\Phi(B^{m})\phi(B)(1-B^{m})^{D}(1-B)^{d}(y_{t}-\mu) = \Theta(B^{m})\theta(B)u_{t}$$

$$D = 1, d = 1, \quad m = 12 \text{ and } \quad x_{t} = y_{t} - \mu$$

$$\Phi(B^{12})\phi(B)(1-B^{12})(1-B)x_{t} = \Theta(B^{12})\theta(B)u_{t}$$
(7)

ARIMA Model for Max. Temperature

Estimates at each iteration

$$\Phi(B^{m})\phi(B)(1-B^{m})^{D}(1-B)^{d}(y_{t}-\mu) = \Theta(B^{m})\theta(B)u_{t}$$

$$D = 1, d = 1, \quad m = 12 \text{ and } \quad x_{t} = y_{t} - \mu$$

$$\Phi(B^{12})\phi(B)(1-B^{12})(1-B)x_{t} = \Theta(B^{12})\theta(B)u_{t}$$
(8)

3. Results and Discussion

The rapid increase in urbanization without corresponding infrastructures in the city of Calabar has led to increased incidences of flood as the available drainage channels cannot contend with the volume of stormwater. The volume of flood water was determined using the stopwatch method (Velocity of flow), and copies of the questionnaire were administered to 200 households proportionally to the sample units. Results from the work revealed that the frequency of flood is compounded with much intensity as over 59% of the sampled population in this study, we plotted the graph of original rainfall data from January 1990 to December 2021 called the time plot. The time plot revealed features of rainfall data collected over a period of 31 years. The time plot showed a pattern that repeats itself every Twelve months. From our timeslot, rainfall is usually low in the months of January, February, and March and gradually increases in intensity from May, and June and picked in the month of July. The rainfall starts reducing from August and the least amount of rainfall is usually recorded for November and December. This cycle repeats every year. Figures 1 to 4 show the prediction models of the multiplicative trend of the rainfall pattern in the Calabar metropolis.



Fig. 1. Trend analyis of normal rainfaill distribution



Fig. 2. The graphs showing the component analysis of rainfallfor multiplative model

The autocorrelation function (ACF) of original rainfall data revealed pattern consistent with seasonality. Most of the spikes fall outside 95 percent confidence interval. Certainly, there is seasonal variation that must be taken care of during modeling.



Fig. 3. The graphs of the autocorrection function (ACF) and partial autoregressive correlation function (PACF)



Fig.4. The graph showing the original rainfall data and forecast for Jan 2021- December, 2022

The study adopted data from different sources and used different methods and approaches to analyze the long-term land use/cover changes and trends in the four decades of the study area. The approaches included imageries from different satellites (Landsat), multi-temporal dates (MSS 1980, TM 1990, ETM 2000, and ETM+2010), fieldwork surveys, and forest inventory application, as shown in Figure 5.



Fig. 5. land cover map and Reclassified DEM

Figure 6 the land cover map and reclassified land cover map respectively. The land cover of an area is important because it reflects the current use of the land and gives an indication of the soil infiltration ability (9). The vegetation or forest cover slows down and reduces the amount of runoff while urban land cover which is characterized by paved and impermeable surfaces absorbs no water and increases runoff and, therefore, increases the probability of flooding. Figure 10 is the flood hazard map.



Fig. 6. Reclassified land cover map and flood hazard map

4.Conclusion

Field investigations in the study area revealed that the majority of the areas lacked proper drainage systems, and existing drainage systems are characterized by inadequately sized culverts which are often blocked by deposition of garbage and an accumulation of silt caused by years of neglect and lack of maintenance. Investigations also revealed that due to increased residential, commercial, and infrastructure developments, there is an increase in impervious surfaces which results in an increase in stormwater runoff. It was also observed that obstruction of flows by buildings across natural stream courses inadequate capacities of culverts and stream channels and contribute to flooding.

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Development of an extension stand to aid performance in table saw machines

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Abstract: The extension stand serves as an assistant in the use of the table saw machine (TSM) without an inbuilt extension. This research developed an extension stand to assist the single user during woodworking operations. SOLIDWORKS software 2021 was used in designing the stand. The extension stand consists of medium wooden members ($50 \times 50 \times 75 \text{ mm}$), having four (4) caster wheels at the upper part of the stand. The designed extension stand was fabricated and evaluated. The produced extension stand performed optimally with the estimated cost of manufacturing at N17, 000.00 (US\$38.04) as of 2021. The extension stand as evaluated passed the reliability test; it was strong enough to support the weight of the applied load during the operational process. The stand provides safety; it is affordable and easy to use.

Keywords: Extension stand, Woodworking operation, Table saw machine.

1. Introduction

Woodworking machines are dedicated equipment that are designed and used for a variety of wood processing activities [1,2]. Expert woodworkers, who need to make wood products including furniture, cabinets, doors, windows, and many other wood-based items in woodworking factories and workshops [3,4,5,6], often employ this equipment. The many pieces of equipment and machinery used for processing wood are divided into categories based on their uses and include sanders, saws, planers, routers, jointers, and lathes among others. According to Lucisano et al. [7] and Landscheidt and Kans [1], these machines are made to carry out specialized operations such as cutting, shaping, drilling, sanding, and polishing wood. Due to the high importation costs, access to this equipment is limited in underdeveloped nations like Nigeria [8]. Industries and factories employ outdated versions of machinery from advanced nations, while those with little financial resources locally manufacture them for usage [9,10].

One of the advantages of using woodworking machines is that they can increase the speed and accuracy of wood processing tasks [9]. For instance, a TSM can cut wood pieces to the exact measurements required, and a router can shape and create intricate designs on wood pieces that would be difficult to achieve by hand. In addition, using woodworking machines reduces physical stress, making work more efficient and less strenuous [11]. Conversely, improper use of woodworking equipment can result in dangers such as injury or damage to the tool or the wood processed [12,13,14]. As a result, woodworkers must acquire the right training and adhere to safety precautions when using machinery [15]. Hence, woodworking machines are essential tools for wood processing purposes, as they aid woodworkers developed high-quality products rapidly and efficiently [16,14].

TMS is a major wood conversion equipment and comes in many shapes, and sizes [17,18]. The ability to make accurate and precise cuts is one of the table saw's key advantages. Users could make bevels, grooves, and other specific cuts because of the blade's ability to adapt to varying angles and depths [19,12]. The machine also cuts through thick, dense materials, which makes it the best tool for slicing through hardwoods, plywood, and other difficult materials [20,21]. It is adaptable and applies to several woodworking projects. It can generate customized cuts and shapes using jigs and fixtures, as well as for ripping, crosscutting, and precision cutting [22,23,12,24].

The use of the TSM as with others requires safety precautions otherwise the implications are fatal. According to the Environmental Health and Safety Office [25], kickbacks can happen resulting in significant injury. Other disadvantages of some TMSs include noise and messy work environment

2. Method

This study was conducted in four phases: The first phase entailed the design, and design considerations involved in the extension stand using CAD/M (SOLIDWORKS) and manual calculations. In the second phase, the material cost of fabricating the stand was estimated and the stand was fabricated using materials locally found within the environs of the University of Cross River, Calabar - Nigeria in the third phase. In the final phase, the extension stand was evaluated.

2.1. Design and Considerations

The extension stand was designed using SOLIDWORKS software with a 3D rendering interface. All parts were carefully considered during the design process. Figure 1 shows the pictorial view of the designed extension stand. A detailed drawing and an exploded view of the extension stand is shown in Figure 1. Further details and dimensions of individual components are presented.



Fig. 1 Pictorial and detailed view of the designed extension stand

2.2. Design Calculations

The extension stand's design took into account estimates for the fasteners' resistance, screw-holding ability, and loading capacity. The fastener design processes outlined in Forest Products Laboratory's General Technical Report from 2010 were adhered to.

Bolts

The bearing stress under a bolt is computed by dividing the load on a bolt by the product LD [16]as given in Eqn. (1), where L is the length of a bolt in the main member and D is the bolt diameter. Bearing stress = L/D (1)

Screws

Tapping screws are commonly used in particleboard where withdrawal strength is important. Care was taken when tightening screws in the particleboard to avoid stripping the threads.

The maximum amount of torque that can be applied to a screw before the threads in the particleboard are stripped is given by [16] in Eqn. (2).

T = 3.16 + 0.0069X

Where: T is torque (N–m) and X is the density of the board (kg m–3).

Equation (T) is for 8-gauge screws with a depth of penetration of 15.9 mm. The maximum torque is fairly constant for lead holes of 0% to 90% of the root diameter of the screw.

Ultimate withdrawal loads P(N) of screws from particleboard will be predicted by the equation given by [11] in Eqn. (3).

$$P = KD1/2 (L-D/3)3/4 G2$$

Where: D = shank diameter of the screw (mm, in.), L = depth of embedment of the threaded portion of the screw (mm), and G = specific gravity of the board based on oven-dry weight and volume at current moisture content. K = 41.1 for withdrawal from the face of the board and K = 31.8 for withdrawal from the edge.

2.3. Material costing Analysis

The materials used for the fabrication of the extension stand were estimated from the list produced by the design software (Fig. 1). Table 1 shows the cost of fabricating the extension stand. The stand cost a total of seventeen thousand, one hundred naira (N17,000) an equivalent of US\$38 as of 2021. This shows that workshops within the town can afford the extension stand with the interest of fabricating the table saw machine.

| Fable 1. Material Cost Anal | lysis of Extension Stand |
|-----------------------------|--------------------------|
|-----------------------------|--------------------------|

| Description of Item | Qty | Unit | Rate | Amount (N) |
|----------------------------|-----|--------|------|------------|
| 50mmx50mm wood | 3 | Pieces | 400 | 1,200 |
| Medium-size top bond glue | 1 | Jar | 800 | 800 |
| Bolt | 2 | Pieces | 500 | 1,000 |
| Knob | 2 | Pieces | 100 | 200 |
| 50mmx75mm wood | 1 | Pieces | 600 | 600 |
| Screws | 1 | Pound | 600 | 600 |
| Washer | 4 | Pieces | 100 | 400 |
| Caster wheel | 2 | Pair | 2600 | 5,200 |
| Transportation | | | | |
| Workmanship | | | | |
| TOTAL | | | | 17,000 |

(2)

(3)

2.4. Fabrication of Extension Stand

Materials for the fabrication of the extension stand were sourced from the local wood market within the research location and taken to the University Wood Products Engineering workshop for the fabrication process. Using the detailed drawings of the extension stand, the parts were processed to specification and assembled piece-by-piece using methods detailed in DeCristoforo [9] and Capototos [6].

2.5. Evaluation

The extension stand after completion was attached to the table saw machine in the University Wood Products Engineering Workshop to test for efficiency. Observations were recorded.

3. Results and Discussion

3.1 Fabrication and Evaluation of Extension Stand

The extension stands as shown in Figure 8 was easy to fabricate using simple and portable tools. It is observed that using fabrication methods according to [9,6] produced satisfactory results. For easy screwing, an improvised method was used to fabricate the nuts for the bolts. The evaluation process was done in the University Departmental workshop using the Table saw machine examined during the design process. Figure 3 shows the finished extension stand ready for use with the table saw. The extension stand was tested with a standard-length plywood Board (Figure 2). The stand was observed to support the user adequately and satisfactorily after the evaluation process.



Fig. 2. Evaluation Process of the Extension Stand on Table Saw Machine



Fig. 3. Extension Stand ready for use with the Table Saw Machine

This study was able to develop and simulate an extension stand, which improves the usage, and safety of the table saw machine thereby encouraging the development of a locally made table saw machine. Future works should focus on modifying and simulating the extension stand to perform similar operations on other woodworking machines and developing additional hardware such as storage compartments or shelves, which can be useful for storing tools, accessories, or other woodworking materials. The extension stand is affordable, easy, safe to use, and adaptable for teaching and research enhancing economic development. Woodworkers can improve their efficiency and precision, and create high-quality wood products.

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Assessment of wood waste for energy generation in Benin City, Edo State, Nigeria

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Abstract: This research primarily deals with the assessment of wood waste generated during the conversion and processing of logs into sawn timber in sawmills. The study was conducted in six sawmills, selected from Oredo and Egor Local Government Areas in Benin City, Edo State. Reconnaissance survey was conducted on the existing sawmills. Multistage sampling method was adopted for the study. Measurements were carried out in these sawmills six days in a week for a period of six weeks. Data for the study were collected by physical measurement using 15 meters tape and diameter tape to generate data of log length and diameter of all the logs before they were fed into the mills. The study showed that there was no significant difference in the number and volume of logs converted in the sampled saw mills. The mean number of logs converted ranged from 42 to 68, while their mean volume ranged from 26.58 m3 to 44.97 m3. Mean volume of lumber produced in the sampled sawmills were between 15.99 m3 to 24.35 m3 per week. The study also showed that the quantity of wood waste produced in the study area was significant (probability value < 0.05). With generation of mean wood waste volume of 10.59 m3 (in sawmill 3) to 20.62 m3 (in sawmill 1).

Keywords: Conversion 1, Assessment 2, Wood Waste 3

1. Introduction

Wastage of wood is one of the factors that have contributed significantly to the rapid depletion of the timber resource of Nigeria [1]. Wood waste is caused by lack of pre-inspection of trees and logs, lack of sufficient saw maintenance, inaccurate processing or conversion of timber and poor harvesting techniques; which results in forest remains in form of stumps, twigs, branches, tree crowns, small diameter sized timbers, off cuts, and others [1]. Nigeria generates about 5.2 million tonnes of wood residue annually [2], of which sawdust alone constitutes 1.8 million tonnes [3]. As a result of inadequate management and utilization methods these large amounts of valuable resource are usually discarded into the environment as materials causing environmental hazards. The practices employed in the utilization and disposal of wood waste contradicts sustainable solid waste management which encourages the efficient utilization of materials in a manner that reduces amount of waste production and the management of waste in a way that meets the economic, social and environmental goals of sustainable development [4].

Thus, in Nigeria and Edo State in particular, both avoidable and unavoidable wood wastes generated during harvesting and conversion are enormous [5,6] and, when pooled together, can be harnessed for the production of charcoal and biofuel for electricity generation in Nigeria which will serve as an alternative to both hydro-electricity and thermal electricity generation.

2. Method

2.1 Study Area

The study was conducted in two locations (Oredo and Egor Local Government Area) in Benin City, the Edo State Capital. Geographically, Benin City is located between latitudes $6^{\circ}11$ ' to $6^{\circ}29$ ' N and longitude $5^{\circ}33$ ' to $5^{\circ}47$ ' E [5]. Topographically, it is a low lying plain with elevation of 80m above sea level and constitutes porous sand that rises gently to the North-East [6]. Climate of the study area

The area receives varying mean annual rainfall of between 1500mm-2000mm per annum with marked wet (April to October), dry (November to April) seasons and cold harmattan (between December and January). While the mean annual temperature ranges from 22°C in the rainy season

and as high as 28°C in the dry season [7-10]. Also, the city is covered with few hills to the eastern part and the lands are drained by the rivers, Orhiomwon, Osse and Ikpoba. The study area and its neighborhoods are endowed with numerous timber processing industries and diversity of timber species which are sources of raw materials for sawmills within and outside the city, there are a total of thirty-nine sawmills in Benin City in the area. These sawmills are distributed amongst Oredo (10 sawmills), Egor (20 sawmills) and Ikpoba-Okha (9 sawmills) local government areas.

2.2 Data Collection

A reconnaissance survey was conducted on the existing sawmills to make sure they were actively involved in sawmilling. Multistage sampling method was adopted for the study. Without bias or replacement, two of the local government areas, Oredo and Egor, were randomly selected for the study. With 20% sampling intensity, 2 and 4 sawmills were randomly selected from Oredo and Egor Local Government Area respectively (Table 1). Data for the study were collected by physical measurements for a period of six days per week in the selected sawmills using 15 meters tape and diameter tape to generate the required data of log length and diameter of all the logs before they are fed into the mills. This was used for computation of volume, wood waste, wood conversion efficiency and wood conversion ratio.

The measurements taken were also used to generate data on wood waste, wood conversion efficiency and wood conversion ratio.

| Lotion | Total No. of Sawmills | 20% sampling intensity |
|--------|-----------------------|------------------------|
| Oredo | 10 | 2 |
| Egor | 20 | 4 |
| Total | 30 | 6 |

2.3 Data Analysis

Data from the study were analyzed using descriptive and inferential statistics. Descriptive statistics involved the use of frequencies, percentages, tables, charts and graphs. Data generated from the study were computed in excel and analyzed using *F-test*, Fisher's least significance difference (LSD), regression and Pearson's correlation packages in Statistical Package for Social Sciences (SPSS) version 20.

Before log conversion each day, the diameter and length of each log in the selected sawmills were obtained and volume generated using Newton's formula [1]. The formula is given below:

$$V_1 = \frac{\pi \left(db_2 + 4dm_2 + ds_2\right)L}{24} \tag{1}$$

Where, $V_1 =$ volume of log (m³)

db = diameter at the large end of log

dm = diameter at midpoint of log

ds = diameter at small end of log

L = Log length (m)

 $\pi = 3.142$ or 22/7

Volume computed using equation 1 was used to compute total volume of the various dimension lumbers obtained logs per day. This was done using:

$$V_2 = [L \times B \times H]n$$

Where, V₂ = Volume of sawn lumbers (m³)
L = Length (mm)

(2)

B = Breath (mm)

H = Thickness (mm)

n = Total number of lumbers obtained.

Wood waste volume computation

The total volume of wood waste generated per day from the conversion of logs to lumbers was estimated using the equation adopted by Aina (2006):

 $V_w = V_1 - V_2$

Where, $V_w =$ Volume of wood waste (m³)

 V_1 = Volume of logs before conversion (m³)

 V_2 = Volume of lumbers obtained aafter conversion (m³).

The percentage waste generated will therefore be calculated using the formula

% waste = $\frac{V_w \times 100}{V_1}$

Sawmill efficiency

The efficiency of each of the six sampled sawmills was calculated using the formula [1],

$$\xi_{\rm mill} = \frac{V_2}{V_1} \times \frac{100}{1} \tag{5}$$

Where, ξ mill = Sawmill Efficiency (%)

 V_2 = Volume of lumbers obtained after conversion (m³)

 V_1 = Volume of logs before conversion (m³).

Sawmill conversion ratio

Conversion Ratio (CR) for each of the sawmills was calculated using the formula (Aina, 2006),

$$CR = \frac{\mu v_2}{\mu v_1} \tag{6}$$

Where, CR = Conversion Ratio.

 μV_2 = Mean of total volume of lumbers obtained after conversion (m³).

 μV_1 = Mean of total volume of logs before conversion (m³).

3. Results and Discussion

The mean number of logs converted per week in each sawmill is shown in Table 2. Sawmill 1 had mean value of 68, sawmill 2 converted 54 logs, sawmill 3 converted 42 logs, sawmill 4 recorded mean value of 59 logs, sawmill 5 converted 43 logs and sawmill 6 converted 58 logs per week. Thus, lowest number of logs converted per week was found in sawmill 3 while highest was found in sawmill 1. The *F-test* analysis yielded a *P-value* of 0.1564 indicating that there was generally no significant difference in the number of logs converted to timber in the sawmills. The. The species of logs converted in each of the selected sawmills are Ekki, Okan, Masonia, Mahogany, Owewe, Obia and Obeche.

The mean volume of logs converted to timber per week in each sawmill are shown in Table 3. Sawmill 1 recorded highest log volume per week of 44.97 m³, sawmill 2 recorded 31.35 m³, sawmill 3 recorded 26.58 m³, 37.24 m³ recorded in sawmill 4, sawmill 5 recorded 28.47 m³ and 38.36 m³ recorded in sawmill 6. The *F*-test analysis yielded *P*-value of 0.1089 indicating that there was no significant difference in the mean volume of logs converted to timber in the study area. Number and volume of lumber produced

The mean number of lumbers produced per week is as shown in Table 4. Mean number of 785.17 lumber were recorded in sawmill 1, 684.50 lumber in sawmill 2, 492.50 lumber in sawmill 3, 661.50 lumber in sawmill 4, 536.00 lumber in sawmill 5 and 762.83 lumber in sawmill 6. There was generally no significant difference (P = 0.1398) in the mean number of lumbers produces in the various sawmills.

The species of logs converted in each of the selected sawmills are Ekki, Okan, Masonia, Mahogany, Owewe, Obia and Obeche.

(3)

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3.1 Number and volume of lumber produced

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| Weeler | | Sa | wmills | | | | |
|---------------|-----------|-----------|-----------|-----------|-----------|-----------|----------------------|
| weeks 1 | 2 | 3 | 4 | 5 | 6 | - P-Value | 2 |
| 1 | 87 | 45 | 36 | 45 | 18 | 84 | |
| 2 | 57 | 66 | 60 | 39 | 51 | 78 | |
| 3 | 60 | 48 | 57 | 87 | 60 | 51 | |
| 4 | 45 | 81 | 39 | 45 | 30 | 62 | |
| 5 | 82 | 30 | 27 | 85 | 30 | 48 | |
| 6 | 78 | 51 | 33 | 54 | 69 | 24 | |
| Total Mean | 409 68 | 321 54 | 252 42 | 355 59 | 258 43 | 347 58 | 0.1564 ^{ns} |

Table 2.Number of logs converted per week

Table 3.

| Weeks | | D Value | | | | | |
|-------|--------|----------|--------|--------|--------|--------|----------------------|
| | 1 | 2 | 3 | 4 | 5 | 6 | - <i>P</i> -value |
| 1 | 56.94 | sss24.72 | 21.06 | 27.15 | 14.67 | 51.57 | |
| 2 | 39.93 | 29.34 | 30.18 | 20.97 | 35.43 | 48.96 | |
| 3 | 30.33 | 33.27 | 38.25 | 49.89 | 39.12 | 28.98 | |
| 4 | 33.39 | 46.53 | 19.14 | 26.28 | 19.26 | 51.66 | |
| 5 | 59.52 | 20.61 | 21.21 | 63.03 | 21.03 | 28.26 | |
| 6 | 49.68 | 33.60 | 29.61 | 36.09 | 41.28 | 20.73 | |
| Total | 269.79 | 188.07 | 159.45 | 223.41 | 170.79 | 230.16 | |
| Mean | 44.97 | 31.35 | 26.58 | 37.24 | 28.47 | 38.36 | 0.1089 ^{ns} |

^{ns} Not significant at 5% probability level

^{ns} Not significant at 5% probability level

Volume of logs converted per week (m³)

Table 5 shows the volume of sawn lumber produced per week in the study area. It was revealed that sawmill 1 produced 24.35 m^3 of lumber, sawmill 2 produced 18.41 m^3 of lumber, sawmill 3 produced 15.99 m^3 of lumber, sawmill 4 produced 21.09m^3 of lumber, sawmill 5 produced 16.60m^3 of lumber, and sawmill 6 produced 22.01m^3 of lumber. Results from the *F-test* yielded *P-value* of 0.2574 indicating that there was no significant difference in the volume of lumber produced between the various sawmills.

3.2 Volume of wood waste produced

The volume of wood waste produced by sawmills in the study area are shown in Table 6. From the results it was observed that the highest volume of wood waste of 20.62m³ was produced in sawmill 1, sawmill 2 produced 12.94m³, sawmill 3 produced 10.59m³ of wood waste, sawmill 4 produced 16.15m³, sawmill 5 produced 11.87 and sawmill 6 produced 16.35m³ of wood waste. The F test analysis yielded a *P-value* of 0.0271 indicating significant difference in the amount of wood waste produced in the various mills.

| Weeler | Sawmills | | | | | | |
|--------|----------|--------|--------|--------|--------|--------|----------------------|
| weeks | 1 | 2 | 3 | 4 | 5 | 6 | - P-Value |
| 1 | 897 | 759 | 375 | 540 | 234 | 944 | |
| 2 | 594 | 843 | 720 | 450 | 531 | 996 | |
| 3 | 720 | 486 | 525 | 957 | 720 | 516 | |
| 4 | 519 | 864 | 657 | 573 | 345 | 993 | |
| 5 | 985 | 516 | 345 | 873 | 507 | 828 | |
| 6 | 996 | 639 | 333 | 576 | 879 | 300 | |
| Total | 4711 | 4107 | 2955 | 3969 | 3216 | 4577 | |
| Mean | 785.17 | 684.50 | 492.50 | 661.50 | 536.00 | 762.83 | 0.1398 ^{ns} |

Table 4. Number of sawn lumber produced per week

Not significant at 5% probability level

Table 5.

Volume of sawn lumber produced per week (m³)

| Weelra | | D Value | | | | | |
|--------|-------|---------|-------|--------|-------|--------|----------------------|
| weeks | 1 | 2 | 3 | 4 | 5 | 6 | - <i>F</i> -value |
| 1 | 30.75 | 14.58 | 12.81 | 15.33 | 8.49 | 29.37 | |
| 2 | 21.51 | 17.16 | 18.36 | 12.06 | 21.12 | 27.93 | |
| 3 | 16.59 | 19.62 | 22.65 | 28.08 | 22.8 | 16.68 | |
| 4 | 18.03 | 27.33 | 11.46 | 14.82 | 11.04 | 29.52 | |
| 5 | 32.85 | 12.09 | 12.75 | 35.49 | 12.09 | 16.14 | |
| 6 | 26.37 | 19.65 | 17.91 | 20.73 | 24.03 | 12.42 | |
| Total | 146.1 | 110.43 | 95.94 | 126.51 | 99.57 | 132.06 | |
| Mean | 24.35 | 18.41 | 15.99 | 21.09 | 16.60 | 22.01 | 0.2574 ^{ns} |

^{ns} Not significant at 5% probability level

Table 6. Volume of wood waste produced per week (m³)

| *** | | — D.1/ / | | | | | |
|-------|--------|----------|-------|-------|-------|-------|----------|
| Weeks | 1 | 2 | 3 | 4 | 5 | 6 | P-Value |
| 1 | 26.19 | 10.14 | 8.25 | 11.82 | 6.18 | 22.2 | |
| 2 | 18.42 | 12.18 | 11.82 | 8.91 | 14.31 | 21.03 | |
| 3 | 13.74 | 13.65 | 15.6 | 21.81 | 16.32 | 12.3 | |
| 4 | 15.36 | 19.2 | 7.68 | 11.46 | 8.22 | 22.14 | |
| 5 | 26.67 | 8.52 | 8.46 | 27.54 | 8.94 | 12.12 | |
| 6 | 23.31 | 13.95 | 11.7 | 15.36 | 17.25 | 8.31 | |
| Total | 123.69 | 77.64 | 63.51 | 96.9 | 71.22 | 98.1 | |
| Mean | 20.62 | 12.94 | 10.59 | 16.15 | 11.87 | 16.35 | 0.0271** |

^{ns} Not significant at 5% probability level

4. Conclusion

The study showed that the quantity of wood waste produced in the study area was significant. With generation of mean wood waste volume of 10.59 m3 (in sawmill 3) to 20.62 m3 (in sawmill 1). Although it was observed that the high rate of wood waste was as a result of poor conversion ratio of the sawmilling machines (ranged between 54.14 % and 60.23%). Thus, It was revealed that the sawmills were producing significant amount of wood waste and if all these waste were collected, rather than burnt or used for poultry or disposed of into a water body. Also the amount of waste could be reduced through the provision of regular power supply, increased efficiency of sawmilling machines.

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Comparative analysis of the effect of using groundnut shell and rice husk waste ashes for soil stabilization

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Abstract: Traditional methods of soil stabilization have limitations, prompting the search for sustainable alternatives, particularly in waste materials. Groundnut shell ash (GSA) and rice husk ash (RHA) were used to stabilise laterite soil due to their high silica content. Different mix ratios of GSA and RHA were subjected to standard compaction tests, California bearing ratio tests and unconfined compressive strength tests. Generally, the results showed improvements of soil mechanical properties on the addition of GSA and RHA. The California Bearing Ratio (CBR) of the laterite soil increases following the addition of RHA and GSA. A mixture composed of 90% soil and 10% GSA demonstrates the least incremental increase at 62.07%, ultimately resulting in a CBR of 5.17%, while a combination of 75% soil, 15% RHA, and 10% GSA exhibited the most substantial rise, boasting an impressive 196.24% increase and achieving a CBR of 9.45%. The unconfined compressive test gave an unconfined compressive strength (UCS) and cohesion of 48.95 KPa and 24.475 kPa respectively for untreated laterite soil. These values were increased to 76.96 KPa and 38.48 KPa for UCS and cohesion of a treated soil consisting of 90% soil and 10% GSA. The mixture comprising 75% soil, 15% RHA, and 10% GSA demonstrates the most significant rise, boasting an impressive 286.31% increase in UCS values and culminating in a UCS of 189.1 kPa and cohesion of 94.55 kPa.

Keywords: Laterite, groundnut shell, rice husk, ash, soil test

1. Introduction

Soil Stabilization is an important technique in civil engineering which aims to improve the soil's engineering qualities such as its durability, decrease compressibility, and boost strength, so as to increase its load-bearing capacity when used for building and construction. In civil engineering and construction, soil stabilization is essential because it directly affects the strength and longevity of infrastructures such as foundations, embankments, and roadways. Some soils are naturally too weak, unstable, or inappropriate for construction, so soil stabilization becomes necessary. Chemical additions such as cement, lime, or other similar substances are frequently used in traditional soil stabilizing techniques. However, these techniques can be expensive, harmful to the environment, and not always long-term sustainable [1-6]; as such the need for affordable and ecologically friendly ways to stabilize soil arises. The use of waste materials is one such option that not only solves environmental issues by recycling garbage but also offers a cost-effective way to improve soil [7-11]. This strategy decreases the use of non-renewable resources and lessens trash disposal concerns, which are in line with sustainable development goals [18]. Rice husk ash (RHA) and groundnut shell ash (GSA) are two waste products that have demonstrated potential for stabilizing soil. Ash from groundnut shells is a waste product that is produced as a result of agriculture. Similar to that, rice husk ash is produced by burning rice husks that would otherwise be thrown away. Due to their high silica content, GSA and RHA may be effective in enhancing the characteristics of soil [12,15].

The amorphous silica, which has pozzolanic qualities is abundant in GSA and RHA. This can combine with calcium hydroxide to generate cementitious compounds and will in turn lead to an increase in the strength and stability of soils as a result of this pozzolanic reaction [13-14]. However, based on variables including their origin, makeup, and the particular type of soil, these waste materials' efficacy may differ [15,16] and as such, the goal of this study is to provide a thorough comparative examination of how GSA and RHA affect soil stabilization. The effects of these waste materials on laterite soil were analysed by determining the soil's unconfined compressive strength, California Bearing Ratio, and maximum dry density. The results of this research will support the

responsible use of waste materials in civil engineering and will also lead to sustainable development of construction techniques, supporting international efforts to lessen environmental effects [17].

2. Methods

2.1 Materials

The materials for the experimental work are Laterite, groundnut shell ash, rice husk ash and water

2.2 Mix proportions

Laterite Soil, Groundnut Shell ash and rice husk ash were mixed thoroughly to have a uniform and homogenous mixture. The samples were prepared using different combinations of Laterite Soil, Groundnut Shell ash, and rice husk ash as shown in Table 1 different tests were conducted on each prepared sample and the results were compared with those of the original Laterite Soil.

| S/N | Soil (%) | RHA (%) | GSA (%) |
|-----|----------|---------|---------|
| 1 | 100 | 0 | 0 |
| 2 | 90 | 10 | 0 |
| 3 | 90 | 0 | 10 |
| 4 | 85 | 10 | 10 |
| 5 | 75 | 10 | 15 |
| 7 | 75 | 15 | 10 |
| 6 | 70 | 15 | 15 |

Table 1. Samples and their mix proportion

Experiments were carried out on each mixed proportion (Table 1). These experiments include:

- Moisture Content Test
- Particle Size Distribution (Sieve Analysis) Test
- Specific Gravity/Density
- Atterberg Limits Test (liquid limit and plastic limit tests)
- Standard Proctor Compaction Test
- California Bearing Ratio (CBR) Test
- Unconfined Compression Strength (UCS) Test

3. Results and Discussion

3.1 Characterization of Soil

Characterization of the soil is the first stage of this study endeavour that gives an overview of the basic characteristics of the soil. It is important to evaluate the initial state before administering any stabilizing drugs. This test gives important details regarding the soil's flexibility and clay content, two important components of soil behaviour. The findings (Table 2 and Fig 1) defined the soil's baseline characteristics and act as a benchmark for assessing how well waste items stabilize the soil.

| Table 2. | Soil | test | results | for | natural | laterite | soil |
|----------|------|------|---------|-----|---------|----------|------|
|----------|------|------|---------|-----|---------|----------|------|

| Soil test | Average moisture | Average specific | Maximum dry | Optimum moisture |
|-----------|------------------|------------------|----------------|------------------|
| | content (%) | gravity | density (g/cc) | content (%) |
| Result | 23.24 | 2.58 | 1.8 | 22.8 |



Fig. 1. Particle size distribution curve for laterite soil

3.2 Mechanical properties of the natural and stabilized soil

Compaction Test, California Bearing Ratio Test and Unconfined Compressive Strength Test were performed to obtain the mechanical properties of the natural and stabilized soil as shown in Table 3.

| S/N | Mix Proportion | OMC (%) | MDD (g/cc) | CBR (%) | UCS (KPa) | Cohesion (Kpa) |
|-----|------------------------------|------------|---------------|------------|--------------|-------------------|
| 1 | 100% SOIL | 22.85 | 1.8 | 3.19 | 48.95 | 24.475 |
| 2 | 90% soil + 10% RHA | 19.8 | 1.981 | 5.21 | 85.92 | 42.96 |
| 3 | 90% Soil + 10% GSA | 18.8 | 1.921 | 5.17 | 76.96 | 38.48 |
| 4 | 75% soil + 10% RHA + 15% GSA | 18.85 | 1.948 | 6.65 | 164.9 | 82.45 |
| 5 | 75% soil + 15% RHA + 10% GSA | 21.7 | 1.8805 | 9.45 | 189.1 | 94.55 |
| 6 | 80% soil + 10% RHA + 10% GSA | 18.7 | 1.911 | 8.56 | 136.03 | 68.015 |
| 7 | 70% soil + 15% RHA + 15% GSA | 20.35 | 1.948 | 7.59 | 155.53 | 77.765 |

Table 3. Mechanical Properties of Natural and Treated Soil

3.3 Optimum moisture content

Fig. 2 to 6 shows the comparative mechanical properties of the natural and stabilized soil.



Fig. 2. Comparative optimum moisture content of natural and stabilized soil

The initial OMC of the lateritic soil was determined to be 22.85%. Subsequently, incorporating different proportions of RHA and GSA led to a reduction in the OMC (Fig. 2), signifying an improvement in soil properties. Specifically, the mixture comprising 75% soil, 15% RHA, and 10% GSA produced the least OMC value of 21.7% showing a 5.033% reduction in OMC.



3.4 Maximum dry density

Fig. 3. Comparative maximum dry density of natural and stabilized soil

The soil was compacted with different proportions of RHA and GSA introduced. Before the introduction of RHA and GSA, the initial MDD of the lateritic soil was determined to be 1.80 g/cc. It was observed that the MDD consistently increased after RHA and GSA were introduced (Fig. 3), signifying an improvement in soil compaction and density. The most substantial increment was 1.981 g/cc, obtained at 90% soil + 10% RHA signifying a 10.06%, increase in values. Similarly, the mixture of 75% soil + 15% RHA + 10% GSA exhibited a significant 10% increment, achieving an MDD of 1.98 g/cc. On the other hand, the sample composed of 70% soil + 15% RHA + 15% GSA showed the smallest increment at 4.47%, yielding an MDD of 1.8805 g/cc. These results emphasize the capacity of waste materials like RHA and GSA to improve the compaction characteristics of soil.



3.5 California Bearing Ratio

Fig. 4. Comparative California bearing ratio of natural and stabilized soil

The initial CBR of the natural laterite soil was established at 3.19%. As different combinations of RHA and GSA were introduced into the soil, it was observed that the CBR consistently increased, signifying an enhancement in the soil's load-bearing capacity. Remarkably, the mixture composed of 90% soil and 10% GSA exhibited the lowest CBR increment, demonstrating an increase of 62.07% (Fig. 4). The CBR value reached 5.17%, emphasizing the effectiveness of this composition in improving the soil's load-bearing capacity. Conversely, the composition consisting of 75% soil, 15% RHA, and 10% GSA demonstrated the most substantial CBR increment, showing a remarkable increase of 196.24%. This led to a CBR value of 9.45%, highlighting the significant enhancement of load-bearing capacity achieved by this particular combination.



3.6 Unconfined Compressive Strength and Cohesion



Fig. 5. Comparative unconfined compressive strength of natural and stabilized soil

Fig. 6. Comparative cohesion of natural and stabilized soil

The UCS and cohesion of the untreated laterite soil were 48.95 Kpa, and 24.475 Kpa respectively. As various combinations of RHA and GSA were incorporated into the soil, it was observed that both the UCS and Cohesion consistently increased (Fig. 5 and Fig. 6), reflecting an improvement in the soil's load-bearing and cohesive characteristics.

Notably, the mixture composed of 90% soil and 10% GSA produced UCS of 76.96 kPa (Fig 5) and a Cohesion of 38.48 Kpa (Fig. 6), indicating a 57.22% increase. Conversely, the composition consisting of 75% soil, 15% RHA, and 10% GSA exhibited the most substantial increments, with a remarkable increase of 286.31%. This led to a UCS of 189.1 Kpa and a Cohesion of 94.55 Kpa,

highlighting the significant enhancement of load-bearing and cohesive properties achieved by this specific combination.

4. Conclusion

Utilizing rice husk and groundnut shell waste materials in soil stabilization is an ecologically friendly and cost-effective way to stabilize soils. Stabilizing soil with GSA and RHA significantly improves the stability and compaction properties of the soil. The unconfined compressive strength tests showed that soil treated by both GSA and RHA is considerably enhanced. Soils treated with GSA and RHA are appropriate for road construction as shown by the California Bearing Ratio (CBR) test results.

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Urea-formaldehyde free particleboards from wood wastes using glutaraldehyde modified cassava starch as binder

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Abstract: Improved, sustainable and eco-system friendly material is the focus to developed material for construction industry, the study evaluated, the physio-mechanical properties of particleboards manufactured from wood solid waste and modified cassava starch (MSC); as reinforcer. The starch was extracted from liquid waste from cassava processing and dried into powder form, modified with 24% glutardialdehyde solution. Density of boards, thickness swelling (TS) Water absorption (WA); modulus of elasticity (MoE) and modulus of rupture (MoR), were evaluated according to ASTM standards respectively. Density of boards were recorded 0.22 to 0.58g/cm3, TS and WS recorded are 2 to 24h immersion, 1.6 67.30% and 31.6 to 140.4%. MoE and MoR, with peak of values 533.5N/mm2 and 35.7N/mm2. The microstructural and elemental analyses of boards were examined with Scanning electron microscope (SEM) and Fourier-transform infrared spectroscopy (FTIR); SEM analysis showed granules of modified cassava starch on the surface of the boards, while FTIR showed presence of eater and aldehyde forms attributed to hydroscopic formation of MCS binder. Particle board manufactured from MCS binder exhibited properties suitable for non-loading bearing capacity with reference to unmodified particleboards.

Keywords: wood fiber, modified cassava starch, mechanical properties microstructure.

1. Introduction

Wood wastes are wood fragments and particle from industrial or saw milling processing industries, forest harvesting, construction and demolition activities. Huge quantities of the post- consumer wood waste are generated in a significant rate and the method and level of recycling is inadequate compared to other construction and demolition wastes. Several, reports showed that between 8 and 50% of the entire wood-based material being used yearly for various end uses application become wastes. Wood wastes consist of; solid timber, timber shavings, sawdust, off-cut, veneer panels and combination of two or more of them. Hence, 10% of solid wastes are associated from demolition and construction site, these wastes are majorly dumped in landfills and burnt in combustion chamber, this opposing hazard to the environment, wood waste could be reused by sorting, recycle and utilized as raw material for the development of values added products (particle board and fiber board); those could be utilized as ceiling board, walls, flooring, furniture etc [1][2][3][4]. However, recycling of wood waste with formaldehyde- based resin will generate high leaching of emissions from the virgin product to the environment than expected dose, basically, those will be in two sources, first the breaking down of the formaldehyde in the parent product, secondly formation of the new formaldehyde adhesive utilized for the new products [5][3]. The leaching of formaldehyde will alter the air quality of indoor facilities made from the second-generation products and imposed serious health challenges for the occupants more than older structure. This health problem, however, showed the important role of formaldehyde inducting illness through immune mechanism and toxicity. Hence, to curbed these problems various study has showed approaches to minimized the formaldehyde emission from engineered wood-based products, through chemical modification with natural resins [6][7][8]. Second method involves the utilization of formaldehyde free adhesives, these are vegetable based, which are environmentally clean and friendly, green and could be utilized for engineered wood products without health issues. Natural latex, oxidase, gum Arabic, corn starch, soy-based adhesive, wheat gluten, and nano- modified starch [9][10]. Amongst others, cassava is one of higher source of starch of natural polymers of low cost and largely variable. The processing of cassava to cassava flake and other end- products of cassava generate commercial quantities of the natural polymer for industrial uses [11][10]. Study showed that, cassava starch contained amylose and amylopectin, amylopectin is a polymer of several D-glucose molecules.80% of amylopectin is present in starch, amylopectin molecules are linked by α -1,4-glycosidic bonds and α -1,6-glycoside bonds. It is a water insoluble fraction. Amylose is a polysaccharide made of α -D-glucose units, bonded to each other through $\alpha(1\rightarrow 4)$ glycosidic bonds. It is one of the two components of starch making up approximately 20-30%. Fig 1 showed the chemical structure of amylose and amylopectin. Nigeria is largest producer of cassava in Africa, contributing 30%, it's a source of food in Nigerian and less application industrial end products, compared to Asia, which has been major raw material for various end product without affect food value chain of the Asia ecosystems [12][13][11]. Studies showed that, cassava thrive in poor fertile soil unlike other sources of starch like yam etc. Resins in wood -based industries has necessitated the utilization of starch based, but, the main drawbacks of bonded boards are the poor dimensional stability and low bonding properties which are associated in cases involving starch as adhesive [14][15][16][9][17]. The hygroscopicity of cassava-based starch in engineered wood based has gears the current study. Nevertheless, some treatments have been used in some studies to improve the bonding capacity of starch as a doable resin in various wood end uses applications [15][10][11]. Studies, showed chemical modification of starch with low percent of Urea formaldehyde as binder, the mechanical properties of the board indicated higher value in MOR, thickness swelling and density were observed in test sample with modified binder in comparison with unmodified[11] Similarly, study by[18] developed composite material of difference sieved sizes, using wood waste, bonded with chemically modified starch, results showed that, MOR and internal bonding of panels aligned with ASTM Standards. Modifications of starch as constituent in formaldehyde adhesive is to input some functional groups to modified it role in end uses applications. The chemical modifications are basically grafting copolymerization, crosslink reactions. Few studies exist on the utilization of cassava starch obtained from residue of cassava processing and its subsequent modification, being utilized with wood waste from saw milling, demolition and construction site for particle board production. However, the aim of the study is to bridge dearth of knowledge gap in the utilization of cassava modified starch in the production of engineered wood products for sustainable ecosystem.

2. Method

2.1. Material preparation

Wood wastes were sourced from a local saw mill in calabar, wood chips were from different species of timber material, sorted from metals and debris, the wood chip waste (WC) were firstly air dried and further oven dried at 800C until reading on the moisture analyzer were $\pm 5\%$ Moisture content (MC), the wood meal were then sieved and packaged into two sieved sizes of 600µm and 0.08mm respectively. The cassava starch (CS) was sourced locally in a cassava processing outlet in a powdered form; the cassava starch is basically byproducts waste material from cassava processing as a waste water, the starch is produced from decantation of waste water for cassava during processing, these waste water is allowed to dry, and solidified to form, as CS. Glutardialdehyde solution is an oily liquid and colourless which is used in health facilities as sterilant to disinfect and clean heat- sensitive equipment such as dialysis, as disinfectant, glutardialdehyde is a hardening agent, it was supplied by AliChemical reagent Co., Ltd. Modification of cassava Starch, to Gludehyde was in ratio of 1:2(w/w)[3][11]. The CS powder was dissolved in deionized water at 23 to 25oC and stirred manually for consistency of 20% for about 40s. 250ml of glutardialdehyde solution was mixed according [18][11][19]. Mixture was given vigorous stirred for 4min. at temperature of 250C to produce the modified cassava starch (MCS). The study employed injection method for the production of Particles boards, different ratio(s) was used of the MCS adhesive of 1:5 and 3:5 by mass ratio. The sieved chipped were batch mixed with MCS and injected to a mould of 150×150× 30mm, the composition was given a cold press to form mat under 7.7N/m2 for 48hrs, the composition was hot pressed at a pressure rate of 3N/m2 using the temperature of 150oC for 2hrs and conditioned

in a controlled temperature of 250C and relative Humidity (RH). Test samples were machined from the manufactured boards of two difference variation, for physio-mechanical properties. Water absorption and thickness swelling tests were examined in accordance with ASTMD 3502-76 for 2hrs to 24hrs immersion in water. Water absorption WA and TS were evaluated.



Fig. 1. Molecular structure of (a) amylose and (b) amylopectin

| Fable | 1.Mix | ratio | design | of | partic | eboard | |
|-------|---------|-------|--------|----|---------|--------|--|
| ant | 1.14117 | rano | ucorgn | O1 | partici | cooura | |

| Particle board | Wood particle sizes (mm, µm) | Vol. (%) of binder | Type of adhesive |
|-------------------|------------------------------|--------------------|------------------|
| D | 0.08 | 1.5 | CS |
| Ι | 0.08 | 1.4 | MCS |
| R | 0.0.8 | 1.2 | CS |
| W | 600µm | 2.0 | MCS |
| А | 600µm | 2.0 | MCS |
| Ν | 0.08 | 1.5 | CS |
| G | 600µm | 1.5 | MCS |

The mechanical properties were carried out, with Universal Testing Machine (UTM); with max tension range of 50kN, stroke resolution 0.001mm, (Model, No M500-50AT); the Modulus of rupture (MoR) and Modulus of Elasticity (MoE)were evaluated respectively (ASTM D 198-05). Fracture test samples were examined using field emission scanning electron microscope (FESEM); at a magnification of 10,000 and 12,000with acceleration potential of 16kV. Functional group of modified CS and crosslinking group were determined using FTIR spectra (Shimadzu FTIR-8400S Spectrophotometer) [19]. Figure 2 shows particle produced from MCS. Results were analyzed via standard deviation and one-part ANOVA.



Fig. 2. Particles board manufactured from MCS

3. Results and Discussion

3.1 Results of physical properties evaluated

Table 2 showed the density of the particle board ranged from 0.28 to 0.58g/cm3, boards produced from sieve sized 600µm having a higher value to particle size of 0.8mm, the values reflected [19][20][21]. Results of density showed higher density with board fabricated from MCS adhesive matrix of 1.2 to 1.5 ranges of dosages. Ratio of adhesive to matrix increase it interfacial bonding (Van der Waals force); these factors contributed to improved mechanical strength of board, some studies has shown that, density is closely related to some mechanical properties of engineered wood panels (bending strength) [21][19][22]. Stability of material is a determinant of its utilization. Starch from studies is hygroscopic nature, the behaviour was observed after modification with glutaraldehyde. Water absorption of board fabricated from MCS exhibited low uptake of moisture compared to samples fabricated from CS. WA uptake for 2hrs ranged from 31.6 to 122%, variation in uptake were observed in respect to sieved sized, 24hrs WA recorded am increase in water uptake ranged from 45 to140%. The variation of difference uptake is indication that, MCS create a film that prevent water movement in internal bonding network of boards. Water absorption and thickness swelling recorded high-density board with MCS in comparison with low- density board fabricated with CS. Developed particle boards of MCS could be utilized for agricultural building, as well as interior purposes in residential building.

| Particle board | Wood particle sizes (mm, µm) | Density (g/cm3) | 2hrs WA (%) | 24hrs WA (%) | 2hrs TS (%) | 24hrsTS (%) |
|-------------------|------------------------------------|----------------------|-------------------------|-------------------------|------------------------|-------------------------|
| D | 0.02 | 0.22(0.02) | 21 ((4 2)) | $Q(\zeta(A,\zeta))$ | 8 0/0 4)3 | 15 2(1 9) |
| D | 0.08 | $0.22(0.02)^{\circ}$ | 31.0(4.3) ^a | 80.0(4.0)" | 8.0(0.4)" | 15.5(1.8)* |
| Ι | 0.08 | $0.43(0.03)^{b}$ | 67.4(5.4) ^b | 57.5(5.4) ^b | $3.0(1.4)^{f}$ | 67.3(0.04) ^e |
| R | 0.0.8 | 0.52(0.03)° | 90.7(5.7) ^b | 58.7(6.4) ^c | $1.6(0.04)^{c}$ | 35.5(0.09) ^a |
| W | 600µm | $0.47(0.01)^{e}$ | $37.6(2.7)^{d}$ | 45.5(4.5) ^c | $1.6(0.05)^{b}$ | $23.7(0.04)^{a}$ |
| А | 600µm | $0.58(0.02)^{e}$ | 45.6(3.5) ^c | 124.4(5.6) ^c | 23.4(4.6) ^e | 24.5(0.04) ^e |
| Ν | 0.08 | $0.37(0.01)^{f}$ | 74.6(4.6) ^b | 123.1(2,5) ^b | 13.5(0.6) ^b | $8.5(0.5)^{r}$ |
| G | 600µm | $0.26(0.02)^d$ | 122.7(3.6) ^c | $140.4(2.6)^{a}$ | 8.6(0.03)° | 11.5(0.6) ^a |

Table 2. Physical properties of the board

Values in parenthesis show standard deviation while different latter shows significant difference between group within the same columns at p $\alpha 0.05$

3.2 Mechanical properties

Variation in mechanical properties of boards shown higher mechanical strength on Modulus Rupture and Modulus of elasticity with MCS Adhesive, this study postulate that, aldehyde groups react with the starch granules and hydroxyl group of the wood particle. This bonding was possible due to capability of hydroxyl group found in wood chip, which enhance self- polymerization and formed cross linking reaction with aldehyde groups [23] [19]. Resistance to mechanical shear exhibited by boards were enhanced due to cross linking reaction between the wood fibers and the starch granules. Reports by [23] [24] shows wood fracture of fiber under influent of mechanical forces on particle boards, the glue line in the experimentation was reported intact, this implied that stronger bond was developed with MCS, which was observed stronger to conventional adhesive used in wood -based industry. Difference test samples of particleboards exhibited difference structural behaviors under same loading conditions, test samples I, W, A, and G bonded with modified cassava starch (MCS) exhibited the following MOR and MOE results; 1813.6 and 20.5N/m2, 1875.6 and 192N/m2, 146.7 and 35.7N/m2, and 533.5 and 19.9N/m2. Faber sizes and adhesive dosages has significant influence on the mechanical properties examined. Increased in material strength was noted from manufactured boards from 600µm sieved sized, these implied that, there proper interfacial bonding between reinforcer and matrix (MCS), and equally aid the curing time. The results from samples manufactured from CS with modification were reported with low MOE and MOR as followed respectively D, R,

N;126.2 and 15.8N/mm2; 90.7 and 19.2 N/mm2; lastly 33.0and 14.7N/mm2. In comparison boards manufactured from CS exhibited lower strength performance under the same structural conditions with boards manufactured with MCS. Furthermore, manufactured sample W and G met with minimum ASTM standards for fiber reinforced composite. Inclusion, the polar constituent in wood particle surface equally aided effective bonding.

| Manufactured Boards | Modulus Of Elasticity (N/Mm ²) | Modulus Of Rupture(N/Mm ²) |
|---------------------|--|--|
| | | |
| D | 126.2(312.3) ^c | $15.8(2.6)^{d}$ |
| Ι | 1813.6(2272) ^v | 20.5(1.9)° |
| R | 90.7(33.5) ^d | 19.2(2.2) ^a |
| W | 1875.6(13.4)° | 5.3(0.06) ^g |
| А | 146.6(7.7) ^a | 35.7(0.06) ^e |
| Ν | 33.0(374.2) ^b | $14.7(4.1)^{d}$ |
| G | 533.5(24.2) ^b | 19.9(2.3)° |

Table 3. Results of Modulus of Elasticity and Modulus of Rupture

Values in parenthesis show standard deviation while different latter shows significant difference between group within the same columns at p $\alpha 0.05$

3.3 Microstructural analysis of board

Particleboards microstructure were study. SEM revealed presence of whitish granules scattered on the surface of the manufactured boards with glutardialdehyde modified with cassava starch, granules were shown mixed with wood chips resulting to higher bonded network formation over the particleboards. The cross linking between the wood chips and granules covered void areas, these improved the mechanical properties, reduced water uptake as recorded in some boards, and showed dimensional stability of particle boards. Some of the boards equally exhibited weak bonding due to surface roughness of wood particles. The micrograph of the modified cassava starch bonded with wood particle board is shown in fig 3. Furthermore, FTIR spectra analysis is presented in fig 4. These shows the water intake of bonds at it peak [1][25]). Spectra analysis proven successful modification of cassava starch. The formation of carboxyl starch and dialdehyde starch is as the result of crosslinking of glutardialdehyde. Chromophores of carboxyl starch aligned with aldehyde modified starch as link between wood fiber and MCS. From the study, the aldehyde and esters forms were at peak of carbonyl chromophores [26][27][19]. FTIR spectra analysis is shown in fig. 4 the absorption peaks.



Fig.3. Micrograph of particle board, MCS spotted with blue arrow



Fig. 4. FTIR of particles board

4. Conclusion

Improved, sustainable and eco-system friendly material is the focus, the study evaluated the modification of cassava starch granule with glutardialdehyde to minimized the hygroscopic nature of cassava starch to improved it bonding properties for the production of particle board. The study showed improved material properties exhibited in various particles sizes and aligned with some standards ASTMs for particleboards. Though there are variation in dimensional stability as result of water intake recorded with some of the particleboards with respect to particle sizes and matrix dosages. Variation across all the boards tested shows a significant difference with matrix (MCS). In conclusion, the utilization of MCS and wood particles in particleboard production could harness the waste generated during the production of cassava and wood processing, for valued added products and its utilization in construction, furniture manufacturing and wall paneling.

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Physio-mechanical properties of cement bonded particle board (CBPB) manufactured from three (3) wood species in Cross River State, Nigeria

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Abstract: The study was designed to evaluate the physical and mechanical properties of the Cement Bonded Particle Board (CBPB) produced from the residues of three indigenous trees species in Cross River State, Nigeria with sole aim that, the wood waste generated in sawmills can be as an alternative material in particleboard industry. The species were, Achi-gum (Brachystegia eurocoma); Rubber (Hevea-brasiliensis) and white afara (Terminalia superba). Production of the board was carried out systematically. A mixture of 1:1:1 (500g of wood-flour, 500g of cement and 2 litres of water) was used. Boiling, Blending, Chemicalization respectively; Moulds and mat were formed. Pressing was carried out at 50k/N. Finally, CBPB was produced. The physical properties of the boards: for Moisture content: Braschystegia eurocoma= 34.7%, Hevea brasiliensis=34.6% and Terminalia superba=28.6%, Density: Braschystegia eurocoma =0.948g/cm², Hevea brasiliensis=0.886g/cm² and Terminalia superba 0.854g/cm². Water absorption: Braschystegia eurocoma=58.9%, Hevea brasiliensis 57.9% and Terminalia superba-=0.8%. For the mechanical properties: Compressive strength for Brachystegia eurocoma=19.73N/mm², Hevea brasiliensis=19.84N/mm² and Terminalia superba=22.6 N/mm². Modulus of rupture: 1.73, 2.83 and 1.66 N/mm² respectively. The particle boards manufactured was dimensionally stable with low absorption and swelling rate. The strength properties were low and not comparable to other boards as read in literature. This result shows that residues of the endemic tree species could be used for particle board production and also waste in the wood based industries could be turned to wealth creation. Further research should be carried out for panel production with rubber residues that can be more structurally stable.

Keywords: Wood properties, brachestegia eurocoma, hevea brasiliensis, terminelia catarpa, wood waste.

1. Introduction

Production of particleboard was forecasted to be on the increase in 1917 [1]. [2] points out "that particleboard still be an excellent engineered wood-based product and the utilisation of wood waste for particleboard production gives more advantage due to its carbon emissions". According to [3], Wood as a raw material contributes significantly in improving a nation's economic base, industrialisation and comfort of its teeming population". [3] in 1993 made it known that, the consumption of sawn wood and wood-based panel products in Nigeria was put at 2.866 and 0.121 million m³ respectively and was projected to increase to 4.704 and 0.688 million m³ by the year 2010.' [4] opined that, "high demands for wood and wood-based products has resulted in over exploitation and the unregulated harvesting of trees in both the natural and plantation forest, thus leading to recent interest in lesser known timber species. [5] reported that, despite these efforts, demand for wood products still exceeds timber supply resulting in continued cutting without replacement. [6] observed that, "only about 50-55% of the original wood harvested becomes marketable after processing in sawmills and plywood mills in Nigeria". Similarly, [7] said that, "a critical study of sawmills should be scattered across the country shows large volume of sawdust and wood flakes waste burnt on a daily basis, thus constituting a major environmental problem" [7]. "The acceptance of CBPB is based on its reliability and resistance to fire, insect attack, decay and their perceived performance during natural disasters such as earthquakes and tropical storms" [8].

However, its use for exterior purposes is rather limited due to lack of proper information on its behaviour against exposure to moisture and sunlight. The increase demand of raw material in wood-based panel industry, led to researches in the utilization potential of substitute lignocelluloses [7].
"In addition, the biodegradation of lignocelluloses waste in landfills, emits methane, a green-house gas which has 72 times heating effect relating to that of carbon dioxide (CO²)" [9]. "The release of these gases into the atmosphere changes the climate, thereby resulting in global warming, thus, there is the need to find out uses for both waste hardwood and soft board residues generated in the world, especially in developing countries. Apart from the fact that the use of these waste will serve as an environmental management system, it will also contribute positively to the economic growth of countries". Wood-cement board is fast becoming an attractive building material in comparison with synthetic resin-bounded boards. This is as a result of its resistance to moisture up-take, decay, noise insulation and high fine resistance. Also, the energy problem which the synthetic resin industries are facing has led to shortage and increase in the price of synthetic resin [1]. Consequently, alternative binders (adhesives) such as mineral cements that are not petroleum based are being considered for particle-boards production. Therefore, study to determines the technical properties of CBPB made from selected tropical species with a view to identifying critical factors affecting performance of strength CBPB of Achi-gum (Brachestegia eurocoma), Rubber tree (Hevea brasiliensis) and White afara (Terminelia catarpa) wood species in Cross River State becomes very imperatives. The result of this study will greatly contribute to the technological development of Cross River State, Nigeria by introducing a new product in Cross River Market as such this study will be of great help to Engineers, Architects, builders and hence integrating in building construction designs in favour of cost-savings, structural and environmental aspect and economical ideas. The low and cost saving industry will help promote livelihood of the people. Entrepreneurial development will be encouraging by introducing the particle board industries with the use of rubber residue found in Cross River State, Nigeria.

2. Method

2.1 The study location

This Research was carried out in the Faculty of Engineering, University of Cross River State, Calabar, Nigeria; Workshop 3 (served as production room) and Workshop 4 (served as testing room and exhibition hall). See Fig 1a. below showing the map of the study location. University of Cross River is a tertiary institution owned by the Cross River State Government, which was established in August, 2002. It was formerly a polytechnic, its "the outcome of the merger of 3 (three) tertiary institutions: The Polytechnic Calabar, Calabar, The College of Education, Awi, Akampka, and The Ibrahim Babangida College of Agriculture, Ovonum, Obubra". Presently University of Cross River State's Capital, Obubra Local Government, Ogoja Local Government and also in Okuku in Yala Local Government.



Fig. 1.a Map showing the study locations in the university

2.2 Material collection and pre-treatment

Fig. 1b. below showing the map of areas of material collected. This includes wood shavings and saw dust of the three (3) wood species;

- Achi-Gum (Brachystegia eurocoma). The residues of this species was collected from Akim Timber Market at No.78 Marian Road, Calabar in Cross River State.
- Rubber (Hevea brasiliensis). The rubber residues were collected from Calabar Wood Company Highway Calabar (EPZ), beside Calabar free trade zone in Cross River State.
- White Afara (Terminalia supaba). The residues of the species were collected from Ikot Uduak Saw Mill (MCC Road, Calabar). 50kg of the materials were collected, weight and conveyed to workshop No.3 University of Cross River, Calabar being the area where treatment started.



Fig. 1.b. Map of Calabar showing areas of material collection

- 2.3 Material preparation: The systematic flow chat for CBPB production is shown in table1 below.
 - Drying: Fig. 2 below showing drying of materials and fig 3-5 showing the displayed of wood shaving; Achi-gum, white afara and Rubber also, fig 6-8 showing drying of sawdust of Achi-gum, white afara and Rubber. The entire 50kg of each bag were placed on boards measuring (2400 x 1200) mm. The saw dust board was separated from wood shavings board formed, ceiling fans and electric bulbs of 100 watts were installed in the hall to help circulate air and heat from the bulbs. The shavings and saw dust in the control room remained there for 18-21 days. Within the period, a control open air drying was also carried out.
 - Screening: After 21 days, the residues were screened by using metal detector. This was to remove particles of metals and silicon that were in the residues. The screening was carried out for 3 times on different days. During screening, apertures sieve of 3.6 and 2.6 were used. The aperture of 3.6 filters out and particle below 3.6 aperture remained up.
 - Weighing: The process of weighing starts immediately after screening. Weighing using electronic weighing balance. Five hundred grams each of the species were weighed and put in cellophane bags and stored
 - Soaking of particle: The residues particles of shavings were soaked in boiled water for 48hrs. This helped to remove inhibitory substances like lignin, cellulose in the shavings. The inhibitory substances would have blocked the adhesive (cement) in

penetrating the cells of the shavings soaking. It helped to prevent internal heat of hydration [10].

- Blending: Blending was also done to help reduce the shavings particles to smaller particles. Soaking in boiled water helped to reduce/remove extractives in wood that may also block the penetration of the cement.
- Bleaching: However, after a thorough bleaching for 3 days, it was sure that the inhibitory particles were removed. This was observed in the materials colour. The colour in the bucket became faint.
- Additive application: In the mixture (i.e Cement, wood particles and water) the additive was added by using 2% of pentachlorophenol (PCP) to remove biodeteriorating agents. Aluminium sulphate (2%) was added to the mixture to accelerate cement curling [11]; [12].
- Mixing proportion: The cement used was Dangote Cement for the production of the board. The quantities used were as follows: Cement 500g, Wood 500g and Water 2 litres at the ratio 1:1:1 factorial i.e (cement/wood particle and water).
- Formation of paste: The mixing of cement, wood and water was on the ratio 1:1:1. The paste was properly mixed through laboratory blender. After mixing it well the paste was then introduced gradually into the wooden mould (figure 9 below).
- Mould construction: Fig 9 below is showing mould formed. A wooden mould was formed to serve as a template for the production of the cement bonded particle board. The dimensions of the mould were (200 x 250) mm with a depth of 18mm. A cover plate was also produced to cover the top of the mould after pouring. The top of the mould was little thicker (20mm) than the bottom plate because the top plate bears load from the press.
- Mat forming: The mix of cement, wood particles and water were poured into the mould gradually, the mix were constantly compacted to have a good mass in the mould once the mould is filled with the mix, the mould was covered with cellophane, oil was applied both side of the mould. The top is then covered, allowed to rest for 30 minutes for press-testing of board.
- Pressing of board: When the mixture has set for 30 minutes, the mould and content were taken to the cold press. This is the process of Harding up. After which a pressure of 50KN was applied on the mould to enable water leave the mix completely. This is the period of curling and it remains there for 48 hours.
- Conditioning of board: The pressed boards were kept in the open hall. Inside the hall, two bulbs of 100 watt and ceiling fans were installed. The fans to ventilate the hall and the two bulbs to produce heat for drying. The pressed board was kept under this condition for 48 hrs.
- Demoulding: The mould was demoulded by removing the top layer very carefully not to allow cracks. The sides of the mould were carefully removed; the board then was taken out or separated from the mould. The panel (wood cement board) was dried for seven days. The weight of the specimen was recorded on daily basis to enable. M.C. determination of the board and the process involves in the production is showing in the table1 below:





2.4 Material testing: The Universal Testing machine was used to test mechanical strength of specimen by exerting tensile stresses, compressive, hardness, modulus of rupture and elasticity. The SCHMIDT REBOUND HAMMER TEST MACHINE (ASTMC 805-79 and BS 1881 part 20) was used for testing the hardness of the material. Other instruments include;

- Speed meter: for moisture content
- Oven: with temperature 105 degrees for MC
- Highly Sensitive Electronic Equipment for absorption and swelling
- Basin of water for absorption and swelling
- The Highly Sensitive Electronic Equipment was used along with a basin of water for absorption test.
- Calliper for measuring the thickness

| • / | Table 2. | Showing | various | sizes | of test | samples |
|-----|----------|---------|---------|-------|---------|---------|
|-----|----------|---------|---------|-------|---------|---------|

| S/N | TEST SAMPLES | NO OF SAMPLES | SIZE OF TEST SAMPLES (MM) |
|-----|----------------------------|---------------|------------------------------|
| 1 | Density | 15 | 75 x 75 |
| 2 | Moisture Content | 15 | 75 x 75 |
| 3 | Water Absorption | 15 | 75 x 75 |
| 4 | Thickness Swelling | 15 | 75 x 75 |
| 5 | Resistance/Impact strength | 15 | 75 x 75 |
| 6 | Compressive Strength | 15 | 75 x 75 |

The experiment design adopted were 1x1x1 factorial with completely randomized design experiment.

2.4 Determination of properties of manufactured board

• Moisture Content:

The three samples; Achi-Gum, Rubber and White Afara were air dried for 24 days and on each day, readings taken and MC calculated according to ASTM 01037, using the formula shown:

$$\frac{w_1 - w_0}{w_0} \times 100\% \tag{1}$$

Where: $W_1 - initial weight$ $W_0 - Final weight$

2.5 Density determination

The density of the board samples was determined using the relationship below. The specimens were cut into uniform shapes of $(75 \times 75 \times 18)$ mm i.e. length, width and thickness. Five replicates were cut from each of the samples for the purpose of determining the density of boards. The equation used for the determination was:

Density = The density were calculated as follows:

 $P = \frac{w_o}{v_o}$

Where:

 $P = Density (kg/m^3)$

Wo = Oven -dry weight (kg)

 $V_0 = Volume (m^3)$

• Water absorption test determination

The water absorption test was carried out by the use of sensitive electronic scale, five replicates from each of the board samples were used. The dimensions were (75 x 75x 18) mm the specimen was immersed horizontally in water, according to (ASTMAD- 190). The absorption after every one-hour weight using equation below;

Water Absorption =
$$\frac{w_o - w_1}{w_1} \times 100\%$$

Where:

1. W_1 – initial weight of specimen

2. W_0 – final weight of specimen.

• Thickness swelling test determination

For the thickness swelling of the three species, each of the samples of the species were cut to $(75 \times 75 \times 18)$ mm. Five replicates were cut from each of the board sample. Dipping of samples for thickness swelling and water absorption is showing in plate 1 below.

• Compressive strength test determination

The compressive strength test was carried out in accordance with the specifications of ASTM, D-1037(1978), EN-310 (1993) and EN 319 (1993); the specimen was cut into cubical sizes of 75x75x18mm before being placed on 'Perrier Maurice' compression machine with 2000 KN capacity''. The samples were place on the machine platen and loaded at bar per second until crushed, Plate 2. The readings of the thickness were carried out with the use of callipers and calculated according to the formula below:

Thickness Swelling = $\frac{T2 - T1}{T1} \ge 100$ Where T₁ = Initial thickness i.e., $\frac{T2 - T1}{T1}$

 $T_2 = Final thickness$

(2)



187

Plate 1: Dipping During Thickness Swelling and Absorption Test.



Plate 2: The Board Samples after Compression Test

• Hardness Impact Test.

The test specimens of 75 x 75 x 18mm were used for the rebound hammer of lower impact energy (2.2Nm). Averages of ten readings were in all 30 replicates were produced. The rebound number average was taken for ten times

3. Result and discussion

3.1 Result for Moisture Content of Boards produced

Table 3. Moisture contents of material samples of saw dust and wood shavings

| S/N | SAMPLES | INITIAL MC of sawdust and shaving (%) | FINAL MC of sawdust and shaving (%) |
|-----|-----------------------------|---------------------------------------|---|
| 1 | Achi Gum Sawdust | 24 | 13 |
| 2 | Rubber Sawdust | 23 | 13 |
| 3 | White afara Sawdust | 17 | 13 |
| 4 | Achi Gum Shavings Samples | 35 | 20 |
| 5 | Rubber Shaving samples | 29 | 20 |
| 6 | White afara Shaving samples | 14 | 10 |

3.2 Result of Density

The average density of the board determined for the three species; Achi-gum (*Braschystergia eurocoma*) was 0.95g/m³; Rubber (*Hevea braciliensis*) was 0.88g/m³ and white afara 0.85g/m³ (Figure 2 below) shows the average density of the three species.



Fig. 2. The average density of particle boards produce

3.3 Water Absorption Result

Figure 3. shows absorption test carried out on the particle boards produced from Achi-gum, Rubber and White afara. The weight of wood samples before immersion in water was 95.8g, 88.2g, and 85.6g respectively. There was a very sharp increase in weight gain after one hour, there-after, the increase was gradual and reaches 3.5g, 0.6g and 1.9g, respectively Comparatively, all three particle board samples displayed similar absorption characteristic with Achi-gum having higher values than rubber and white afara (Figure 11).

Table 4. Absorption test result

| Species | Weight of sample (g) | | | | | | | |
|-------------|----------------------|-------|---------|---------|-------|-------|--|--|
| | | 1 | 2 hours | 3 hours | 4 | | | |
| | Initial | Hour | | | Hours | 5 | | |
| | | | | | | Hours | | |
| Achi gum | 95.8 | 148.8 | 152.3 | 154.9 | 155.5 | 156.8 | | |
| Rubber | 88.2 | 138.7 | 139.3 | 140.3 | 140.7 | 140.5 | | |
| White afara | 85.6 | 135.7 | 137.6 | 138.8 | 140.4 | 141.1 | | |



Fig. 3. Comparative Absorption test for Particle Boards of three species

3.4 Thickness Swelling

Table 5 below shows increase in thickness of the particle boards of Achi-Gum, Rubber and White afara respectively. A comparative graph is presented in Figure 4. It was observed that within the period of one hour, the thickness of Achi-gum and Rubber increased by 3mm while White afara increased by 2mm. The thickness remained relatively constant for the next three hours before Achi-gum increased to (21.5mm), Rubber (22.5mm) and White afara (21mm) from the initial 18mm thickness. This is relatively similar in range to values as observed by [14] who noted possibilities in thickness and swelling in some wood species

| Species | Thickness of sample (mm) | | | | | | | | | |
|-------------|--------------------------|------|---------|-------|-------|-------|--|--|--|--|
| | | 1 | 2 hours | 3 | 4 | | | | | |
| | Initial | Hour | | Hours | Hours | 5 | | | | |
| | | | | | | Hours | | | | |
| Achi gum | 18 | 21 | 21 | 21 | 21 | 21.5 | | | | |
| Rubber | 18 | 21 | 21 | 21 | 21 | 22.5 | | | | |
| White afara | 18 | 20 | 21 | 21 | 21 | 21 | | | | |

Table 5. Thickness swelling test

3.5 Mechanical Properties of Manufactured Boards

• Compressive Strength

Figure 4 presents compressive strength data for particle boards produced from Achi-gum, Rubber and White afara. The average compressive strength for Achi-gum, Rubber and White Afara was 19.73N/mm², 19.84N/mm² and 22.60N/mm² respectively. The optimum compressive strength of the particle boards produced from three wood species of Achi-gum, Rubber and White afara are 20.44N/mm², 20.62N/mm² and 22.75N/mm² respectively. This range of values is higher comparatively showed differently at wood materials that exert load.



Fig. 4. Showing different compressive strength of the three species samples



Fig. 5. Minimum and maximum compressive strength result of the three Species

| Table 6. | Readings | of rebound | numbers |
|----------|----------|------------|---------|
|----------|----------|------------|---------|

| Position | Type of specimen | | Rebound number | | | | | | | Average rebound no. | Compressive strength (mpa) | | |
|----------|---------------------|----|----------------|----|----|----|----|----|----|---------------------------|----------------------------------|------|----|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | | |
| | Ac | 10 | 10 | 10 | 10 | 10 | 12 | 12 | 10 | 10 | 12 | 10.6 | 10 |
| 90° | Rubber | 13 | 12 | 15 | 13 | 15 | 12 | 12 | 13 | 12 | 14 | 13.2 | 13 |
| | Wa | 16 | 12 | 12 | 15 | 15 | 13 | 13 | 12 | 12 | 12 | 13.1 | 13 |
| | Combined | 13 | 11 | 12 | 12 | 13 | 12 | 12 | 11 | 11 | 13 | 11.8 | 11 |

• Resistance to Hardness

Table 6 above, shows the average rebound number of the three wood species used for the particle board production which indicates the resistance to hardness. The rebound number of Achi-gum, Rubber and White afara were 10.6, 13.2 and 13.1 respectively; therefore, from observation, the range

of value are lower compared to that of [14] in thinner stranded board production. The rebound number for combined species is 11.8 and higher than rebound number for Achi-Gum.

From the result obtained in the physical and mechanical properties of the board shows that, the physical properties of the board were smooth due to the methodology used. The blending and removal of lignin from the shaving, made the fine product physically smooth and decoration on the body of the board was not found. The binder used cement did not add color to the board.

The determination of the moisture content of the saw dust and shaving have to bring stability of board. The moisture content of the material used to produce the board was equalized. Other physical properties deduced from the result that affected the board was moisture content determination which help the board moisture in the board to stabilized on Achi-gum 9%, Rubber 10% and White afara 10% respectively. This help in uniformed test of the properties.

• Density

From the result in figure 10. it shows that, Achi-Gum had the highest density of 0.948g/m³which shows that Achi-gum had a greater mass than Rubber 0.89 and white afara 0.82g/m³. it clearly shows that penetration of the binder agent and additive was higher than others. Curling took place and remained to increase the weight of board. In all of this, the nature of the board remains the same. The material species of Achi-gum is denser than others.

• Absorption

Generally, the result shows that absorption rate was higher in the initial hour from all the three species as demonstrated in the figures. However, the absorption slow down and become almost horizontal for the remaining hours. Hence absorption showed a very rapid increased in the first hour in the three species. See the absorption comparative result in figure 11. The rate was very fast and the binder quickly absorbed the water and after a period, it became saturated and it took no more water into the cells. The result is similar in range to other values in the literature.

• Thickness swelling

Thickness swelling was much minimized. The swelling shows that Achi-gum was 3mm, while Rubber shows 2mm. thickness also shows value ranging from 21.5mm, Rubber 22.5 and White afara 21mm from original thickness of 18mm. these values were similar in range to those observed by [14].

• Compressive strength

From the result, the capacity of the board to withstand load in the three species read as follow: Achigum was 20.25N/mm, Rubber was 19.73N/mm² and white afara was 22.70N/mm while the optimum compressive strength was Achi-gum 20.44N/mm² Rubber 20.62N/mm² and White afara 22.75N/mm². The value was higher than found in. Hence white afara curry more load than others.

• Resistance to Hardness

The ability to withstand load and the necessary force to cause damages to the board was found to be Rubber having 13.2 rebounds compared to Achi-gum with 10.6 rebounds and 13.1 rebound for white afara. Wet cement as binder has a very low values compared to [15] on the whole. Wood cement board with cement as a binder, is a very weak material and cannot be used for combination

• Summary

Manufacturing cement particle board from three species of Achi-gum (*Brachystegia eurocma*), Rubber (*Hevea brasiliencis*) and white afara (*Terminalia superba*), the physical properties of the three boards were determined and tend to be comparable with other board in the literatures. Some of the physical properties were tend to be higher than others found in the literature; physically, the boards were smooth in texture, but the board of Achi-gum and that of Rubber looked almost similar in colour and in texture but that of White afara glitters. More-so, the mechanical properties like impact tests prove that wood cement board cannot withstand impact strength using the rebound test, it was observed that wood cement board in a none structural materials having rebound less than 20 in number. Even the compressive strength is weaker than the compressive strength of the board using urea/phenol formaldehyde. The uses of cement in manufacturing of board is not encouraging, the binding strength of cement with other material is weak. However, this cannot be concluded completely because the ratio of wood cement mixture could have affected the bonding, they could be verified using different mixing ratio between cement and wood. The boards will be mechanically better with the procedure of 50kN used for initial pressing will be increased. The time was change from 48 hours to 72 hours, were formed with better board while manual mixing method used should be change to mechanical approach as deduced.

4. Conclusion

Particle boards using the residue of different wood species, Achi-Gum (*Brachystegia eurocoma*) Rubber (*Hevea brasiliensis*) and White afara (*Terminalia supapa*) were successfully produced using cement as binder. The physical properties (moisture content, density, thickness swelling and water absorption) of the manufactured boards were determined. The particle boards were dimensionally stable with low absorption and swelling rates. The mechanical properties of the boards (compression strength and resistance to hardness) were also measured with the data obtained comparable with those in literature. Particle boards from this result can be used for wood floors, ceiling boards, wall insulation amongst others. The study shows that wood cement board could be manufactured from waste of rubber trees found in a Cross River State Forest plantations rather than felling and producing billet for export. It is proven that Rubber tree species can also combine favourably with other species of wood to produce particle boards

Also the use of Dangote cement has proven a suitable binder for the production of CBPB and comparable to other readily used cement types and it is particularly recommended that; The residues used in the production process should be properly crushed before application, Testing apparatus and equipment should be within range to facilitate record taking and minimise errors, Boards for testing should be sealed with cellophane paper in order not to loss or gain moisture before testing for the mechanical properties, The university can undertake the production of such boards to ease flooring and wall partitioning. Thus, helping the department of wood products engineering generate income and showcase it abilities in technology, Materials from rubber whether sawdust, shavings, flake and others have never been used for the production of board or boards composite, but in this project, it has been proven that rubber trees can be used. Hence, waste found in a wood processing industry in C.R.S. be used for board production rather than burning them.

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Microstructural developments in plain and slag-blended cements

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Received 10 November 2023; Accepted 18 November 2023 Abstract: The microstructures of cement systems such as pastes, mortars and concrete control other physical properties such as strength, transport properties and durability. The microstructure of cement is made up of hydrated and anhydrous phases, including pores containing pore water. This study investigated changes in the microstructures of plain and slag-blended cement pastes from 7 to 28 days. These were achieved using scanning electron microscopes (SEM) - backscattered electron (BSE) images. Two slags (S1&S2) were blended with CEM I 52.5R at 30% and 70% replacement. These were compared with plain CEM I 42.5R for microstructural developments. X-ray diffraction (XRD) was used to follow patterns of hydration products. The results for plain cement pastes show more coarser microstructure at 7 days than 28 days, indicating refinement as hydration progressed. In the slag blends, unhydrated Portland cement clinker grains were scarcely present after 28 days of hydration. Less presence of calcium hydroxide and more outer product calcium silicate hydrate were observed in the slag blends. Hydration of plain cement at 20°C increased between 7 and 28 days, from 74% to 79%, while the weighted hydration of the slag-blends at 20°C increased from 50% for 70% slag-blend, to 85% for 30% slag blend.

Keywords: Cement, hydration, microstructure, slag

1. Introduction

The microstructure of cement paste comprises: hydrated phases, anhydrous phases and pores with pore water. The hydrated phases are dominated by calcium silicate hydrate (C-S-H) gel and calcium hydroxide (CH), both products of tricalsium silicate (C₃S) and dicalsium silicate (C₂S) hydration, which are the most abundant phases, constituting about, 75-90% in normal cements. These phases are also known to be the main strength controlling phases at early and later ages respectively [1, 2]. In ground granulated blast-furnace slag (slag)-blended cements, these phases still occur but with the C-S-H modified to C-A-S-H and more reduced quantity of CH because of its consumption during slag's pozzolanic reaction [3, 4].

2. Method

Two slags (S1 and S2) of similar physical properties but different chemical properties were used to replace CEM I 52.5R at either 30 wt.% or 70 wt.% replacement. The particle size distribution of the slags and Portland cements (PC) as determined by laser diffraction, using a Malvern Mastersizer 2000, is shown in Fig. 1. The binder configurations and mix ratios are shown in Table 1, while the chemical oxide compositions of the cementitious materials used are provided in Table 2.



Fig. 1. Particle size distribution of slags (S1 & S2) and CEM I (C1 & C2)

| Table 1. | Binder | configur | ation | and | mix | ratios |
|----------|--------|----------|-------|-----|-----|--------|
| | | <u> </u> | | | | |

| No. | Binder | CEM I | CEM I | | GGBS | | Effective |
|-----|--------|--------|-------|--------|--------|-----------|-----------|
| | | 42.5 R | 52.5R | Slag 1 | Slag 2 | w/b ratio | w/b |
| | | | | | | | ratio |
| 1. | C1 | 1 | 0 | 0 | 0 | 0.500 | 0.493 |
| 2. | C2 | 0 | 1 | 0 | 0 | 0.500 | 0.493 |
| 3. | 30S1 | 0 | 0.7 | 0.3 | 0 | 0.500 | 0.493 |
| 4. | 30S2 | 0 | 0.7 | 0 | 0.3 | 0.500 | 0.493 |
| 5. | 70S1 | 0 | 0.3 | 0.7 | 0 | 0.500 | 0.493 |
| 6. | 70S2 | 0 | 0.3 | 0 | 0.7 | 0.500 | 0.493 |

| Table 2. Chemical compositions | (wt.% |) of cementitious | materials |
|--------------------------------|-------|-------------------|-----------|
|--------------------------------|-------|-------------------|-----------|

| Component | CEM I 42.5R | CEM I | Slag 1 | Slag 2 |
|--------------------------------|-------------|-------|---------|----------|
| _ | | 52.5R | (S1) | (S2) |
| SiO ₂ | 20.17 | 20.50 | 36.58 | 40.14 |
| Al ₂ O ₃ | 5.33 | 5.43 | 12.23 | 7.77 |
| TiO ₂ | 0.29 | 0.29 | 0.83 | 0.30 |
| MnO | 0.05 | 0.05 | 0.64 | 0.64 |
| Fe ₂ O ₃ | 2.65 | 2.51 | 0.48 | 0.78 |
| CaO | 63.01 | 63.43 | 38.24 | 37.90 |
| MgO | 1.45 | 1.51 | 8.55 | 9.51 |
| K ₂ O | 0.76 | 0.79 | 0.65 | 0.55 |
| Na ₂ O | 0.14 | 0.17 | 0.27 | 0.36 |
| SO ₃ | 3.33 | 3.43 | 1.00 | 1.47 |
| P_2O_5 | 0.12 | 0.14 | 0.06 | 0.02 |
| LOI 950°C | 2.12 | 1.37 | (+1.66) | (+0.40)* |
| Total at 950°C | 99.42 | 99.62 | 99.88 | 99.43 |
| Glass content | na | na | 99.3 | 97.1 |

* The sample was oxidized with HNO₃ before the determination of LOI

2.1 Degree of hydration by SEM/EDX image analysis (IA)

The degrees of clinker and slag hydration were investigated using scanning electron microscopy/ energy dispersive x-ray spectroscopy (SEM/EDX), image analysis of backscattered electron (BSE) images in conjunction with EDX magnesium maps. These were acquired using Zeiss EVO MA 15 SEM equipped with Oxford Instruments X-max SDD EDX detector. 30 BSE images and corresponding EDX maps were obtained per sample, at 800x magnification and working distances between 8 and 9mm, using an accelerating voltage of 20KeV. Image analysis was carried out using ImageJ software in line with previous studies [5, 6].

2.2 X-ray diffraction (XRD)

Crystalline hydration products were followed using a Bruker D2 phaser diffractometer with a Cu Ka source, operating at 30 KV and 10 mA. Scanning was performed on back-loaded, powdered samples

from 5° to 70°: 20, at 0.034° increment with a scan time of 2 s and sample rotation of 15/min. Phases were identified using BRUKER XRD DIFFRAC.SUITE V3.0 software.

3. Results and Discussion

Typical SEM-BSE images (Fig. 2 to Fig. 5), showing microstructural developments in the investigated pastes, from 7 to 28 days, reflecting early and later stages of hydration. At 7 days, the microstructure of the reference PC cured at 20°C (Fig. 2a), appear coarser with more pores than 28 days, reflecting the refining of microstructure as hydration advanced with time. Most of the fine-grained PC clinker had hydrated, leaving anhydrous grains of sizes ranging approximately 20 to $50\mu m$.

The microstructures appeared a lot more refined for the slag blends, consistent with the literature [7, 8]. More presence of Op C-S-H and less of CH was observed at 28 days. Unhydrated PC clinker grains were scarcely present in the slag blends, even with the low 30 wt.% replacement, indicating the acceleration of PC hydration by the presence of slag in the paste. There were clear pore refinements as hydration progressed from 7 to 28 days.

At 38°C (Fig. 3), hydration was clearly accelerated for all the systems. However, micro cracks were observed at 28 days for the reference PC, which may be related to the disadvantage of curing PC systems at elevated temperatures. Many researchers have reported on the detrimental effects of elevated temperature curing [9-13]. These effects were less present in the microstructures of the slagblended pastes, consistent with earlier findings concerning the robustness of slags to the detrimental effects of elevated temperatures.



Fig. 2. SEM-BSE images of paste samples cured at 20°C: (a) C1-7day, (b) C1-28day, (c) 30S1-7day, (d) 30S1-28day, (e) 30S2-7day, (f) 30S2-28day



Fig. 3. SEM-BSE images of paste samples cured at 38°C: (a) C1-7day, (b) C1-28day, (c) 30S1-7day, (d) 30S1-28day, (e) 30S2-7day, (f) 30S2-28day

The microstructural developments of 70 wt.% slag blends at 20 and 38°C curing temperatures are shown in Fig. 4 and Fig. 5 respectively. The changes in the microstructures between 7 and 28 days were similar to 30 wt.% slag blends discussed earlier, although more unreacted slag grains were seen. This is due to the high volume of slag in the paste compared with PC, and the consequent decrease in the weighted degree of hydration of the blend. Although the degree of slag hydration decreased only slightly (2-6%), the effect of increased slag content was more significant (>10%), considering the weighted degree of hydration of the blended paste as a whole. The large volume of unreacted slag grains explains the lower compressive strength observed at 28 days, for the 70 wt.% slag blends. The presence of limited quantity of CH was also observed. Increasing slag load to 70% had a significant positive effect on capillary porosity (Fig. 6).



Fig. 4. SEM-BSE images of paste samples cured at 20°C: (a) 70S1-7day, (b) 70S1-28day, (c) 70S2-7day, (d) 70S2-28day



Fig. 5. SEM-BSE images of paste samples cured at 38°C: (a) 70S1-7day, (b) 70S1-28day, (c) 70S2-7day, (d) 70S2-28day



Fig. 6. Capillary porosity from SEM-BSE images of pastes exposed at 20°C

3.1 Degrees of slag and clinker hydration by SEM-EDX

The weighted degrees of hydration of the slag blends obtained at 7 and 28 days, from image analysis of coupled SEM-BSE images with SEM-EDX magnesium maps are presented in Table 3. This shows the combined effects of slag composition, slag loading, and exposure temperature. At 7 days, a higher temperature led to significant acceleration of slag hydration, with up to a 50% increase for 30% slag blends, and about a 30% increase for the 70% slag blends. This increased hydration however dropped to between 2 and 7% at 28 days, showing that the acceleration of slag hydration during early ages become diminished at later ages. This follows the hydration of neat PC shown by the precipitation of CH where at 38°, XRD analyses (Fig. 8) showed rapid increase in CH to approximately maximum levels up to 7 days, while only increasing gradually to maximum at 28 days, for samples cured at 20°C. This behaviour can be related to slag hydration which is activated by the presence of CH in a slag-PC blend. The more basic slag 1 showed higher rate of hydration, exceeding the mean value (Fig. 7) by 7 days for samples cured at 38°C. This agrees with Ogirigbo [6] who investigated the hydration of similar slags using 30 wt.% replacement in CEM I. Increasing slag content to 70% had a slight retardation effect on the degree of slag hydration. This may be due to decreased availability of CH (Fig. 8), which is a precursor for slag pozzolanic reaction. The consumption of portlandite is known to be associated with pozzolanic reaction [14-20].

| | | Wt.% | Degree | of hydrati | on (%) at 20 |)°C | C Degree of hydration (%) at 38°C | | | | |
|--------------|------|------------|--------|------------|--------------|--------------|-----------------------------------|---------|----------|--------------|--|
| Age (day) | Mix | of slag | Slag | Clinker | Weighted | Std Error | Slag | Clinker | Weighted | Std Error | |
| | C1 | 0 | 0.00 | 74.91 | 74.91 | 0.74 | 0.00 | 75.76 | 75.76 | 1.02 | |
| | 30S1 | 30 | 38.73 | 91.33 | 75.55 | 0.80 | 58.60 | 91.67 | 81.75 | 0.50 | |
| 7 | 30S2 | 30 | 31.32 | 90.83 | 72.98 | 0.99 | 47.60 | 89.87 | 77.19 | 0.79 | |
| | 70S1 | 70 | 37.78 | 96.88 | 55.51 | 0.72 | 50.35 | 98.56 | 64.81 | 0.82 | |
| | 70S2 | 70 | 30.86 | 96.99 | 50.70 | 0.79 | 37.70 | 95.43 | 55.02 | 0.77 | |
| | C1 | 0 | 0.00 | 79.28 | 79.28 | 0.70 | 0.00 | 80.31 | 80.31 | 0.65 | |
| | 30S1 | 30 | 63.22 | 94.53 | 85.14 | 0.60 | 67.57 | 96.02 | 87.49 | 0.52 | |
| 28 | 30S2 | 30 | 52.09 | 94.26 | 81.61 | 0.76 | 53.47 | 95.93 | 83.19 | 0.49 | |
| | 70S1 | 70 | 62.11 | 98.47 | 73.02 | 0.77 | 63.32 | 99.84 | 74.28 | 0.60 | |
| | 70S2 | 70 | 49.35 | 98.43 | 64.07 | 0.56 | 51.67 | 98.64 | 65.76 | 0.74 | |

Table 3. Weighted degrees of hydration



Fig. 7. Degree of hydration of slag cements: (a) at 7 days. (b) at 28 days



Fig. 8. XRD patterns showing of hydration of CEM I and slag cements from 1 to 180 days

4. Conclusion

This study has shown that the more basic, alumina-rich slag 1 blend showed overall, more compact microstructure than slag 2 blend. This behaviour was more consistent at early age than later age and reflects the reactivities of the 2 slags. Slag 1 had higher degree of hydration and reacted more quickly at early age, leading to a considerably different microstructure. However, at later age when hydration had slowed down considerably, the performance of the 2 slag systems seems to be on a par. The 2 slag systems showed significantly more compact microstructures than that of the reference Portland cement.

Effect of temperature

Samples were investigated at 20 and 38°C simultaneously, to understand the influence of elevated temperature on the hydration and microstructural properties of pastes. Elevated temperature led to accelerated hydration. This was particularly detrimental to the reference PC. Elevated temperature was however, more beneficial for the slag blends as slag hydration was accelerated over longer periods than PC. The effect of temperature was more pronounced at early ages than later ages. The slag blends showed improved and more compact microstructures at elevated temperature, while the reference PC was more porous and more permeable. This difference in the porosity and consequently, permeability, due to increased temperature, was more pronounced at 7 days than 28 days. This study

has shown that, while much higher temperatures from 60°C may cause adverse effects on microstructure of slag blends as reported in literature, exposure to moderately high temperatures such as 38°C did not show any adverse effects on paste and mortar microstructures up to 28 days.

Effect of slag loading

Increasing slag load from 30 to 70 wt.%, caused a retardation in the rate of hydration of the slagblended pastes. However, this was beneficial with respect to the transport properties of the blended systems. All the tests indicated reduced porosity, indicating a significant decrease in penetrability by any attacking compound. This has great positive impact on the resistance of the paste and mortar or concrete systems to the ingress of destructive salt solution.

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Performance evaluation of laterite crushing machine for sustainable housing delivery in Nigeria

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Abstract: Laterite is a soil and rock type rich in iron and aluminium and is considered to have formed in hot and wet tropical areas. Almost all laterite is rusty-red in colour because of the presence of high iron-oxide content. This material is used in building blocks, road construction, waste water treatment and in some cases for agricultural purposes. The Nigerian Building and Road Research Institute (NBRRI) has been involved in series of research works on effective utilization of lateritic soil such as the development of an Interlocking Compressed Stabilized Earth Block (ICSEB), which is produced from laterite stabilized soil. In the production of interlocking block, there is need for the laterite to be crushed into the required particle size before mixing it with Ordinary Portland Cement (OPC) and water for onward production of the block. In view of the above and the need to eliminate manual sieving, increase production, reduce wastage and production cost reduction, thus a laterite crushing machine was designed and fabricated. The performance evaluation of the fabricated laterite crushing shows that, the machine has a crushing capacity of 22 tonnes per eight hours, grinding efficiency of 93%, and crushing velocity of 11.4m/s with particle size range of 0.6mm to 0.075mm which indicates an improved surface area.

Keywords: Laterite, crushing, efficiency, performance, size

1. Introduction

Beside food and clothing, housing has been one of the basic necessities of man which need to be met. However, in Nigeria provision of affordable housing has been a very big challenge [1,2]. According to [3], housing can be described as a physical structure meant for provision of shelter or accommodation to its occupants. Problem of inadequate housing faced by poor people around the world has been a matter of concern to governments in various countries especially in the developing world whereby significant portion of the population is mostly characterized by poverty. In Nigeria, Nigerian Building and Road Research Institute (NBRRI) was established to conduct integrated applied research and development into the various aspects of building and construction sector of the economy in order to address this challenge. In order to address the problem of affordable housing in Nigerian, some innovations were made into the building materials available within the country and modifying the technology involved in processing them. Some of the efforts made include production of roofing sheets using clay, development of Pozzolana cement as an alternative building materials, design and fabrication of manual brick making machine, interlocking block making machine which can be diesel powered or electrically powered, tile making machine and so on.

The use of laterite as compressed stabilised earth block (CSEB) is an improvement form of one of the oldest materials used in building construction. However, the quality of compressed stabilised earth blocks (CSEB) in some construction schemes is far from adequate and often materials are wasted in the production process. In order to enhance the quality of compressed stabilised earth building blocks used in low-cost housing within rural and urban areas, production techniques need to be further improved so as to achieve better quality and reduced production costs. In the production of interlocking block, there is need for the laterite to be crushed into the required particle size before mixing it with Ordinary Portland Cement (OPC) and water for onward production of the block.

A laterite crushing machine was designed and fabricated to eliminate manual sieving, increase in production, reduce wastage associated with manual sieving and reduction of material cost. The

laterite crushing machine will ensure efficient mix of laterite and OPC to produce bricks with regular surfaces and edges as well as elimination of additional surface coating. The Figures below show laterite before and after crushing.



Fig. 1a. Laterite before crushing

Fig. 1b. Laterite after crushing

In this research work, performance evaluation of laterite crushing machine was carried out to ascertain its efficiency. The laterite crushing machine is a single unit operation designed to reduce the size of lump laterite to smaller pieces (powder); this process involves cracking, abrasion, and size reduction of the laterite. The fabricated laterite grinding machine is diesel engine powered; parts are mechanically fabricated and assembled to allow for necessary relative motion, feeding process, discharge operation as well as ease of maintenance are all considered during manufacturing stage.

2. Method

2.1. Description of laterite crushing machine

The laterite crushing machine was designed and fabricated by the Engineering Materials Research Unit, North Central Zonal Office, Nigerian Building and Road Research Institute, Jos, Plateau State, Nigeria. This machine consists of the hopper, crushing chamber and the prime mover. Materials used for the fabrication of this machine include mild steel plates and rods of different dimensions, angle iron, bearings, bolts and nuts, belts and pulleys. All materials were sourced locally.

2.2. Hopper design

Laterite is fed into the crushing chamber through the hopper. The feeding of laterite into the hopper should be done gradually so as to prevent blockage or caking and ensures free flow of the laterite from the hopper through the grinding chamber to the discharge outlet. The laterite should be dried in order to remove excess moisture. The design of hopper is in the form of a truncated prism which the top dimension is 550 X 470mm while the base is 330 X 210mm and 3mm thick mild steel was used for the fabrication of this hopper. Shielded metal arc welding process was employed for the welding operation.

2.3. The Crushing chamber and prime mover

The crushing chamber of laterite crushing machine is the part of the machine where the actual crushing takes place, it comprises the main shaft, hammer shaft, the hammers and the mesh. The second section of laterite crushing machine is the 22hp prime mover which is diesel engine powered with operating speed of 2200rpm. The prime mover drives the main shaft on which the crushing mechanisms are mounted using belt and pulley system.

2.4. The crushing mechanisms

The crushing mechanisms which are sets of hammers systematically arranged and attached to a shaft so that as the shaft is made to rotate by the pulley connection, the hammers strike the laterite with the centrifugal force and breakdown the laterite into smaller size particles. A total of 40 hammers were arranged on small shafts of diameter 12mm and 400mm length, these small shafts were 4 in numbers, and they were connected to square plates which were also attached to the main shaft of

45mm in diameter and 700mm in length. This shaft is rotated by pulley system, each hammer is 5mm in thickness and the dimension is 150 x 40mm.

2.5. The mesh

The mesh is basically made of 5mm thick metal plate, drilled to the required pore size and rolled according to designed dimensions. The mesh allows the crushed laterite to pass through it to the discharge outlet and thus sieves the crushed laterite so that the particles which are greater than the mesh sizes are further crushed into the desired size before it can pass through to the discharge outlet. The mesh can be interchanged; hence mesh of different sizes can be fixed as desired and it is fixed beneath the crushing mechanisms. The crushing mechanisms and the mesh are the components in the crushing chamber of the fabricated laterite crushing machine; 5mm thick mild steel plate was used as the mesh in order for it to withstand the vibrations due to rotation of the shaft on which the hammers were mounted and the crushing force of the hammers. Below is the 3D view of the mesh and hammer shaft.



Fig. 2. Mesh and Hammer Shaft

2.6. Performance evaluation

The performance evaluation of laterite crushing machine was carried out at the laboratory of Nigerian Building and Road Research Institute, North Central Zonal Office, Jos, Plateau State, Nigeria. The laterite used for the performance evaluation was obtained from Du, Jos south Local Government Area, Plateau State, Nigeria. The following factors were considered for the performance evaluation of the fabricated laterite crushing machine; crushing efficiency, crushing capacity and particle size distribution.

2.7. Mass of laterite

Samples of laterite were collected from Du, Jos South Local Government Area, Plateau state, Nigeria. The sample for performance evaluation test were measured using weighing balance at Nigerian Building and Road Research Institute laboratory, North central zonal office, Jos, Plateau state, Nigeria.

2.8. Crushing efficiency

A representative sample of 30kg of laterite was fed into the laterite crushing machine through the hopper. The crushing process was noted according to [7]. The process was repeated seven times and average reading was used for calculating the crushing capacity. The obtained results is shown in Table 1 [7].

2.9. Particle size distribution

According to [8], information on particle size, shape, porosity and pore distribution of constituent materials are very important for choice and their appropriate use in construction. The level of information required on these particles and their fineness level thereby called for adoption of more efficient approach to particle size analysis. Sieve analysis (also known as gradation test) is a simple technique and possibly the most common procedure in use for assessing the particle size distribution of granular materials. It is used for determination of the relative proportions of different grain sizes that make up a given soil/material mass. It involves the passing of particles through stack of sieves

with known opening sizes and shaken for 10 minutes as recommended by [9], using a set of sieves on a mechanical sieve shaker as shown in Figure 3.



Fig. 3. Set of sieves

3. Results and Discussion

3.1. Results

Table 1. The Crushing capacity

| Trials | Mass before crushing (kg) | Mass after crushing (kg) | Time (sec) |
|--------|---------------------------|--------------------------|------------|
| 1 | 30 | 28 | 38 |
| 2 | 30 | 28.5 | 36 |
| 3 | 30 | 28.3 | 37 |
| 4 | 30 | 28 | 36 |
| 5 | 30 | 27.5 | 38 |
| 6 | 30 | 28 | 37 |
| 7 | 30 | 28 | 37 |

Average mass of laterite before crushing = 30Kg Average mass of laterite after crushing = 28Kg Average time taken = 37 Secs Crushing efficiency = $\frac{Mass \ of \ laterite \ grinded \ by \ the \ machine}{Mass \ of \ laterite \ loaded \ into \ the \ machine} \times 100$ (1) Therefore, $\frac{28}{30} \times 100 = 93\%$ And $losses = \frac{Mass \ of \ laterite \ before \ grinding(Mb) - Mass \ of \ laterite \ after \ grinding(Ma)}{Mass \ of \ laterite \ before \ grinding(Mb)}$ (2) $Loss = \frac{30-28}{30} = 0.07 \ in \ \% = 7\%$ Grinding Velocity (GV)

$$GV = \frac{\pi DN}{60} \tag{3}$$

The crushing velocity of the locally fabricated laterite hammer crusher is as calculated below: $GV = \frac{\pi DN}{60} = \frac{\pi \times 99 \times 2200}{60} = 11.4 m/s$

3.2 The Crushing capacity (C_C)

This is the rate at which the laterite crushing machine crushes laterite loaded into it and is calculated as:

$$Cc = \frac{Q}{t}$$
(4)

where,

 C_C = Machine crushing capacity (powder produced/min) Q = Quantity of crushed laterite t = Time for crushing the laterite (min) Therefore,

The Crushing Capacity= $\frac{196.3}{4.32}$ = 2,724.4 kg/hr

Table 2. Particle size distribution

| Sieve sizes (mm) | Mass retained (g) | Percentage retained (g) | Percentage passing (%) | | |
|------------------|--------------------|-------------------------|------------------------|--|--|
| +10 | - | - | - | | |
| -10+5 | - | - | - | | |
| -5+3.35 | -5+3.35 0.56 0.112 | | 99.89 | | |
| -3.35+2.36 | 35+2.36 2.24 0.448 | | 99.44 | | |
| -2.36+2.00 | 2.67 | 0.534 | 98.91 | | |
| -2.00+1.18 | 34.10 | 6.82 | 92.08 | | |
| -1.18+0.6 | 103.68 | 20.736 | 71.34 | | |
| -0.6+0.425 | 70.03 | 14.006 | 57.32 | | |
| -0.425+0.3 | 62.99 | 12.598 | 44.72 | | |
| -0.3+0.15 | 104.65 | 20.93 | 23.78 | | |
| -0.15+0.075 | 94.63 | 18.926 | 4.84 | | |
| Pan | 24.19 | 4.838 | 0 | | |

Particle size distribution also known as gradation, refers to the proportions by dry mass of a soil distributed over specified particle-size ranges. Gradation of soil is used to classify soils for engineering and agricultural purposes, since particle size influences how fast or slow water or other fluid moves through a soil [11]

A representative sample of 500g were used to carry out the particle size distribution analysis to determine the effectiveness of the crushing machine. The obtained result is presented in Table 2.



Fig. 4. Fabricated laterite crushing machine

3.3 Discussion

The result of the grindability of the laterite grinding machine is presented in the Table 1, it shows the effectiveness of the grinding machine in crushing 30kg of laterite which was achieved in an average time of 37secs with an average grinding efficiency of 93%. Table 2 shows the particle size distribution analysis of the crushed laterite. The results obtained shows that after crushing, the mesh size 0.15mm has the highest weight fraction of 20.93% of the total fraction, follow by the mesh size 0.6mm with 20.74% of the total weight fraction. The result thus shows that 87.196% of weight fraction falls within the fine particles range. This shows that the laterite is well graded and since a well graded soil has higher compressibility than poorly graded soil [12]. That means the laterite has fewer voids and is suitable to be used as CSEB material. This result suggests the effectiveness of the grindability of the laterite crushing machine.

4. Conclusion

A laterite crushing machine with an interchangeable sieve was designed, fabricated and tested using locally sourced materials. The performance evaluation of the machine was carried out and the results obtained satisfied the purpose for which it was fabricated. This machine can be used for large scale production as it has a crushing capacity of 22 tonnes per eight hours a day operation. Using this machine will bring about reduction in the challenge of manual sieving of the laterite as well as increase the quantity and quality of laterite needed for the production of interlocking compressed earth blocks for sustainable housing delivery in Nigeria.

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Development of a low-cost slider-crank apparatus for teaching purposes

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Abstract: The slider-crank apparatus is a significant device for demonstrating the conversion of rotary motion to reciprocating linear motion in laboratories and workshops. It is the basic mechanism used in diesel and gasoline internal combustion engines, these machines play an indispensable role in modern technology. However, the exorbitant cost of these devices has limited their availability for students' use. This study therefore reported the utilization of sustainable engineering in the development of a low-cost prototype slider-crank mechanism for instrumentation in the laboratory. Locally available materials were utilized in the development of the apparatus and evaluation performed following standard test procedures. Experimental results obtained from the apparatus Parameters measured include slider displacements, crank angles, velocity and acceleration for a crank angle of 0° to 90° in the clockwise direction at angular intervals of 15°. Analytic results obtained with the use of design equations are comparable to literature values. The dynamics of developed apparatus compared favourably with imported devices. Observed strokes of the developed apparatus are similar to the strokes of conventional apparatus with higher output torque.

Keywords: Mechanism, slider-crank, apparatus, acceleration, displacement

1. Introduction

Slider-crank mechanism is an apparatus widely used in converting circular motion to linear motion positioned vertically, horizontally or in angular direction in usage areas [1]. They are equally used in critical engineering applications, and its design considered vital for the conversion of rotary to linear motion, applicability in different applications, simplicity of design and compatibility ideal for applications within limited space. These mechanisms are used automotive and the other industries. The Slider-Crank mechanism is one of the most used global tools, with perhaps multiple designs, and frequently applied planar linkages in engineering [2,3]. It also find use in pumps, compressors, steam engines, internal combustion engines, feeders, crushers, punches etc. [4].

Several studies have been conducted on the simulation, development and construction of slider-crank mechanisms. For instance, [5] experimented on the dynamic behaviour of planar flexible slidercrank mechanism with clearance using ADAMS programme, [6] research was concerned with the analysis of kinematics and kinetic of slider-crank mechanism of the engine in maximum power, maximum torque and downshifting situation. Reference [7] studied a slider-crank mechanism with a revolute clearance joint between the slider and the connecting rod. Reference [8] performed simulations using the longitudinal response of the slider block along with reaction forces at crank joints. Reference [9] study review on kinematics and dynamic analysis produces useful insight to details of the successful design, fabrication and testing of a pneumatically powered Slider-Crank mechanism for the purpose of classroom experimentation. The kinematic behaviours of the flexible Slider-Crank mechanism using mathematical models and MATLAB software [10]. Reference [11] experimented the integration of a dynamic model of the slider-crank mechanism into a wear prediction procedure. The prediction procedure builds upon a widely used iterative wear scheme. The accuracy of the predictions is validated using results from an actual slider-crank mechanism. The analytical method was used to define the various positions of the crank and respective positions of slider with coupler point using MATLAB programs [12].

Reference [13-15] used the FORTRAN computer program for the analytic synthesis of the Slider-Crank mechanism parameters.), the reported analysis based on the mathematical model performed The design and control of a slider-crank mechanism can be complex, especially for systems with many degrees of freedom but provide economic values, prevents mechanical faults, quick service and easy intervention. However, sustainable development has become a priority for the world's policy makers since human impact on engineering has been greatly accelerated in the past century with rapidly increasing population and the concomitant sharp decrease of ultimate natural resources. By implication, the range of motion of a slider-crank mechanism is limited by certain factors and orientations of the crank and connecting rod and the constraints imposed by the pivot points. Critical among such factors are machine kinematics and the resulting dynamic forces [9].

Few available slider-crank apparatuses in use in Nigeria are mostly imported, with high costs and lengthy delivery time, thereby making multiple import difficult for large population of students in mechanics and other related fields, hence justification for this study. This study therefore seek to develop and construct a manually powered slider-crank apparatus using sustainable locally available engineering materials for classroom teaching and laboratory experimentation.

2. Method

2.1. Material Selection

The major component parts of the slider-crank mechanism include the main bench, the bench stand, and slider mechanism. The material chosen to produce the main bench is medium density fiberboard (MDF) due to material availability, cheap, light weight, good machinability, strength and rigidity. The Bench-stand unit was constructed of smoothly planed hardwood, and four (4) plastic rollers bought-out from the open market. The slider-crank mechanism unit primarily comprised of rotary elements (the crank) with a graduated disc produced from plywood, angular indicator made of plastic, connecting bar produced from hardwood and a 200 mm scale rule to measure the stroke and linear motion. The overall dimensions of the apparatus is 400 x 300 x 100 mm approx. and weighs approximately 3 kg.

2.2. Design equation and calculations

Complete analysis of the apparatus's kinematics assumed a constant angular acceleration. The forces acting at the link joints were geometrically calculated and designed for statically and dynamically balanced configurations at the same constant angular velocity.

Crank kinematics: Kinematic equations were used to generate the results for the constructed slidercrank mechanism using the following input parameters from Fig. 1. The input parameters for the design of the slider-crank mechanism include crank radius r, connecting rod length *l*, crank angle θ , crank pin angle β , mass of slider m, and crank angular speed ω .



Fig. 1. Slider-crank mechanism (in vertical direction)

For a given Slider-Crank mechanism, the connecting rod length is related to the crank radius was expressed by equation (1) [17].

$$\frac{r}{l} \le \frac{1}{3} \tag{1}$$

The path traced out by crank arm; OB is given by r when the link bar CB travelled a vertical distance equal to one stroke which is the required block width (Fig. 1b).

From Fig. (1a), the displacement S, between the crank-arm radius r, and connecting bar length, and R is the vertical distance between the slider head and the crank. For any change of position of the crank and slider, there is a corresponding change in angular positions θ , and β , denoting the crank and slider angular positions respectively.

For any given value of θ and β [18], equation 2 is validated:

$$r\cos\theta + l\cos\beta - R = 0 \tag{2}$$

Also, from Fig. (1b), when $\theta = 0^{\circ}$, $\beta = 0^{\circ}R = R_{max}$

Hence, from equation (2):

$$r\cos 0 + l \cos 0 - R = 0$$
$$\Rightarrow r + l - R = 0$$

Also, from equation (1),

 $l \ge 3r$ $\therefore r + 3r - R = 0$

For construction purposes, assume r = 70mm, then R = 70 + 3x70 = 280mm

Similarly:

$$l \ge 3r \therefore l \ge 3*70 \ge 210mm$$

Also, for construction purposes, values r, and *l* chosen are 70mm and 250mm, respectively, and $R_{max} = 70 + 250 = 320mm$.

The slider position, x at any given time with respect to the crank angle, θ can be evaluated from equation (1), while the displacement S of the slider head defined as a function of crank's angular position when the crank has turned θ^0 from the upper or lower limits was given by in equation 2.

Length of the slide guardrail: The stroke value was used to determine the length of the slide guardrail evaluated thus:

$$S = 2r = 140mm$$

For construction purposes, the length of slide rail was estimated at 180mm.

Crank speed: The crank speed was evaluated using the expression:

$$\omega = \frac{2\pi rN}{60} \tag{3}$$

Dynamics of the link mechanism: Taking the origin O at the center of the shaft and *x* and *y* coordinates as shown in Fig. 2, the link arm on the crank disc experience rotary motion and produced an inertia force along Ox. Link BC experienced reciprocating motion in the direction Oy.



Fig. 2. Slider-crank lift-arm link mechanism

Point B executes a rotary motion about a fixed axis from O. Considering the inertia forces due to the masses of the entire system, the center of gravity of the crank pin, crank arm and the shaft, the concept of equivalent mass is used to determine the inertia force components X_B and Y_B due to the dynamic components from the equations (4-7) [19]:

Horizontal Component:

$$X_B = X_e + X_r = M_B \omega^2 \cos\theta \tag{4}$$

Vertical Component:

$$Y_B = Y_e + Y_r = M_B \omega^2 r \cos\theta \tag{5}$$

Where

 M_B = Total mass of crank, crank pin and equivalent mass of rotating members.

Point O perform rotary motion, point C is fixed along the vertical axis and performs a reciprocating motion. The inertia force produced in that direction is given by equation 6.

$$X_A = M_A W^2 \left(\cos \theta + {r \choose l} \cos 2\theta \right) \tag{6}$$

The vertical component YA = 0

Where

$$M_A = M_P + M_C \tag{7}$$

 M_P = equivalent mass of counter weight, and

 M_C = Mass of upper link arm and pin.

Force system and equilibrium: In solving the problem of the forces acting on the pins and links, the unknown forces are resolved into *x*- and y- coordinates and force and moment equations written for each link. P is a known force (weight of slider block) acting horizontally at point C (Fig. 3). N_C is an unknown force reacting on the wall due to W₁ and P. B₁ and B₂ are reactions on the pin at B. Q_B (Nm) is the unknown limiting friction couple in the pin. The direction of the limiting couple is determined by assuming that load P acting is in equilibrium [20].

At the point of overcoming P, in sliding, link AB exert an anticlockwise couple on BC causing AB to experience a clockwise couple Fig. 3b. The two approaches used by [20] were employed in the determination of the unknown forces N_C and couple Q_B . Writing equation for one moment and two force equations for each link thus resulting in equations with six unknowns solved simultaneously,

212

or taking moments about B for link BC only and obtaining a relationship between P and the unknown for N_c . Hence, N_c can be found by taking moments about A for the two connected links.



Fig. 3. Forces acting on the linkage mechanism

Taking moments about point B in Fig 2c

$$\Sigma B = 0 \implies Q_B = x N_c + y W_I + Z_p \tag{8}$$

For the entire system and taking moment about O

$$\sum M_o = 0 \Rightarrow N_c = \frac{(yW_1 + uW_2)}{x}$$
(9)

Free body moments: The free body diagrams (FBD) for the links BC and BO are shown in Fig. 3b. With the force components at B on AB equal and opposite to those at B, on BC, which is equal and opposite to those at B on BO (Newton's third law), the directions of the forces otherwise, being chosen arbitrarily (an axis perpendicular to the *xy*-plane).

At equilibrium, the following conditions were identified:

 $\Sigma F x = 0, \qquad \Sigma F y = 0, \Sigma M o = 0$

Therefore, for link BC Fig. 3a

$$\sum Fx = 0 \Rightarrow B_2 - N_c = 0$$

$$\sum Fy = 0 \Rightarrow B_I - N_I - P = 0$$

$$\sum MB = 0 \Rightarrow Q_B = xN_c + yW_I + zF$$

For link BO Fig. 3b

$$Fx = 0 \Rightarrow H_A - B_2 = 0$$

$$\sum Fy = 0 \Rightarrow B_A = B_1 + W_2$$

$$\sum M_A = 0 \Rightarrow Q_B = zB + vB_2 + uW_2$$

For the entire system Fig. 3c

$$\Sigma F_x = 0 \Rightarrow H_A - N_c = 0$$

$$\Sigma F_y = 0 \Rightarrow w_1 + w_2 + P - B_A = 0$$

$$\Sigma m_A = 0 \Rightarrow N_c = (yw_1 + uw_2)/x.$$

Wood shear stress: The wood shear stress is evaluated by equation 10 [21]:

$$T_{\rm s} = \frac{\pi.\,\tau_{\rm s}.\,\mathrm{D}^2}{16} \tag{10}$$

Where

R = radius of the shaft

D = diameter of the shaft

 τ_s = shear stress at radius

From the design data: $T = T_{human} = 2..5Nm$; d = 35mm

 $\tau_{\rm s} = 9MPa$ for iroko wood [21]

 $\tau_s \gg \tau_{ut}$

This means that the material will not fail, hence, wood satisfies the design criteria for maximum shear stress.

2.3. Description of apparatus

The slider-crank mechanism is a reversible system that is able to transform the rotational motion of the slider block into linear motion of a crankshaft. Its main application is in internal combustion engines. It consists of a disc crank connected to a rigid connecting bar, called connecting rod, to move the slider blockhead back and forward. This mechanism is made of wood and consists of a rotary element (graduated disc), called crank, connected to a rigid bar, called connecting rod. When the crank rotates, the connecting bar moves backwards and forwards.

The input angle is set on the mounted crank disc and read on an angle measuring scale. A millimeter scale is fitted on the slider guardrail to measure the displacement of the slider block while the connecting rod exhibit linear motion. The engineering drawings of the apparatus is shown in Fig. 4.



Fig. 4. Orthographic drawing of the slider-crank mechanism

The entire components were arranged in synchronous manner on a 40 x 600 mm MFB board, which served as frame support. The entire unit was mounted on two wooden beams with end castors for

214

stand. The material of construction of the entire components is wood, and the overall dimension (400 x 600×200) mm.

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract. Abbreviations such as IEEE, SI, MKS, CGS, sc, dc, and rms do not have to be defined. Do not use abbreviations in the title or heads unless they are unavoidable.

2.4. Performance evaluation

Performance evaluation were carried out on the apparatus by determining the slider velocity and acceleration at different slider block displacement. Assume the Slider-Crank mechanism moves with uniform angular velocity in the clockwise direction, at any point B, the slider block slides along the fixed guardrail D, AB is the couplet joining A and B.

Preliminary evaluation of simulated number of revolutions per minute of an average person cranking a manual grinding mill was 65rpm. The following values were the constants used for evaluating the equations: r = 70mm, l = 320mm, $\omega = 7.94 rad/s$

$$\omega = \frac{2x\pi x70x65}{60} = 7.94 \ rad/s$$

Slider position with respect to the crank angle, the slider velocity with respect to the crank angle, slider acceleration with respect to the crank angle obtained

2.5. Method of data collection and analysis

Data collection and analysis applied during the process of executing the project include physical measurements from the linear and angular scales of the constructed prototype. The angular displacement of the crank and the corresponding linear displacement were measured, while the velocity and acceleration were calculated using the measured displacement values and time.

3. Results and Discussion

The slider-crank mechanism developed using locally available materials was successfully developed. All component parts fabricated from the first principles are according to design considerations. Satisfactory operation of the mechanism was achieved with minimal stress. As the crank disc exhibited rotational motion, the slider block exhibited linear motion. The linear and angular measurements of the slider and crank disc were read from the linear scale and the 360° angular measuring scale fixed on the board. The device operated without complications. The mechanism is suitable for laboratory and classroom demonstrations.

Performance evaluation carried out on the apparatus include determination of slider velocity and acceleration at different slider block displacement. The measured and derived data recorded by the device at five replications as shown in Table 1. The displacement (x), velocity (v) and acceleration (a) of the slider were analytically obtained with the use of equations (10), (11), and (12) respectively.

| | | | | - | | | |
|-----|--------------------------|----------------|-------|----------|-----------------------------|-------------------|----------------------------------|
| S/N | Slider displacement (mm) | Crank rotation | | Time (s) | Slider position $x(\theta)$ | Velocity (m/s) | Acceleration (m/s ²) |
| | | (In deg.) | (rad) | | | | |
| 1. | 15 | 39.50 | 0.69 | 3 | 0.34 | 0.59 | 1.16 |
| 2. | 30 | 51.34 | 0.90 | 3 | 0.35 | 0.51 | 2.24 |
| 3. | 45 | 62.00 | 1.08 | 3 | 0.37 | 0.39 | 3.15 |
| 4. | 60 | 70.85 | 1.24 | 3 | 0.38 | 0.25 | 3.85 |
| 5. | 75 | 79.50 | 1.39 | 3 | 0.39 | 0.09 | 4.28 |
| 6. | 90 | 89.00 | 1.55 | 3 | 0.39 | -0.06 | 4.41 |
| 7. | 105 | 91.50 | 1.60 | 3 | 0.38 | -0.20 | 4.25 |
| 8. | 120 | 110.50 | 1.93 | 3 | 0.37 | -0.31 | 3.79 |
| | | | | | | | |

 Table 1.
 Measured and derived slider and crank parameters

| 9. | 135 | 124.50 | 2.17 | 3 | 0.36 | -0.39 | 3.09 |
|-----|-----|--------|------|---|------|-------|------|
| 10. | 150 | 144.50 | 2.52 | 3 | 0.35 | -0.45 | 2.18 |
| 11. | 165 | 171.00 | 2.98 | 3 | 0.33 | -0.48 | 1.14 |

The slider displacement versus crank rotation chart is shown in Fig. 5. The crank rotation has direct linear relation with increase in slider displacements. The slider displacement increased with increase in angular rotation.



Fig. 5. Exploded drawing of the slider-crank mechanism

In Fig. 6, the slider displacements and crank rotation relationship obtained from the prototype device followed a sinusoidal path and the maximum and minimum values of both curves coincide at the same angular displacements obtained by [4].



Fig. 6. Relationship between slider displacement and crank rotation

Fig. 7 and 8 shows the slider velocity and slider acceleration with respect to the crank angle respectively. In Fig. 7, the crank velocity decreased with increase in slider displacement, with a

216
point of inflection at 90°. However, there is a decrease in velocity as the slider displacement increased beyond the peak displacement. The relationship between acceleration and crank rotation showed maximum and minimum readings at 90°, and $0^{\circ}/180^{\circ}$ respectively.



Fig. 7. Relationship between the speed of the slider and slider displacement



Fig. 8. Relationship between slider acceleration and the crank rotation

4. Conclusion

The Slider-Crank apparatus developed was compared with the imported slider-crank mechanism with similar performance characteristics. However, slight frictions experienced during cranking was due to mechanical advantage associated with crank bearing design and fabrication error. However, this error is not significant, and neglected. The model also provided a better understanding of the prototype built compared to the analytic design because it gave a visual representation of the design. The developed prototype also showed some minor aesthetic variations from imported apparatus

however, these deviations were largely due to material selection and instrumentation. Because of the negligible variations, the prototype quality passed assurance and useful for laboratory demonstration. For comparison, the dynamic analysis results of developed slider–crank mechanism compared favourably with imported slider–crank mechanism. Observed strokes of the developed apparatus are similar to the strokes of conventional apparatus with higher output torque. For future research activities, the apparatus requires calibration, while the crank disc-bearing block be replaced with ball bearings for firmness and smooth operation.

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Biodiesel a sustainable fuel: exploring the feedstocks and production process

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Abstract: The imperative for a sustainable fuel source to mitigate the challenges posed by climate change, utilizing agricultural, industrial, and domestic waste, is of paramount importance. This study delves into biodiesel as a viable sustainable fuel, investigating both its feedstock options and production processes. The analysis encompasses the progression of feedstock generations from first to fourth, while also scrutinizing biodiesel production methodologies, such as batch processing, esterification, transesterification, direct blending, micro emulsion, and pyrolysis. The research expounds upon the versatile applications of various feedstocks and production techniques within biodiesel synthesis. Transesterification emerges as the most costeffective, accessible, and widely employed method due to its ease of access to requisite materials. Notably, biodiesel, derived from biodegradable feedstocks, exhibits commendable yield and properties, rendering it a clean, renewable, reliable, environmentally benign, and economically feasible alternative compared to conventional diesel, which experiences substantial cost escalation. Consequently, conventional diesel poses a substantial threat to the environment and exacerbates energy insecurity. Furthermore, biodiesel and its blends demonstrate superior applicability as automotive fuel sources, affirming their potential as a promising alternative.

Keywords: emissions, biodiesel, environmental impact, feedstocks

1. Introduction

The persistent global demand for fossil fuels to power industries and transportation has triggered severe environmental repercussions, notably the depletion of the ozone layer and the release of harmful pollutants. This escalating concern has spurred extensive research and exploration into alternative energy sources that not only substitute traditional fuels but also mitigate environmental degradation. Chief among these sustainable alternatives is biodiesel, a promising fuel derived from renewable sources such as vegetable oils, animal fats, or recycled greases through the process of transesterification [1]. Biodiesel production involves a spectrum of feedstocks, each characterized by unique compositions of fatty acids (lipids), free fatty acids, and moisture content, often influenced by geographical variances [2]. Over time, an array of feedstock options, including cassava peels, gmelina, orange peels, plantain peels, among others, have been rigorously evaluated for their potential in biodiesel production. The classification of these feedstocks into different generations, as illustrated in Figure 1, offers insights into their suitability and availability for biodiesel synthesis.

The urgency to address the environmental impact of conventional fossil fuels has elevated the significance of biodiesel as an eco-friendly, renewable alternative. The exploration of various feedstocks and their lipid compositions, accounting for regional disparities, plays a pivotal role in assessing the feasibility and efficacy of biodiesel production. These efforts aim to cultivate a sustainable energy landscape that aligns with environmental preservation. Biodiesel's appeal as an environmentally responsible fuel lies in its capacity to significantly reduce greenhouse gas emissions, offering a cleaner combustion process compared to conventional diesel. Additionally, biodiesel's biodegradable nature contributes to lower levels of harmful exhaust emissions, fostering cleaner air quality. Its renewable nature and reduced carbon footprint position biodiesel as a pivotal player in mitigating climate change and curbing environmental degradation caused by conventional fuels. Furthermore, the versatility of biodiesel usage extends beyond traditional transportation fuels. It finds application in various sectors, including industrial machinery, power generation, and heating applications. This versatility enhances its potential to reduce dependence on finite fossil fuel reserves

across multiple domains, thereby contributing to a more sustainable and environmentally conscious energy future. Biodiesel emerges as a beacon of hope in the quest for sustainable energy solutions, offering a viable alternative to conventional fossil fuels while prioritizing environmental well-being through its renewable nature, reduced emissions, and diverse applications across industries.



Fig. 1. biofuels production sources [2]

1.1 Generation of feedstocks in biodiesel production

The first-generation feedstock is gotten from vegetable oils which are edible such as coconut oil, groundnut oil, sunflower oil, oat oil, and cotton seed oil. Subsequently, the availability of crop and its easy conversion procedure were the major advantage of the first-generation feedstock but it affected the world crop bank since there where edible [3]. The second generation used non-edible oils gotten from plants and animal fats such like koroch seed oil, sea mango seed, rubber seed tree (*havea brasiliensis*), rice bran, silk cotton tree (*caba pentandra*), pork lard, and beef tallow and the non-edible oils are very efficient, environmentally friend and economical [4]. The third generation are feedstocks gotten from microalgae, which is generated from photosynthesized microorganism which converts water and carbondioxide into algal biomass using simple photosynthesis process to produce the microalgae and this feedstock does not pose a threat to food shortage [5]. The fourth-generation feedstock which is genetically engineered considers development in synthetic biology, which are synthetic cell production, purposed-designed photosynthetic microorganisms and the combination of microbial and photovoltaic fuel [6].

1.2 Biodiesel and its properties

Biodiesel is a renewable burning clean mono-alkyl ester which is similar to petroleum-based diesel fuel since it can be blended with diesel to achieve a stable yield (B10, B20, B40, etc.) [7]. Though the biodiesel blends are stable and considered as a constituent of petroleum base fuel, there are properties to be considered which are cetane number, oxygen content/stability, flash point/fire point, cold flow properties, kinematic viscosity, density, heating value, cloud point/pour point [8].

2. Method

2.1. Feedstock collection and preparation

The selected feedstock for biodiesel production is sourced for from vendors or local farmers and is prepared to remove impurities and also air dried to reduce the moisture content. The feedstock oil is then extracted using the aid of a Soxhlet extractor containing a measured amount of methanol or ethanol.

2.2. Biodiesel production

The production of biodiesel can be achieved through the following methods;

a. Batch processing: this involves a production system with fixed amount or volume of feedstock is processed at a time through series of distinct production steps [9].

b. Esterification and transesterification: esterification is the process used to produce an ester while transesterification is the modification of esters through chemical reactions [10] as seen in Fig 2 and 3 for transesterification process.



Fig 2. Schematics of transesterification process for biodiesel production [10]



Fig. 3. Conversion of triglycerides (biooil) through transesterification to biodiesel and glycerol [10]

- **c. Direct blending:** This method involves the mixing of vegetable oil with diesel under certain proportions, which is done through splash blending, in-tank blending, in-line blending, rack injection blending and cold-water blending [11].
- **d. Micro-emulsion:** This involves the use of emulsifying agents mainly alcohol such as methanol, ethanol, propanol or butanol to produce emulsions. Due to the alcohol contain in micro emulsion which gives it less volumetric heating value when compared to diesel fuel but a useful cooling effect due to a high latent heat of vaporization in the combustion engine of the alcohol [12].
- e. Pyrolysis: Pyrolysis involve heating in the absence of oxygen, biomass to high temperature of about 400 600°C. Pyrolysis involve thermal energy converting triglycerides of vegetable oil into alkenes, alkanes, alkadines, ketone, carbonxylic acid, aromatics, aldehydes, linear and cyclic paraffins and olefins [13] as shown in Fig. 4 and the different types as seen in Fig. 5.



Fig. 4. Pyrolysis of vegetable oils into alkanes, alkenes and aromatics [13]



Fig. 5. A schematic of microalgae pyrolysis types, product, reactor configuration and application for bio-fuel [13]

3. Results and Discussion

3.1. Conventional transesterification

The easiest way in biodiesel production is the use of transesterification process or method which involves the catalyzed chemical reaction involving alcohol and vegetable oil in yielding fatty acid alkyl esters (biodiesel) and glycerol. The reaction involves the use of a catalyst to give improve reaction rate and better yield. Since it's a reversible reaction, excess alcohol is needed to shift the reaction to the product side and methanol is most suitable due to its low cost, chemical and physical advantage, which can easily react with vegetable oil and easy dissolution of NaOH (using a strong base catalyst). One mole of oil will react with about three moles of alcohol (methanol or ethanol) in the presence of a more suitable catalyst in forming three moles of fatty acid alkyl esters and one mole of glycerol. The catalyst used is usually enzymes, alkali or base.in transesterification process, alcohol reacts with algal/vegetal (bio) oil in the presence of a catalyst. Methyl or ethyl-alcohol is used to produce methyl/ethyl esters. At completion, two separated layers (methyl or ethyl ester and glycerin) appear which can be separated. Methanol (mixed with catalyst) reacts with vegetable oil yielding the production raw biodiesel and glycerin. Fig. shows the transesterification process [14].

223



Fig. 6. Schematics of transesterification process for biodiesel production [14]

Transesterification is the preferred method for biodiesel production due to its low cost and simplicity. The synthetic transesterification of biodiesel reaction is shown in Eq. (1).

$$RCOOR' + R"COOR" \rightarrow R'COOR" + R"COOR$$
(1)

Transesterification of animal fat and vegetable oil is an equilibrium reaction that is reversible. The triglycerides react with suitable alcohol (Methyl, Ethyl and others) in the presence of catalyst within a controlled temperature for certain duration. The end product is Glycerin and Alkyl esters. The alkyl esters have favorable properties to fuel thereby making it suitable in CI engines been the major product and glycerin its bye product. The chemical reaction of the triglyceride and methyl alcohol is shown in Fig. 7.



4. Conclusion

Biodiesel is a renewable alternative fuel to fossil fuels because it is clean, reliable, cheap and environmentally friendly. Extracted oils from various feedstocks from non-edible sources are widely used for its production. Transesterification is considered the best option in this production process because it is readily available, cheap, and common compared to other production methods. The biodiesel production will reduce agricultural, industrial and domestic waste since their feedstocks are

224

considered in the production processes. Biodiesel is a promising renewable fuel option that offers environmental, energy security, and economic benefits and it has the potential to play a significant role in reducing dependence on fossil fuels and mitigating climate change.

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Assessment of quality of tanker vended water in Enugu metropolis

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Received 02 September 2023; Accepted 18 November 202 Abstract: Twenty water samples were collected from tanker operators and household storage tanks. Seventeen physicochemical and two microbiological parameters were tested according to standard procedures. Colour, pH, conductivity, TDS, temperature, nitrate, chloride, sulphate, alkalinity, total hardness, calcium hardness, magnesium hardness, calcium, potassium, sodium, iron, total coliform and E.coli were tested and compared with the World Health Organisation (WHO) and Nigerian Industrial Standard (NIS) drinking water guidelines to ascertain whether there is violation. It was observed that there was no violation in the physicochemical parameters except in 40% of the samples for pH. Also, there was 30% violation for total coliform and E.coli. Pearson's correlation was applied on the water quality data to ascertain whether there are significant relationships between the tested parameters. Principal Component Analysis (PCA) and Cluster Analysis (CA) were applied on the data to know the sources of contamination of the tanker supplied water. Results of the analysis showed that contaminants enter into the tanker supplied water through influence of anthropogenic activities on groundwater chemistry, poor hygiene during the collection, transportation of water by tanker operators, interaction between groundwater and geological formations and leaching of iron into the water as a result of interaction between the tanker material and water. Treatment of the water is recommended before use to avoid the risk of exposure diseases.

Keywords: Tanker vendors, water quality, water supply

1. Introduction

From the recent past till date, the supply of safe water for domestic use is a major challenge for the development effort in Nigerian cities. Unfortunately, the increasing gap in the demand and supply of water has acquired crisis proportions. Most of Nigeria's State Water Agencies (SWAs) are grappling with the multiple problems of erratic power supply, corrupt policies, diversion and theft of heavy equipment, poor maintenance culture, faulty distribution system, and the topography of the area. In addition to the aforementioned factors, population growth and bad-housing in some towns and cities have meant that most public water facilities put in place by the SWA are over-stretched and incapable of efficient water delivery to the people. Consequently, water supply at public water taps is often irregular and of short durations and most residents of cities rely heavily on commercial borehole owners and itinerant (water tanker drivers) water vendors for their daily supplies.

Inhabitants of Enugu metropolis currently depend largely on drinking water transported from boreholes at 9th mile corner, Udi Local Government Area. Such water provision using truck water tankers involves collection, transportation and storage in households in either open-top or closed-top portable containers. Numerous studies have demonstrated the deterioration in microbiological quality drinking safe water as it moves from one source to point of use [1], [2], [3], [4], leaving the water unsafe for human consumption [5], [6], [2], [3]. Factors considered to contribute to deterioration in water quality include poor hygiene and sanitation practices, the use of contaminated transport and storage containers, insertion of contaminated hands and utensils into water, contact of water with particulate matter, animals and insects as a result of openings in containers, and a poor environment surrounding the water source [7], [8], [5], [2], [9], [4]. Water stored in open-top containers are more prone to faecal contamination than water stored in closed-top containers and may contain faecal pathogens that could cause illness such as diarrhoea [7], [8]. Faecal contamination of water results from users dipping faecally-contaminated utensils and hands into storage containers [10], [11], [12], [2].

All the water from tanker vended water sourced from borehole to the consumption level ought to meet the standards laid down by world health organization for drinking water to make the water portable. Substandard water sample can lead to diseases such as cholera, dysentery, typhoid fever, and other types of gastrointestinal disturbances. For drinking water to be safe, the concentration of undesirable substances should not exceed the levels established by world health organization.

2. Method

2.1. Data collection

Semi-structured interviews were conducted using semi structure questionnaires. These questionnaires were pretested and modified to improve clarity of some questions. The survey was designed and administered to 50 water tanker vendors and 100 household selected from Asata, Onu-Asata, GRA, Ogui New Layout, China Town, New Haven, independence layout, Ogui township, Uwani east, Achara Layout East, Achara layout west, Awkunanaw east Awkunanaw west, Abakpa 1, Abakpa 2, Ibagwa-Nike/Edem, Ugwuogu Nike. Random sampling was used to determine the 50 water tanker vendors and 150 households to be tested

The sample size was determined using the Eqn. (1) [13];

$$n \geq N/e2$$

$$\frac{1}{2}e2 + N \tag{1}$$

Where n is the sample size, N is the population size and e (0.05) is the sample error which ranges between 0.01 and 0.2 [13]. Error which was discovered through sampling that about 75% of the house hold used tanker vended water and 350 water tanker vendors and also that an average household is made of six (6) persons in the study area. This makes the population size to be 90,334 houses household. Water tanker vendors were asked about the source, quality, and access to water, frequency of washing tanker, disinfection of pumps, hose and if the tanker lid is open before/after loading. It was hypothesized that these site-specific conditions affected the quality of tanker vended water. The residents were also asked about access to water, sanitary conditions, storage of water, and the distance of storage tank from septic tank, if the tank top open or close, how and how often the tank washed? To ascertain the health impact of tanker vended water in the study area. They were asked about the water related disease experienced as result of drinking tanker vended water.

2.2. Sample Collection and Laboratory Analysis

10 tanker vendors and their respective customers (households) of the sample area where selected. Water sample was collected from the tanker vendor and labeled 'A' and from the household tank in which the tanker vendor 'A' supplied and was labeled 'B'. Consequently 10 water samples were collected from tanker vendors and 10 samples from their respective households, samples were transported to the National water quality reference laboratory, federal ministry of water resources, Enugu, within 24hours of sampling. A total of 17 physiochemical parameters were tested for sample. Color, pH, Electrical Conductivity (EC), total dissolved solid, temperature, nitrate, chloride, sulphate, alkalinity, total hardness, calcium hardness, magnesium hardness, calcium, magnesium, potassium, sodium, iron. Concentration of tanker vended water and household water samples were measured according to standard [14].

3. Results and Discussion

Table 1. Table showing some responses to some of the questionnaire questions

| Questions | Percentages | |
|-------------------------|------------------|-----|
| | | |
| Capacity of the Tankers | 8m ³ | 6% |
| | 10m ³ | 94% |
| Colour of tankers | White | 4% |

| | Red | 42% |
|------------------------------|--|------|
| | Green | 30% |
| | Blue | 14% |
| | Black | 10% |
| Method of cleaning tankers | Entering inside and washing once a month | 16% |
| | Entering inside and washing once in three months | 6% |
| | Flushing with remnants while ascending a hill | 50% |
| | None | 28% |
| Where the water is collected | 9 th mile corner boreholes | 100% |

Only 6% of the respondents clean their hose and pump regularly. This is another source of microbial contamination in tanker supplied water. About 36% of the tanker drivers close the lid of their tanker after loading. This can also be another significant source of contamination. We also noticed that TDS was found in low concentrations. This is as a result of the high quality of the 9th Mile borehole water. Average distance travelled by the tanker water vendors is 19.611 km. All the tankers tested are made of metal which explains the presence of iron in the tanker supplied water. The capacity of the tankers ranges between 8m3 and 10m³.

| Parameters | Minimum | Maximum | Mean | Std. Deviation | NIS 977:15 | WHO (2011) |
|----------------|---------|---------|---------|----------------|------------|------------|
| | | | | | | |
| Colour | .00 | 82.00 | 26.4500 | 21.66364 | 5 | - |
| pН | 5.98 | 8.08 | 6.6365 | .56147 | 6.5-8.5 | 6.5-9.5 |
| Conductivity | 10.80 | 183.00 | 45.0450 | 44.00483 | 1000 | - |
| TDS | 5.45 | 110.00 | 26.9625 | 26.46727 | 500 | 600 |
| Temperature | 27.30 | 29.50 | 28.2300 | .52626 | Ambient | - |
| Nitrate | 1.10 | 31.00 | 6.5300 | 6.84252 | 50 | 50 |
| Chloride | .00 | 20.00 | 2.7000 | 4.70274 | 250 | 250 |
| Sulphate | .00 | 5.00 | 2.1040 | 2.01351 | 100 | 250 |
| Alkalinity | .00 | 2.00 | .1000 | .44721 | - | - |
| Total hardness | .00 | 30.00 | 6.4000 | 8.27425 | - | - |
| Ca Hardness | .00 | 22.00 | 2.9000 | 4.96196 | - | - |
| Mg Hardness | .00 | 28.00 | 3.5000 | 6.54941 | - | - |
| Calcium | .00 | 8.80 | 1.1600 | 1.98478 | - | - |
| Magnesium | .00 | 6.72 | .8400 | 1.57186 | 0.02 | - |
| Potassium | .00 | 5.00 | 1.3350 | 1.79686 | - | - |
| Sodium | .12 | 8.69 | 1.4500 | 2.06764 | 200 | - |
| Iron | .00 | .36 | .0895 | .10374 | 0.3 | - |
| Total coliform | .00 | 460.00 | 38.2000 | 108.70123 | 10 | 0 |
| E.coli | .00 | 40.00 | 3.5000 | 9.28780 | 0 | 0 |

Table 2. Descriptive statistics of water analyses results

3.1 Statistical Analysis

Pearson's correlation was applied on the physicochemical and microbiological parameter results to ascertain whether there are significant relationships between them. The Pearson's correlation coefficients are presented in Table 3.

Conductivity had a strong and positive correlation with colour with a Pearson's coefficient of 0.515 significant at p < 0.05. Total dissolved solids (TDS) had strong and positive correlation with colour (r = 0.514, p < 0.05) and conductivity (r = 1.0, p < 0.01).

Nitrates had a strong and positive correlation with conductivity and TDS with

Pearson's coefficient of r = 0.860 at p < 0.01.

Chloride had a strong and positive correlation with conductivity and TDS (r = 0.860, p < 0.01) and nitrates (r = 0.963, p < 0.01).

Sulphate had a weak and positive correlation with nitrates (r = 0.480, p < 0.05) and chloride (r = 0.470, p < 0.01). Alkalinity had a positive correlation with colour (r = 0.604, p < 0.01).

Total hardness had a strong and positive correlation with colour (r = 0.643, p < 0.01), conductivity (r = 0.518, p < 0.05), TDS (r = 0.518, p < 0.05) and alkalinity (r = 0.671, p < 0.01).

Calcium hardness had a strong and positive correlation with conductivity (r = 0.547, p < 0.05), TDS (r = 0.547, p < 0.05), nitrate(r = 0.487, p < 0.05), chloride (r = 0.517, p < 0.05) and total hardness (r = 0.611, p < 0.01). Calcium showed the same results as calcium hardness.

Magnesium hardness had a strong and positive correlation with colour (r = 0.510, p < 0.05), alkalinity (r = 0.880, p < 0.01) and total hardness (r = 0.880, p < 0.01). Magnesium showed the same results as magnesium hardness.

Potassium had a positive and high correlation with conductivity (r = 0.756, p < 0.01), TDS (r = 0.756, p < 0.01), nitrate (r = 0.692, p < 0.01) and chloride (r = 0.640, p < 0.01).

Sodium had a positive and high correlation with conductivity (r = 0.961, p < 0.01), TDS (r = 0.961, p < 0.01), nitrates (r = 0.940, p < 0.01), chloride (r = 0.962, p < 0.01), calcium hardness (r = 0.544, p < 0.05), calcium (r = 0.544, p < 0.05) and potassium (r = 0.714, p < 0.01).

Iron had a weak and significant correlation with colour with a Pearson's coefficient of r = 0.487, p < 0.05.

Total coliform had a positive and strong correlation with conductivity (r = 0.677, p < 0.01), TDS (r = 0.676, p < 0.01), nitrate (r = 0.659, p < 0.01), chloride (r = 0.694, p < 0.01), sulphate (r = 0.446, p < 0.05), total hardness (r = 0.486, p < 0.05), calcium hardness (r = 0.896, p < 0.01), calcium (r = 0.896, p < 0.01) and sodium (r = 0.693, p < 0.01).

E. coli has a strong and positive correlation with calcium hardness (r = 0.773, p < 0.01), calcium (r = 0.773, p < 0.01) and total coliform (r = 0.850, p < 0.01).





The dendrogram shows a cluster of physicochemical and microbiological parameters.

| Rotated Component Matrix ^a | | | | | | | | |
|---------------------------------------|------------|-------------|-------------|------------|------------|--|--|--|
| | Component | | | | | | | |
| | 1(41.305%) | 2 (21.902%) | 3 (12.315%) | 4 (6.826%) | 5 (6.181%) | | | |
| Colour | .270 | .335 | .619 | 129 | .378 | | | |
| pН | 197 | .101 | .264 | .121 | 735 | | | |
| Conductivity | .904 | .310 | .272 | .064 | .012 | | | |
| TDS | .904 | .310 | .271 | .064 | .012 | | | |
| Temperature | 137 | .147 | .123 | 882 | .154 | | | |
| Nitrate | .916 | .256 | 195 | .172 | .082 | | | |
| Chloride | .916 | .301 | 113 | .132 | .002 | | | |
| Sulphate | .263 | .379 | 120 | .699 | .242 | | | |
| Alkalinity | .064 | 103 | .937 | 110 | 021 | | | |
| Total hardness | .179 | .497 | .813 | 030 | 035 | | | |
| Ca Hardness | .279 | .931 | .079 | .008 | 046 | | | |
| Mg Hardness | .014 | 077 | .967 | 044 | 009 | | | |
| Calcium | .279 | .931 | .079 | .008 | 046 | | | |
| Magnesium | .014 | 077 | .967 | 044 | 009 | | | |
| Potassium | .828 | 078 | .138 | 013 | .159 | | | |
| Sodium | .926 | .300 | .076 | .135 | .046 | | | |
| Iron | 045 | .192 | .384 | .143 | .736 | | | |

Table 3. Correlation of water quality variables against components

.860

.885

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

-.018

-.063

^{a.} Rotation converged in 6 iterations.

.451

.084

Total coliform

E.coli

From Table 3, the first principal component had high positive loadings on conductivity, TDS, nitrate, chloride, potassium and sodium. Hence the first principal component can be said to represent the influence of anthropogenic activities on groundwater chemistry. These ions leached from waste dumps, agricultural farms and open market squares within and around the city.

.034

.052

.079

.142

The second principal component has high positive loadings on total hardness, calcium hardness, calcium, total coliform and E.coli. This explains microbial contamination as a result of poor hygiene during the collection and transportation of the water in tankers. Some of the vendors do not clean their tankers at all and this can be a major source of contamination.

The third principal component has high positive loadings on colour, alkalinity, magnesium and magnesium hardness. PC3 is said to represent water hardness as a result of interaction between groundwater and geological formations.

The fourth principal component has high positive loading on sulphate and high negative loading on temperature. This is as a result of leaching of ions into the water as it passes through geological formations.

The fifth principal component has high positive loadings on pH and iron. This is the leaching of iron into the water as a result of the interaction between the tanker material and the water.



Fig. 2. Component plot in related space

4. Conclusion

There was no violation of the drinking water guideline values of physicochemical parameter except for pH and iron. Results show that the pH of the water sample vary for slightly acidic to neutral. Also, the presence of iron in the water is believed to be linked to the low pH values. There was also violation of the microbiological parameters. Microbial contamination in the tanker supplied water could be as a result of poor hygiene (washing of the tankers).

PCA and CA results shows us that contaminants present in the water could be through the influence of anthropogenic activities on groundwater chemistry and microbial contamination as a result of poor hygiene during the collection and transportation of the water in tankers.

It has been recommended that;

- Frequent cleaning of the tankers and hose to avoid microbial contamination.
- The vendors should ensure that they collect clean water (for example Ninth mile water) before distribution.
- The government should monitor and regulate the activities of the vendors to ensure that they deliver potable water to consumers.
- The government should penalize any vendor that fails to comply.

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Positive environmental impact of biodiesel as an alternative fuel

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Abstract: This research investigated the emmison impact of biodiesel in contrast to conventional diesel using a diesel engine test bed. The findings revealed that diesel engines fired with biodiesel and its blends exhibited reduced emissions of CO2, CO, and exhaust smoke when compared to standard diesel. At a brake power of 2kW, B100, B10, B20, B30, and B40 demonstrated CO2 emissions of 3.21%, 4.11%, 4.36%, 4.69%, and 4.81%, respectively, in comparison to diesel's emission rate of 4.97%. Additionally, CO emissions for these biodiesel blends were recorded at 0.06%, 0.12%, 0.13%, 0.17%, and 0.2%, respectively, in contrast to diesel's 0.2%. Furthermore, the levels of exhaust smoke observed for B100, B10, B20, B30, and B40 were 40%, 56%, 54%, 53%, and 42%, respectively, compared to diesel's 64%. These results underscore biodiesel as a promising alternative to conventional diesel, showcasing notable advancements in reducing both greenhouse gas and air pollutant emissions. Ongoing developments in feedstock sourcing, production technology, and sustainable practices further enhance biodiesel's potential. By offering substantial environmental benefits, biodiesel emerges as a pivotal solution in addressing environmental concerns while simultaneously contributing to bolstering energy security and diversification.

Keywords: emissions, biodiesel, transesterification, feedstocks

1. Introduction

Environmental concerns remain a critical challenge associated with energy generation derived from fossil fuels [1]. The escalating global population has intensified the demand for energy across diverse sectors, including transportation, mining, agriculture, and more [2]. Consequently, there has been a notable surge in the number of energy companies rooted in fossil fuel extraction and utilization. These industries collectively discharged approximately 37.12 billion metric tons of global carbon dioxide emissions (GtCO2). The emissions from fossil fuel sources exhibited a 0.9% upsurge in 2022, reaching a total of 37.5 GtCO2, as depicted in Fig. 1 [3].

From 1990 to 2022, statistical records reveal a staggering 60% increase in global CO2 emissions, predominantly attributed to the economic advancements of nations worldwide [4]. Notably, during the COVID-19 outbreak in 2020, there was a temporary 5% decline in CO2 emissions due to enforced restrictions leading to reduced activities [5]. However, the persistent emissions of CO2 and other hazardous gases could be mitigated significantly or even eradicated through the adoption of alternative energy sources, such as biodiesel [6].



Fig. 1. Statistics of GtCO2 Emission

Biodiesel presents a viable solution that holds promise in addressing the environmental repercussions associated with conventional fuel sources. By harnessing biodiesel for energy generation, the reliance

234

on fossil fuels can be diminished substantially, subsequently reducing or eliminating the harmful emissions typically produced. This alternative fuel source not only provides a potential remedy to mitigate environmental degradation but also offers a pathway towards sustainable energy practices. The utilization of biodiesel offers several advantages beyond emission reduction. It provides an opportunity to diversify the energy portfolio, diminishing the overreliance on finite fossil fuel resources. Furthermore, the production of biodiesel can be sourced from renewable raw materials, potentially alleviating concerns related to resource depletion and providing a sustainable energy solution.

Transitioning to biodiesel as an alternative energy source demands concerted efforts in research, technology development, and infrastructure enhancement. Innovations in production techniques, feedstock sourcing, and distribution networks are imperative to establish a robust biodiesel industry capable of meeting global energy demands while mitigating environmental impact. The integration of biodiesel into the energy matrix signifies a paradigm shift towards a more sustainable and environmentally conscious approach to energy generation. It represents a pivotal step in curbing the escalating emissions linked with fossil fuels, fostering a cleaner and greener energy landscape for future generations. Embracing biodiesel as an alternative energy source signifies a commitment towards combating climate change and advancing towards a more sustainable energy future.

1.1. Biodiesel Production

Biodiesel, derived from agricultural, animal, or residential waste such as fats, bones, waste cooking oil, and various plant residues like corn chaff and millet chaff, stands as a renewable and biodegradable fuel source [7]. This clean-burning fuel constitutes ester-based compounds, oxygenated and synthesized from natural, sustainable origins like virgin or used vegetable oils and animal fats. The production process, often termed transesterification or alkoholysis, involves the reaction of seed oils from plants, vegetable oils, or animal fats with short-chain aliphatic alcohols, typically methanol or ethanol [8]. Through this process, biodiesel production offers an eco-friendly solution, utilizing a range of waste materials while providing an alternative to conventional fossil fuels. This renewable energy source not only promotes sustainability but also contributes to reducing environmental impact by utilizing readily available organic resources in its production.

2. Method

2.1 Feedstock collection and preparation

Farmers gathered palm kernel shells and cocoa pods, which underwent grinding, filtering, and air drying to eliminate moisture from the feedstock. The specific weight of each material was gauged before using a Soxhlet extractor to determine its suitability for biodiesel production. The extracted bio-oil underwent transesterification to yield pure biodiesel (B100). This B100 biodiesel was subsequently blended with diesel in various proportions like B10, B20, B30, and B40, among others. The process involved the conversion of these agricultural residues into biodiesel and its blending with conventional diesel, marking a crucial step toward assessing their potential as alternative fuel sources.

2.2 Emission analysis

Emission analysis utilized an engine test bed along with an exhaust gas analyzer to ascertain emission levels as a percentage in comparison to conventional diesel fuels. The assessment encompassed crucial performance parameters such as carbon dioxide, carbon monoxide emissions, and exhaust smoke. This comprehensive evaluation aimed to gauge the emission levels of these specific pollutants concerning conventional fossil fuel benchmarks. The utilization of an engine test bed and exhaust gas analyzer facilitated a meticulous examination, providing essential data regarding the emissions produced by the engine while running on alternative fuels or fuel blends. This analysis served as a pivotal means to quantify the environmental impact and efficiency of the engine operating with these alternative fuel sources in contrast to traditional fossil fuels

3.1 Emission test of CO2 on brake power

Observations from Figure 2 indicate a direct correlation between engine load and combustion rate, leading to an augmented fuel combustion, subsequently resulting in higher CO2 emissions. Notably, in this investigation, pure petrol diesel exhibited the highest CO2 emissions. Conversely, as the proportion of biodiesel in the blends decreased from B10 to B40, there was a corresponding decline in emissions. Unadulterated biodiesel demonstrated the lowest CO2 emissions across the range of blend ratios. Throughout variations in brake power, the emissions of CO2 from petrol diesel consistently surpassed those of both biodiesel blends and unblended biodiesel. This trend highlights the propensity of biodiesel, particularly in its pure form, to significantly curtail CO2 emissions compared to traditional petrol diesel, demonstrating its potential as a more environmentally friendly alternative.



Fig. 2. Effect of brake power on CO₂ emission

3.2. Emission test of CO on brake power

As seen in Fig. 3, the diesel fuel emitted more CO than biodiesel. Biodiesel B_{100} has the least CO emission. Cumulative CO emission reduced as biodiesel blend ratio increased from B_{10} to B_{40} . CO emission generally reduced as break power increases following reduction in fuel oxygen content. Biodiesel has lower CO emission as it has initial higher oxygen content than petrol diesel.



Fig 3. Effect of brake power on CO emission

3.3. Emission test of exhaust smoke on brake power

Exhaust smoke test is an essential fuel combustion test expressed in percentage. As seen in Fig. 4, the biodiesel B_{100} and its blends had the least smoke emission percentage than the petrol diesel (D_{100}). Petrol diesel at 2.0 kW brake power has a smoke emission of 64%, while at same point biodiesel blend (B10) had an emission of 42%.



Fig 4. Effect of brake power on exhaust smoke emission

4. Conclusion

Biodiesel stands out as a highly promising alternative fuel source, showcasing remarkable emissionreducing qualities. Extensive research has consistently highlighted its impact on emissions, particularly in curbing greenhouse gases and air pollutants. This study aligns with previous findings, demonstrating that biodiesel and its blends emit significantly fewer pollutants compared to conventional diesel fuel. The conclusive evidence underscores biodiesel's efficacy as a cleaner burning fuel, solidifying its potential as a pivotal player in mitigating environmental impact within the energy sector.

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Performance evaluation of the travelling wave tube design for security and surveillance operations

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Abstract: This paper focuses on the performance evaluation of the travelling wave tube design for security and surveillance operations. The problems associated with travelling wave tube includes low operating efficiency and non-linear behavior associated with the system. Most significant parameters that affect the performance of the travelling wave tube are amplitude to phase modulation conversion, harmonic intermodulation, distortion and noise output injection which influenced the carrier-to-noise ratio of the radio frequency signal. The method employed involves the engineering design of various types of traveling wave tube (TWT), such as missile TWT design which requires minimal size and weight, high efficiency, moderate bandwidth and reliability that utilize unique cathode heater design. The instrumentation TWT design for laboratory and test equipment which incorporates a control grid that can be used to turn on and off TWT beam current. The electronic counter measure (ECM) design involves high continuous wave, high peak power and bandwidth. The RADAR TWT design requires high peak power and the communication TWT design needs high reliability, efficiency, linearity and moderate power output. In conclusion, these travelling wave tubes design can be used to track, monitor, block, attack terrorists, armed robbery, kidnapping and insurgences at various locations.

Keywords: Security operation, Travelling wave tube, Harmonic injection, Engineering design, Terrorism.

1. Introduction

The TWT contains an electron gun which produces and accelerates an electron beam along the axis of the tube. The surrounding magnet provides a magnetic field along the axis of the tube to focus the electrons into a tight beam. The helix, at the center of the tube, is a coiled wire that provides low impedance transmission line for the radio frequency (RF) energy within the tube. The radio frequency input and output are coupled onto and removed from the helix by waveguide directional couplers that have no physical connection to the helix. The attenuator prevents any reflected waves from travelling back down the helix [1]. The travelling wave tube is a high-gain, low-noise, widebandwidth microwave amplifier. It is capable of gains greater than 40dB with bandwidths exceeding an octave. The wide-bandwidth and low-noise characteristics make the TWT important for use as a radio frequency amplifier in microwave equipment. The travelling-wave tube is a microwave tube of special design using a broadband circuit in which a beam of electrons interacts continuously with a guided electromagnetic field to amplify microwave frequencies [2]. Microwave frequencies are generally identified as frequencies above 500MHz and at microwave frequencies, it is necessary to use electromagnetic theory to describe the electric and magnetic fields that exist in electromagnetic waves. The electron beam bunching normally starts at the beginning of the helix and reaches its highest expression on the end of the helix. If the electrons of the beam were accelerated to travel faster than the waves traveling on the wire, bunching would occur through the effect of velocity modulation. Velocity modulation would be caused by the interaction between the travelling wave fields and the electron beam [3].

Travelling wave tube are used for wide band amplification at microwave frequencies. The electrons are focused into a beam through the center of the helix by a powerful magnetic field around the length of the tube. A continuous wave signal is coupled into the gun end of the helix and as its travels around

the helix, the signal has its velocity reduced by an amount corresponding to the ratio of the length of wire in the helix [4].

The potential difference between the helix and the cathode is so adjusted that the electron beam itself is made to travel at a slightly larger velocity than the continuous wave signal. However, there will be continuous interaction between the electric field due to the electron beam and the electric field of the continuous wave signal so that the signal on the helix is amplified [5].

Bunching would cause the electrons to give up energy to the traveling wave if the fields were of the correct polarity to slow down the bunched action. The energy from the bunched would increase the amplitude of the traveling wave in a progressive action that would take place all along the length of the TWT.

The traveling wave tube amplifier (TWTA) is integrated with a regulated power supply and protection circuit. It is used to produce high power radio frequency signals. The bandwidth of a broadband TWTA can be as high as one octave with operating frequencies ranges from 300 MHz to 50 GHz. Broadband TWTAs generally used a helix TWT, and achieve less than 2.5KW output power. TWTAs using a coupled cavity TWT can achieve 15KW output power, but at the expense of bandwidth [6].

All these configurations can be adapted and designed for warfare systems for intelligence and security purpose such as the radar, electronic counter measure (ECM), space surveillance and missiles for tracking, monitoring, jamming and attacking. The trend in search radar has been toward much higher powers and towards new techniques which would have the effect of increasing visibility even while being jammed, good anti-jamming radar must be able to shift frequencies over a wide bandwidth quickly to avoid dwelling at the jammer's source frequency [7].

The travelling wave tube is a microwave device operating at a high frequency range of electromagnetic radiation. Microwaves exhibits several properties of visible light and they travel in straight lines at the speed of light and are only minimally refracted by the earth's atmosphere.

Microwaves can be focused into narrow beams which are subject to complete reflection when they impinge upon a conducting surface [8]. These properties make microwave especially useful for radar and telecommunications systems.

2. Method

The materials used for the design of a travelling wave tube are electron gun that produces a highdensity electron beam. The microwave slow-wave circuits that supports a travelling wave of electromagnetic energy with the electron beam interaction. The collector that collects the election beam that emerged from the slow-wave circuit and the travelling wave tube package which provides cooling for power of the beam focusing structure.

The method adopted involves the amplification of an electromagnetic radio frequency wave to travel along a propagating structure in close proximity to an electron beam. When the cathode is heated, it emits a continuous stream of electrons and these electrons are drawn through an aperture in the anode and are then focused into a well-defined cylindrical beam by a magnetic field. The beam was caused to travel inside the slow-wave circuit for the length of the tube. The electrons were finally collected and their kinetic energy was dissipated in the form of heat in the collector.

However, at the same time the cylindrical electron beam was moving along the length of the tube axis and the RF signal to be amplified was fed into the slow-wave structure consisting of a coiled wire called a helix. The RF energy travels along the helix wire at the velocity of light and the energy progress along the axial length of the tube at a considerably lower axial velocity, determined by the pitch and diameter of the helix.

The phase velocity of the RF wave was made slightly slower than the velocity of the electron beam and as a results, synchronism results in a continuous interaction between the electron beam and the RF signal. Some of the electrons in the beam were slowed by RF field while others were accelerated. As the velocity-modulated electrons moved down through the helix they form bunches. This bunches in turn overtake and interact with the slower helix RF wave surrendering kinetic energy to the wave on the helix and this results in a cumulative amplification of the radio frequency signal. Fig. 1. shows the block diagram of the traveling wave tube.



Fig. 1. Block diagram of a travelling wave tube

2.1 Controlling the Beam

The electron gun functions like the lens in a projector. The object is to get as much electron current as possible flowing within a concentrated beam without distortion. A good gun design is extremely important since the gun is the source of electrons for the beam. A wide variety of gun designs have been developed in an effort to provide well behaved electron beams that can be readily adapted to new travelling wave tube types. With increasing performance, demands in traveling wave tubes, the quality of the electron gun design is a key factor. Design tools, such as computer programs for analysis and gun analyzers for experimental evaluation are continuously upgraded and improved [9]. Electron guns used in traveling wave tubes are generally convergent. This means that the current density at the cathode is significantly lower than the current density in the beam and below a specified maximum value.

The design of high convergent guns is well established and is based on Pierce's spherical diode concept in which a conical flow of electrons converges into a well-defined beam having uniform current density across the beam cross sections. The design procedure provides data on cathode and anode radii of curvature and aperture angles but do not give sufficient details on the shape of the beam focusing electrode and anode.

The design of these electrodes can be determined with a large-scale computer program that enables the designer to evaluate a variety of electrode shapes and to establish an optimized configuration [10].

2.2 Analysis of the design and applications

The design of a TWT originates with the requirements to provide certain amount of gain and power over a certain frequency band. The final design of the TWT usually results from a tradeoff study that includes considerations involving the power supply, sometimes called the electronic power conditioner (EPC) and interfaces between the TWT and the system.

These considerations lead to compromises that affect each of the major subassemblies of TWT. These considerations include the type of slow-wave circuit to be used in meeting the power and bandwidth requirements including the selection of cathode voltage and current.

Again, the higher thermal dissipation capability in coupled cavity TWT circuits can provide two orders of magnitude greater power output capability than availability from TWTs having helix circuits at the consequence of increased size and weight. The method to be employed for focusing the electron beam. The method to be used for varying the beam current, including the method used for turning the TWT on and off as well as any modulation required during TWT operation. The environmental conditions such as ambient pressure, ambient temperature, shock and vibration levels. The type of cooling available and the size and weight limitations.

There are various areas of applications for using traveling wave tube design and these include radar travelling wave tube for airborne and sea level, electronic counter measure TWTs for airborne and sea level, TWT for space communications, missile TWTs for active seekers and instrumentation TWTs for laboratory and test equipment. Detail description of these design includes:

• RADAR TWTs for airborne and sea level

The RADAR TWT requirements are usually met by using TWTs that have either helix or coupled cavity slow-wave structures and solenoid focusing [11]. The features that influence the design of these TWTs are high peak power with moderate average power, moderate bandwidth, cooling and forced air or circulating liquid, operation at altitude usually requires high voltage leads that are encapsulated in dielectric fluid and operation in extreme environments requires rugged construction.

• Electronic Counter Measure (ECM) TWTs for airborne and sea level

The ECM TWTs make use of two categories namely those that requires high peak power and those that require high continuous wave. In most cases, the bandwidth must be wider than for radar TWTs because the exact frequency of operation is not defined until the threat is unidentified.

The helix-derived circuits are essential for those applications requiring octave or multiple octave bandwidths. Coupled-cavity circuits are required when the power requirement exceeds the capability of helix-type circuits and the reduced bandwidth can be tolerated [12]. Permanent magnet focusing is widely used in these devices. This design is very useful for air and sea surveillance, airborne and sea level operation, counter measures and attacks.

• Traveling wave tube in space communications

These features usually dictate that the TWTs have helix slow-wave circuits, high area compression ungirded election guns, periodic permanent magnet (PPM) focusing, multiple stage depressed collectors and conduction cooling. The use of a linearizer is often dictated by the linearity requirements. Linearized travelling wave tube amplifiers (LTWTAs) represent as integrated design in the designs of the TWT, EPC and linearizer are closely coordinated [2].

Features that influence the design of these TWTs are long life and high reliability, high efficiency, moderate power output (usually less than 300W), moderate bandwidth (1 percent to 5 percent), low phase and gain distortion and well controlled manufacturing facility and manufacturing documentation.

• Missile TWTs for active seekers

These TWTs are normally of the Periodic-Permanent Magnet (PPM) and normally utilize unique cathode-heater designs to provide fast warm up requirement and have multiple stage depressed collectors with conduction cooling [4].

The features that influence the design of this TWTs include minimal size and weight, narrow to moderate bandwidth, off to fully operational turn-on times of 1 second or less than 1 second, high efficiency and high reliability after long inactive storage periods.

• Instrumentation TWTs for laboratory and test equipment

These features are always considered by using travelling wave tube incorporating a control grid that can be used to turn on and off the TWT's beam current. The TWT acts as an RF amplifier only when the beam is turned on. Turning the beam off when no radio frequency output is needed results in a significant reduction in power consumption and the amount of heat to be dissipated [13].

The features that influenced the design of this TWTs include fold back protection, character alphanumeric display, existence remote status and control through a GPIB (IEEE-488) interface.

3. Results and Discussion

The results are obtained by considering detailed evaluation of the intermodulation distortion, harmonic injection, power versus frequency, conversion of amplitude and phase modulation, phase non-linearity or time delay distortion and gain flattens phase linearity and group delay of the travelling wave tube.

In intermodulation distortion, the results in intermodulation products was displaced from the carriers at multiples of the difference in frequency. When more than one carrier was introduced at the travelling wave tube input, intermodulation process took place through the TWT interaction.

The power levels of these intermodulation products are dependent on the relative power levels of the carriers and the linearity of the TWT. For amplitude and phase modulation, the intermodulation distortion was significantly reduced in the small signal region of the radio frequency drive range.

In the small signal region, the third order intermodulation output power decreases by 3dB for every 1dB decrease in input signal drive power. As a result, communications TWTs are operated below their saturation power level.

In harmonic injection, the efficiency enhancement was unique to broadband helix which does not involve any alternations of the internal parts of the traveling wave tube. Again, the correct amount of second harmonic when properly phased will increase the fundamental power output and suppress the second harmonic at the output of the amplifier.

In power against frequency characteristics, the power versus frequency should be nearly constant for efficient and effective operation of the traveling wave tube. This factor also assures that proper bandwidth, gains and noise figure were maintained thereby resulting in higher efficiency. For instance, for 1 stage depression of the collector, the efficiency increases to 52%.

When the depression was increased to 2 stages, the efficiency increases to 60%. Again, when the stage of collector depression was 3, the efficiency was 66% and when the depression was increased to 4 stages, the efficiency increases to 68%. The result indicates that the efficiency increases with the number of stages to which the collector was depressed.

In amplitude and phase modulation, conversion in traveling wave tube was caused by the reduction in beam velocity that occurs as the input signal level was increased and greater amount of energy was taken from the beam and transferred to the input radio frequency wave. At a level of 20dB below the input required for saturation, amplitude and phase modulation conversion was negligible. Also, beyond this point, amplitude modulation and phase modulation conversion increase sharply. In phase non linearity or time delay distortion, the same mechanisms which can change the gain variations as a function of frequency will also cause phase non linearity. Since time delay and phase are closely related, the mechanisms which cause phase non linearity are responsible for time delay distortion.

In gain flattens phase linearity and group delay, it was realized that within narrow bandwidths, the dominant effect upon radio frequency output flatness was the gain ripples. The gain ripple was always caused by some feedback path within the travelling wave tube. The effect of the signal traversing the feedback path can be degenerative depending upon the closed loop phase shift. Also, since traveling wave tube is electrically long, a small change in frequency can cause the closed loop phase shift to change by 360 degrees.

4. Conclusion

Traveling wave tube can be designed for various security operations and surveillance such as the electronic counter measures and missile applications, especially for electronic warfare which is a military action to take advantage of the enemies' use of electromagnetic spectrum.

Specifically, security operations and surveillance also include the radar TWT for airborne and sea level operations that check terrorist on the air, land and illegal bunkering and oil theft in the seas. Again, travelling wave design will also check criminals such as arm robbers and kidnappers and surveillance operation to check other insurgences such as illegal immigrants entering any country of the world, rail, road and air.

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Development of an SMS-based accurate notification system for improved pipeline leakages

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Abstract: In this study, an SMS-based accurate notification system for improved pipeline leakages is developed. Monitoring the flow rate of petrol and gas through pipe lines has been made easy through the use of hall effect water flow sensor normally connected within the pipe channel. The hall affect flow sensor is designed to generate pulses as the fluid passes through it and transmits these pulses to the ATMEGA328p micro-controller embedded within the admits UNO module used in this research. An additional 16x2 Alphanumeric Liquid crystal display (LCD) is incorporated in the design to persistently display quantities and variables like the volume and flow rate of the fluid in liter/minute (L/M). these results are consistently collated and the moment a decline or drop in the flow rate is perceived by the microcontroller, an error notification is forwarded via SMS to the user through the registered phone number providing information on the drop-in flow rate experienced. This research funds strong relevance in numerous applications ranging from gas factories water board stations amongst other areas where the flow rate of fluid is needed and a means of dissemination of a fact condition is required.

Keywords: Pipeline Leakage, Notification System, Leakage Detection, SMS

1. Introduction

The effective management and maintenance of pipelines are crucial for ensuring the safe and reliable transportation of fluids such as oil, gas, and water. Pipeline systems are subject to various risks and potential failures, including leaks, corrosion, and mechanical damage, which can lead to environmental hazards, disruptions in supply, and significant economic losses. To mitigate these risks and enhance the efficiency of pipeline maintenance, the development of an improved and accurate notification system is essential. Traditionally, pipeline maintenance has relied on periodic inspections and manual monitoring, which can be time-consuming, costly, and prone to human error. These conventional approaches often result in delays in identifying and responding to maintenance issues, increasing the chances of accidents or breakdowns. To overcome these limitations, there is a growing need for a more advanced and automated notification system that leverages cutting-edge technologies to detect, analyses, and to communicate pipeline maintenance requirements promptly. [10] Using wireless sensor networks, a data collection system for irrigation and gas pipelines is described. The design outcomes from the experimental prototype of a wireless sensor-based network for gathering pressure data for watering systems and gas pipelines were reported by the authors in this paper. The system's foundation consists of Telos B motes arranged in a WSN with an appropriate network protocol that also offers data control and aggregation.

The [12] research was presented. A study titled "Smart Pipes: Smart wireless sensor networks for leak detection in water pipelines" examined wireless smart sensor networks, which the authors claimed to be a practical method for keeping track of subterranean water pipes' pressure and, consequently, leaks. Their advantage over other widely used leak detection techniques is that they have some degree of redundancy, allowing for continuous monitoring without human involvement and preventing individual bad nodes from making the entire system obsolete. Smart wireless sensor networks with ultra-low power consumption can operate without maintenance for long periods of time. They can now be used with both traditional and cutting-edge power sources as a result [2] "Oil and Gas Pipeline Monitoring during COVID-19 Pandemic via Unmanned Aerial Vehicle" research was presented. He discussed the idea of using drones to conduct inspections and recording video and pictures in order to find potential hazards before they become serious. He also provided details of a survey that professionals in the oil and gas sector had undertaken to determine the functional and

non-functional requirements of the suggested system. In [9], reliable solution was developed in the study titled "Remote Pipeline Monitoring Security System" for the wireless monitoring of the pipelines for various parameters that were embedded together. Remote monitoring was used to wirelessly monitor the pipelines in real time and report to the control center whenever a value was found that was higher than the threshold value. These pipelines underwent remote monitoring, which meant watching them from a distance. Temperature, relative humidity, dew point, liquefied petroleum gas leakage, liquefied petroleum gas leakage rate, liquefied petroleum gas leak rate, movement of persons around the facility, fire, and smoke are the variables that are tracked. A monitoring device was created and built to keep track of these parameters. To provide a reliable method of remotely monitoring the pipelines, a monitoring device for these parameters was designed, built, and software in the C programming language was created to communicate with the hardware.

[4] The principles and approaches are in "Recent Advances in Pipelines Monitoring and Oil Leakage Detection Technologies: Approaches". analyzed the state-of-the-art accomplishments of various leak detection and localization systems and conducted research on pipeline leak detection technology. The best leak detection technique for a given operating environment was chosen using comparative performance studies as a guide. The location of sensors in pipeline monitoring is then brought to the attention of additional study. Before a complete real-time leakage detection in the pipeline can be realized, research gaps must be filled.

Radio Frequency Identification (RFID) and mobile sensors based on MICA were combined in the study published in "Remote pipeline monitoring using wireless sensor networks" [11] to enable effective remote pipeline monitoring. A prototype model was developed that enables actuators to react to detected anomalies while allowing a topology-aware robot agent to sense desired parameters. The system's cost and scalability were shown through thorough testing, but additional study is required to track the effects of fluid on mobile sensors. [14] developed a wireless sensor network of mobile sensors that may be employed inside the water pipelines in their study titled "Mobile sensor networks for optimal leak and backflow detection and localization in municipal water networks." A mixed integer nonlinear optimization problem is used to solve the placement of sensors and beacons in a single joint formulation. It was determined that the disjoint method was an effective and reliable solution for solving the sensor and beacon placement problem in WDSs due to the joint formulation's time complexity. In a later project, algorithms will be extended to WDSs with dynamic pipe flow rates.

In their article "Operation of remote mobile sensors for security of drinking water distribution systems [6] examined a mobile water sensor that can wirelessly capture and send data as it is being constructed and manufactured. Several test results showed that adding inline observatory systems to online monitoring systems was an effective strategy to boost security and reduce the mean time of threat detection.

In the 2015 publication by. [8] Four wireless sensor network (WSN) methods for detecting leaks, including magnetic induction-based WSN for underground pipeline leakage detection and localization, were reviewed in "Sensors for Fluid Leak Detection. Sensors". Due to its low attenuation, this technology offers an inexpensive monitoring system and low power consumption for underground wireless communications. Even so, there is still room for improvement in terms of communication range, effectiveness, and dependability.

In a paper titled "Leak detection in gas pipeline by acoustic and signal processing" published in 2015, [1] discussed the fundamental wave propagation in gas pipelines and various techniques that exposed the signal's hidden information through the simulation of synthetic signals. In the pipeline system, wave propagation caused friction to be created, which was a key factor in the leak detection process. The results showed that the optimum method for detecting gas pipeline leaks is to use acoustic signal as the wave propagation and Hand-Held terminals (HHT). To quickly detect leaks, properly estimate

their location, and manage the reduction of false alarms, more simulations and tests must be performed.

In 2013 [3] Introduced four Wireless Sensor Network methods for leak detection in "Wireless Sensor Networks for Leakage Detection in Underground Pipelines". The use of WSNs with magnetic induction technology for locating and detecting subterranean pipeline leaks was discussed. This approach used magnetic induction for underground wireless communications, which looks to be efficient due to its low attenuation and provided a low-cost monitoring system and power usage. Despite the fact that this research introduces the theoretical framework for MI-based, the solution is limited to liquid pipelines. For effective leakage detection that offers accurate and real-time detection, Wireless Signal Networks (WSN) and underground to above ground WSN were also suggested methods. Only point measurements of the soil's characteristics can be provided by the WSN, and the data must first be processed before being sent. To effectively increase its communication radius and resolve the current problems, it will need to put in a lot of future work.

"Wireless and Mobile Technologies for the Internet of Things [7] presented a cloud-based trust management scheme (CbTMS), which was also suggested for use in networks for mobile crowd sensing (MCS) in order to detect Sybil assaults. The proposed CbTMS framework may manage trust and conduct reputation checks to validate the MCS network's nodes. To find suspicious Sybil nodes, it combines two systems, namely the Characteristics Checking Scheme (PCS) and the Trust Credit Assessment (TCA). While TCA was suggested for determining how trustworthy the suspicious Sybil nodes, such as time, density, and topology in the MCS.

[5] "Pipeline Monitoring System by Using Wireless Sensor Network" In this study, a sensor network platform for pipeline system monitoring was described. They covered how sensor networks can locate and quantify bursts, leaks, and other irregularities in pipeline systems in their paper. According to research, active sensing technologies like Lead Zirconate Titanate (PZT) for simultaneous actuation and sensing can be used to detect faults over a wide region. For the purpose of creating and monitoring guided waves that travel along the pipes, PZT sensors can be installed on the curving surface of the pipelines. In order to attain adequate performance for real-time monitoring, we will talk about approaches to cope with the Lamb wave dispersive propagation.

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2. Method

2.1. Design and system description

This design is done using the Arduino having embedded within it, the ATMEGA328P microcontroller which constitutes the brain of the entire design. Other fundamental components employed in the design are the YFS201 water flow sensor, 16×2 Liquid Crystal Display (LCD), SIM8OOL GSM module and ESP8266 Wi-Fi module.

The assembly of these components were used to monitor the flow of fluid, through the pipes. As the fluid flows through the pipes and through the water flow sensor, pulses are generated dependent upon the rate of flow and pressure of the flowing fluid and then consistently sent to the microcontroller. This information regarding the rate of flow is furthermore, progressively communicated to the user through SMS text messages through the registered phone number and then results of the rate of flow also uploaded on the Think Speak cloud environment where they can be accessed from anywhere in the world.

This method is employed as a prototype which with no doubt, is sufficient enough to be used as a model for monitoring pipe lines in different regions and locations. Multiple units of these can be scattered around different region where the rate of flow of fluid, in this case petroleum is to be measured and the data disseminated. These multiple units are tagged as seen below for different regions.

- Unit 1
- Unit 2
- Unit 3
- Unit 4
- Unit 5
- Unit 6
- Unit 7
- Unit 8
- Unit 9
- Unit 10

These units represent duplicated version of these design proximate in ten different regions where the data was collated both through the SMS received from each of them and the database in the environment which provides up to data information on the condition or rate of flow of the fluid in the pipe lines.

Features of Flow Sensor:

Model: YF-S201

Sensor Type: Hall effect

Working Voltage: 5 to 18V DC (min tested working voltage 4.5V)

Max current draw: 15mA @ 5V

Output Type: 5V TTL

Working Flow Rate: 1 to 30 Liters/Minute

Working Temperature range: -25 to +80°C

Working Humidity Range: 35%-80% RH

Accuracy: ±10%

Maximum water pressure: 2.0 MPa

Output duty cycle: 50% +-10%

Output rise time: 0.04us

247

Output fall time: 0.18us

Flow rate pulse characteristics: Frequency (Hz) = $7.5 \times$ Flow rate (L/min)

Pulses per Liter: 450

Durability: minimum 300,000 cycles

2.2. Arduino uno

This is the brain of the entire design; it determines the operation of the entire system by managing the information received from the water flow sensor and projecting resultant feedback both on the LCD and SIM800L GSM module. It receives consistent data from the flow sensor on the flow rate of the fluid and adequately relates that to the user through the registered phone number encoded within the program as expected. This Arduino UNO module has embedded within it the ATMEGA328P microcontroller which is the main processing unit in the module.



Fig. 2. Circuit diagram of a fluid sensor with SMS notification system

2.3. SIM800L GSM module

This module is configured and designed to transmit information received from the Arduino UNO on the condition and nature of flow of the fluid based on the cooling sequence and to the registered phone number encoded in the programming of the micro-controller through SMS. It has a VCC voltage input of 3.7v to 4.2v and is connected to the Arduino UNO through the transmitter and receiver pins (Tx and Rx).



Fig. 3. Block Diagram of a Fluid Flow Sensor with Cloud Based Notification System



Fig. 4. Block Diagram of a Fluid Flow Sensor with SMS Notification System

2.4. YFS - 201 water flow sensors

This sensor transmits pulses consistent with the degree of rotation of its valves caused by flow of the fluid passing through it. As the fluid passes/flows through it, it carries a rotation of those value which in turn, causes the transmission of pulses sent to the Arduino UNO board to initiate certain working condition. The flow rate of the fluid is monitored by this sensor and then communicated to the microcontroller.

3. Results and Discussion

The result of the flow is obtained as prepared in the code using the expression below,

X = pulse in (input, H GH);

Y = pulse in (input, Low);

This expression above depicts the time ON and time OFF of each pulse generated from the fluid flow sensor which is dependent upon how many liters of fluid or the fluid flowing through per minute

The TIME = X+Y i.e., for one complete cycle.

Frequency = 1000000/TIME;

Fluid (L/m) = Frequency /7.5; -flow rate

The above expression for the time and frequency is dependent upon the flow rate pulse characteristics of the YFS201 hall effect water flow sensor as seen below.

Flow rate pulse characteristics: frequency (Hz) = $7.5 \times \text{flow rate (L/m)}$

Liter/second (L/s) = FLUID/60;

Now, for every liter of fluid that flows through the pipe and by extension, the senor, it was observed that the flow sensor outputs 4.5 pulses, hence, 5 liters of fluid were used for demonstration and the results below were obtained from the LCD screen for every 0.5 liter. The graph in Figure 4 and 5 shows the results.







Fig. 6. Graph of Time against Volume/ Pulses/Flow Rate

3.1 System testing

The developed system was tested using functional testing method. A set of test cases was created based on the system requirements. Figure 6 shows the text message alert during the testing process. The pressure drop text message was sent when the detected rate of flow dropped below the set parameter in the Arduino program. The message consists of the location or unit being monitored, time of monitoring and an indication of a drop in pressure or flow.



Fig. 7. Notification message via SMS



Fig. 8. Diagram of SMS Notification of the Pressure-Drop



Fig. 9. Results displayed from the Liquid-Crystal Display (LCD)

3.2 LCD display (16 x 2)

This liquid crystal display is saddled with the task of presenting a visual pipeline of the operation and condition of the Arduino UNO dependent upon the sequence of coding done in the micro controller. It takes a VCC voltage input of 5v and receives data from the Arduino UNO module through its Rs, E, D4, D5, D6, D7, pins and its backlight powered through a 5v voltage potential.

4. Conclusion

In conclusion, the Development of an SMS-Based Accurate Notification System for Improved Pipeline Maintenance is a significant step towards enhancing the safety, efficiency, and reliability of pipeline infrastructure. By integrating remote sensing technologies, data analytics, real-time monitoring, machine learning, and a user-friendly interface. This system addresses the limitations of traditional approaches and offers several key benefits.

Furthermore, the integration of automatic capturing algorithms enhances the accuracy and reliability of the notification system. By developing robust models, the system can effectively differentiate between normal operational conditions and potential maintenance issues, minimizing false alarms and improving overall efficiency.

In the future, further advancements can be explored, such as the integration of advanced technologies like artificial intelligence and blockchain for enhanced monitoring, analysis, and security. Collaboration with industry stakeholders and wider adoption of the system will also be essential for its long-term success and widespread implementation. Overall, Development of an SMS-Based Accurate Notification System for Improved Pipeline Maintenance represents a significant advancement in the industry, offering a proactive approach to mitigate risks, optimize maintenance operations, and ensure the reliable functioning of pipeline infrastructure.

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Monitoring of leakages in crude oil/gas pipelines using a wireless system network internet of things (IoT)

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Abstract: In this study, the use of an internet of things (IoT) analytics platform service to mimic real-time pipeline monitoring and determine the location of damage on a pipeline. The whole network comprises mainly of HK1100C oil pressure sensor, Arduino Uno board containing ESP32 Micro- controller Wi-Fi, SIM900L GSM module, JHD162ALCD module, audio alarm buzzer, 9V supply. The ATmega328P microcontroller was programmed in C++ programming language. When deployed in Nigeria pipelines, the wireless sensor network is able to monitor oil pipelines against leaks and therefore reduce environmental degradation and economic losses resulting from oil leakages. An Arduino and a Wi-Fi module were combined, programmed and used to produce the wireless communication device which interface with the analytics platform. Signal data was collected once every 15 s and all the channels were updated every 2 min. Thing Speak provided instant visualizations of data posted by the wireless communication device. Online analysis and processing of the data was performed as it came in. Results showed that a drop in pressure is associated with leak and the wider the size of the leak, the more drop in pressure that is observed. The experimental results obtained showed that the performance of the wireless communication device compared satisfactorily with the data logger and successfully detects the location of damage on real pipelines when used for real time monitoring. Using this communication device and an analytics platform, real-time monitoring of pipelines can be carried out from any location in the world on any internetenabled device.

Keywords: Leakage monitoring, crude oil/gas pipelines, wireless sensor system, internet of things (IoT), real-time monitoring

1. Introduction

In this study, we demonstrate the usage of an internet of things (IoT) analytics platform service to identify pipeline damage locations and simulate real-time pipeline monitoring. In order to gather data from the five sensors utilized in the experimental test rig using wireless connection, a total of ten (10) channels were constructed on the platform. Every 15 seconds, signal data was gathered, and every 2 minutes, all the channels received updates. The wireless communication gadget posted data, which Thing Speak instantly visualized. ThingSpeak allows you to aggregate, visualize and analyze live data streams in the cloud. Some of the key capabilities of ThingSpeak include the ability to easily configure devices to send data to ThingSpeak using popular IoT protocols and visualize your sensor data in realtime.

Data processing and analysis were done online as it came in. A second test setup was constructed that processed data using a data logger. Using the data recorder and air as the transport medium, the recorded pulse propagation velocity was 355 m/s. Between 4.243 m and 4.246 m was the range of the computed estimations of event location for the 50 measurements made. In comparison to the actual measured event location of 4.23 m, this had a scatter of just 3 mm. The results of the experiment demonstrated that the wireless communication's performance The testing findings demonstrated that, when utilized for real-time monitoring, the wireless communication device's performance could be satisfactorily compared to that of the data logger and was capable of locating damage on actual pipelines. Real-time pipeline monitoring can be done on any internet-capable device from anywhere in the world using this communication tool and an analytics platform.

[12] considered the use of Wireless Sensor Networks (WSNs) with Internet of Things (IoT) technology in oil pipelines, which offers options to deal with these issues. Wireless wide area network technology, which connects battery-operated, low-bandwidth devices across large distances. LPWAN
single-hop LoRa model is also used to monitor above-ground oil pipelines. Two scenarios were used to assess the LoRa model's scalability and capacity before the results were discussed. [16] designed and built an intelligent network of wireless sensors to monitor the water supply network. The ideal arrangement of pressure measuring stations was investigated using a matrix of pressure sensitivity coefficients. The leakage simulation was completed by setting the injector coefficient on the basis of online pressure monitoring. The monitoring requirements of urban water supply networks and the reasons why the current SCADA system and commercial monitoring equipment cannot meet the application of pipe network monitoring are presented, with a goal of building a multilevel networked water supply monitoring system to achieve the monitoring network requirements of large-scale, low-cost, and low-power.

[4] used an acoustic approach to detect gas leaks in pipeline systems. When a leak develops, a major component of the acoustic approach is the wave propagation in the pipeline, and the friction between the pipe's walls will provide the pressure balance. In order to deconstruct the raw signal and display it in time-frequency, signal processing is performed. Future comparison studies can make use of the acoustic method's findings. The most effective approach to find leaks in gas pipelines is acoustic signal and HHT. To quickly determine leaks and estimate, more simulations and experiments must be conducted.

[19] presented a wireless sensor network (WSN) that incorporates pressure sensors, an Arduino board with an 8-bit AVR family microcontroller (ATmega328P), a GSM module, and an LCD for data acquisition, processing, communication, and analysis, to be used for the localization of leaks (whether caused by the environment or by humans). At a predetermined place along the prototype oil pipeline, an experimental assessment of the relationship between leaks or bursts and pressure changes was conducted. The findings indicated that a leak is connected with a loss in pressure, and that this drop in pressure increases with the extent of the leak. The pressure parameter is monitored in the prototype pipeline (field or transmitting section) using the ideas of signal (energy) conversion and processing in a modular manner. The pressure information (signal) is transformed into an electrical signal, processed, and sent as radio waves before being received at the monitor or control centre (master or receiving section) once the monitored pressure drops below a minimum predetermined pressure point. The buzzer and LCD are driven by electrical signals that were originally converted from the radio signals that were received. By monitoring pressure changes along the pipelines, we came to the conclusion that a wireless sensor network had been set up that could monitor oil pipelines for leakage. However, more study is required. [13] suggested a multiparameter handover process optimization technique based on a vertical handover scheme for M2M communications in Hetmanate. He intends to create an optimization method based on fuzzy logic and decision modelling for subsequent work. [17] compared the leak signal with the disrupting signal using the methods for extracting the time and frequency domain from acoustic signals using test data. The methods for identifying and extracting acoustic signals are tested and compared, and the results show that while the analysis of the time and frequency domain can effectively remove disturbing signals, the new characteristics of the accumulative value difference, mean value difference, and peak value difference of signals in adjacent intervals can detect leaks effectively and significantly lower the false alarm rate.

[7] explored the idea of sensor networks, which has been made feasible by the fusion of digital electronics, wireless communication and microelectromechanical systems technology. First, a review of the elements impacting the design of sensor networks is given, followed by an examination of the sensing tasks and prospective applications for sensor networks. After that, the communication architecture for sensor networks is described, and the literature's created algorithms and protocols for each layer were examined. [1] claims that pipeline failures have severe negative effects. Fire catastrophes are the outcome, destroying cash crops that could have been harvested and sold for profit. Therefore, it is essential that current policy frameworks be reviewed, and that a thorough regulatory framework be introduced and put into place with effective enforcement and monitoring systems that can help to maintain proper safety management systems in order to reduce pipeline failures and vandalism incidents. [2] presented the findings of a research that was done with a pipeline in late 2004. The respondent comes to the conclusion that the top four causes of pipeline incidents that reduce productivity are sabotage, corrosion (both internal and external), mechanical impact, and equipment failures. Pipeline integrity managers should therefore create a data integration approach that enables integrity managers, risk assessment experts, and pigging engineers to see and analyse information in order to limit the causes of pipeline incidents. [3] evaluated numerous attempts to situate the causes, effects, and implications of the phenomena of oil thefts, illegal bunkering, and pipeline vandalism in relation to Nigeria's economy, regional security, and national security. The study found that vandalism and illegal bunkering have caused the Nigerian government and oil firms to experience economic hardship, as well as environmental damage, insecurity in the Niger Delta, and a threat to global and national security. The work also looked at the attempts made by various Nigerian governments to address the issues, and it was suggested that failure had occurred because of enthroned corruption by Nigerian elites, a high rate of youth unemployment, institutional decay and dysfunction, poor governance, ineffective and corrupt law enforcement agencies, international crime collaborations, a lack of political will by those in power, wealth, etc. [5] highlighted the negative effects of pipeline failures because it would be a waste of resources if not done in a systematic and efficient manner. They also stressed the necessity for the Nigerian government to expressly address these threats by putting in place remedial measures and benchmarking performance against clearly defined criteria.

According to [6], recent developments in wireless sensor networks have spawned a plethora of novel protocols created especially for these networks, where energy awareness is a key factor. The routing protocols, however, have received the majority of attention because they can vary based on the application and network architecture. This research analyses current sensor network routing methods and provides a classification of the various strategies used. Data-centric, hierarchical, and location-based categories are the three main ones that are examined in this research. The relevant category is used to describe and discuss each routing protocol. In addition, protocols use cutting-edge approaches like network flow and quality of service modelling

In [8], a shipwreck in Kattegat was used as a case study to evaluate the danger of an oil spill using the created model. Expert elicitation and Bayesian updating are used in an FTA framework to assess the likelihood of spill from the wreck. [9] presented an innovative approach to (a) collect divergent spatiotemporal data on pipeline interception of oil, (b) statistically assess regional variations in pipeline interception, and (c) connect interception with socioeconomic characteristics to assist identify patterns. The coarse spatial resolution at which the pipeline-related data are collected at source is a drawback of this investigation. Examining interdiction statistics, identifying spatiotemporal patterns, and discussing correlations with socioeconomic variables revealed the following findings: (a) a strong inverse relationship between pipeline interdiction and poverty; and (b) statistically and nonstatistically significant mean differences in the pattern of interdiction occurrence among the five geographic regions. Finally, we emphasize the importance of improving data collecting and reporting in order to lessen the adverse socio-environmental effects of interdiction incidents. [11] measured a simultaneous oil and gas flow in pipelines with a diameter of four to ten inches. These findings were compared to information from the literature for pipelines with a diameter of 1.5 to 3 inches. For the purpose of forecasting the pipeline flow pattern, a generalized chart was created using previously disclosed data. The flow patterns mentioned include stratified flow, annular flow, bubble flow, plug flow, wavy flow, slug flow, and plug flow. It was demonstrated that the generalized flow pattern chart and our experimental results were compatible. A modified version of the aforementioned method is described, with a separate equation for each type of flow pattern.

This study shows a thorough investigation on data aggregation, specifically as it relates to WSNs. In this study, a methodical examination of data aggregation in WSNs was presented. This research covered data aggregation methodologies, tools, methodology, and problems. The research literature has also proposed potential research questions and directions.

2. Method

2.1. Approach

The method of monitoring crude oil leakage system was successfully done using a flow sensor which gave the flow rate, and total volume by simulating the output of the total flow/volume of the system. Moreover, the Hall-effect-based Temperature and Humidity Sensor (DHT11). (a hall effect sensor is a type of sensor which detects the existence and amplitude of a magnetic field utilizing the Hall effect).

VH = -VdBd where Vd is the drift velocity of the charges.

The Hall voltage was employed to measure the drift velocity since it is proportional to the magnetic field. A Hall sensor's output voltage is inversely proportional to the field's intensity. a piece of magnet placed on a circumferential disk that revolves around the Hall effect sensor, which is read by the

microcontroller unit (ATMEGA328P, Arduino), served as the basis for how the flow sensor evaluates the flow rate and volume. By identifying the first change or threshold for the system's flow, the Temperature/Humidity Sensor (DHT11) provided a real-time picture of the rise and fall in temperature and humidity as it influences crude oil leakage. However, the magnetic field perpendicular to the electric current induces a voltage differential in a conductor, according to the Hall effect calibration. In this case, a tiny fan or propeller-shaped rotor was placed in the fluid flow path to take advantage of the Hall effect in the flow meter from which all simulated readings were viewed and analysed via a cloud server (thingspeak.org).

This study's goals are to examine potential solutions to the problems caused by oil pipeline vandalism for the Niger Delta's population, economy, and agriculture. Human existence and economic progress are the dependent variables, and oil pipeline vandalism/vandalism is the independent variable. The link between the variables can be described as follows:

| HE = f(OPV) | (1) |
|-------------|-----|
| | |

$$ED = f(OPV) \tag{2}$$

Hence, the models to be adopted for this study are as follows:

$$HE = 0 + 1OPV + U \tag{3}$$

$$ED = 0 + 1OPV + U \tag{4}$$

Where;

HE = Human Existence

- ED = Economic Development
- OPV = Oil Pipeline Vandalization
- 0 = Constant
- 1 = Parameter estimate

U = Error term or stochastic variable

Apriori Expectation: 1 < 0.

2.2. Design of the communication (GSM) unit

The communication (GSM) unit was made up of a SIM800L GSM module and a dc power source. The SIM800L is a cellular module which allows for GPRS transmission, sending and receiving SMS and also for making and receiving voice calls. Low cost, small footprint and quad band frequency support marked this module the perfect solution for this project work. After connecting power, the module boots up, searches for cellular networks and login automatically. Selecting SIM800L for this design was based on the following specifications:

- Supply voltage: 3.8V 4.2V
- Recommended supply voltage: 4V
- Power consumption:
 - \blacktriangleright sleep mode < 2.0mA
 - \blacktriangleright idle mode < 7.0mA
 - ➢ GSM transmission (avg.): 350 mA
 - ➢ GSM transmission (peak): 2000mA
- Module size: 25 x 23cm
- Interface: UART (max. 2.8V) and AT commands
- SIM card socket: micro-SIM (bottom side)
- Supported frequencies: Quad Band (850 / 950 / 1800 / 1900 MHz)
- Antenna connector: IPX
- Status signalling: LED

- Working temperature range: -40 do + 85 ° C
- RING (not marked on PBC, first from top, square) LOW state while receiving call
- DTR sleep mode. Default in HIGH state (module in sleep mode, serial communication disabled). After setting it in LOW the module woke up.
- MICP, MICN microphone (P + / N -)
- SPKP, SPKN speaker (P + / N -) Pinout (bottom side - right):
- NET antenna
- VCC supply voltage
- RESET reset
- RXD serial communication
- TXD serial communication
- GND ground
- In this design, the GSM module was interfaced to the Arduino microcontroller through the serial pins.
- Communication was provided by the MTN network provider using the SIM card.

2.3. Design of software for the field sensor node

The development environment for the system software was Arduino Software (IDE), and the programming language was C++. The system software was divided into two programs: the main processor program, which was responsible for processing the pipe pressure parameters collected by the sensor(s), and the GSM communication program, which was designed for sending the pipe pressure parameters. The integration of the two programs enabled the node to sense, collect, process, and transfer the low-pressure information to the master node.

The microcontroller was programmed in the C++ programming language to follow the flowchart shown in Figure 1.







Fig. 2. Logic diagram of the system circuit



Fig. 3. Microcontroller unit



Fig. 4. Complete simulated master circuit diagram

3. Results and Discussion

3.1 Energy equations and flow rate

The following energy types exist in a flowing liquid or gaseous medium. Potential energy due to position energy, pressure energy and kinetic energy.

| Position energy | Pressure energy | Kinetic energy |
|-----------------------|---------------------|-------------------|
| $= m \times g \times$ | $hm \times p/\rho$ | $m \times v^2/2$ |
| m = mass | p = static pressure | v = flow velocity |
| g = gravity | $\rho = density$ | h = height |

According to Bernoulli Law of conservation of energy, the sum of energy at every location in the flow passage or pipeline must remain constant. So, the mass flow qm is constant giving

 $g \times h + p/\rho + v^2/2 =$ Constant

For pipelines, position changes are minor so qm becomes:

(5)

 $p/\rho + v^2/2 = Constant$

So, for monitoring at different locations or points1 and 2, etc along the pipeline,

$$p_1/\rho + (v_1^2)/2 = p_2/\rho + (v_2^2)/2$$
(7)

In this research, monitoring is expected at several locations along the pipeline through different terrains and from equation (8) the mass flow or volume flow should normally be the same at each location.

Re-arranging equation (8) provides the equation when a pressure drop occurs due to significant leakage or damage to the pipeline.

Change in pressure,

$$\Delta p = p1 - p2 = \rho/2 \quad (v \quad 2^2 - v_1^2)$$
(8)

The Flow sensor was configured to measure either Flow volume V or the velocity, v.

3.2 Experimental results presentation, analysis and discussion

Using the experimental circuit built, the flow rate, temperature, pressure and humidity data were measured and recorded using data log software and Sim800L 5V Wireless GSM GPRS Module. The data were saved in the cloud using "thingSpeak.org". The measured and recorded results were presented. ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize, and analyze live data streams in the cloud Simulation results for flow rate condition

With an Arduino-uno and a water flow sensor, a IoT-based monitoring system was created in this research. It was connected to the YFS201 Hall Effect Flow Sensor. A cloud visual was displayed to show the total volume and flow rate. The hardware was integrated with the IoT Server. The "Thing speak App" as an IoT server was created. The information about the flow rate and volume was uploaded to Thing speak Server and accessed/ monitored from anywhere in the world by login in into with ThingSpeak.org using the email and the password that was created with it. Looking at the figure above being the Simulation Results for Flow Rate Condition, the flow rate shows drop of pressure indicating that there was a leakage at the pipeline. As shown below.

Figure 5 to 7 shows the rate of flow of the fluid from 2nd August to 5th 2023. August indicating a rise from zero to ten, a drop and then a consistent rise through 3rd, 4th and 5th August, 2023. This means that between 2nd August and 5th August, 2023. There was a drop and then rise in the flow rate of the fluid as seen in the chart below.



Fig. 5. Graphical simulation of an ideal flow rate condition chart 1

(6)



Fig. 6. Graphical simulation of an ideal flow rate condition chart 2

This chart above depicts a consistent drop in the flow rate of the fluid as it flows through the pipe. This drop happened between 3:00 and 3:20 PM. It indicates a leakage in the pipeline.



Fig. 7. Graphical simulation of an ideal flow rate condition chart 3

The flow rate as seen in Figure 7 shows that the flow rate remained at zero indicating that there was no flow of fluid between 3:15 and 3:30 PM. Nevertheless, the flow remains stable when there is no vandalization, leakages or corrosion.

Simulation results for volume condition

The volume of the fluid as seen in Figure 8 and 9 shows the volume rising from zero at about 3:35 through 6.75 litres even beyond 7 litres up to about 7.15 litres then remained constant.



Fig. 8. Graphical visualization of the ideal volume condition



Fig. 9. Graphical visualization of the volume condition

Here the volume of the fluid remained at zero from 3:20 up to 3:31 and then rises to 7 litters and then further rises to 7.5 litters at about 3:35.

4. Conclusion

Gas and crude oil pipeline monitoring is essential for the safe and effective transit of these resources. One advantage of a wireless system network is that it is scalable, allowing pipeline operators to easily add new sensors or expand their network as needed. This is especially important for pipeline that are located in remote areas, where access is limited and traditional monitoring method may not be feasible. A wireless system network for monitoring crude oil and gas pipeline is also relatively low-cost compared to other monitoring method, as it eliminates the need for physical infrastructure, such as wiring and communication towers. This makes it attractive option for pipeline operators who want to monitor their pipeline without incurring significant expenses. By implementation of a wireless system network (IoT), pipeline operator can ensure the safe and efficient transportation of crude oil and gas, and minimize the impact of any incidents that may occur.

In this study, we presented the use of an internet of things (IoT) analytics platform service to mimic real-time pipeline monitoring and determine the location of damage on a pipeline. Pressure pulses, based on the principle of vibration in pipes were used for pipeline monitoring in this study. The principle of time delay between pulse arrivals at sensor positions was also adopted in this study. An Arduino and a Wi-Fi module were combined, programmed and used to produce a wireless communication device which communicates with the Thing Speak internet of things (IoT) analytics platform. A total of ten channels were created on the platform to collect data from the ten sensors that were used in the experimental test rig that made use of wireless communication device. Signal data was collected once every 15 s and all the channels were updated every 2 min. Thing Speak provided instant visualizations of data posted by the wireless communication device. Online analysis and processing of the data was performed as it came in. A second test rig was built that made use of a data logger for processing of data. The measured velocity of pulse propagation using the data logger to transport fluid was 355 m/s. The computed estimates of event location for the 50 measurements taken ranged between 4.243 m and 4.246 m. This had a scatter of just 3 mm against the actual measured event location of 4.23 m. The experimental results obtained showed that the performance of the wireless communication device compared satisfactorily with the data logger and is capable of detecting the location of damage on real pipelines when used for real time monitoring. Using this communication device and an analytics platform, real-time monitoring of pipelines can be carried out from any location in the world on any internet-enabled device.

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Design and implementation of a university smart attendance tracking system using geo-location and IOT

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Abstract: In educational institutions, keeping track of attendance is a crucial duty that frequently requires manual methods, which can be time-consuming and error-prone, in order to automate and improve the accuracy of attendance tracking at universities and colleges, this project describes the design and implementation of a University Smart Attendance Tracking System (USATS). USATS makes use of the geolocation and Internet of Things (IoT) technologies. The IoT and geolocation-based University Smart Attendance Tracking System improves the efficiency, accuracy, and transparency of attendance tracking, thereby enhancing the quality of education at universities and colleges. For tracking users' current locations, this app makes use of Geolocation API. The terms "geolocation" and "longitude" are used to describe a location's position in space. This browser tool for tracking the student's current location is very helpful in the creation of an attendance tracking system. Geofencing is the process of creating an algorithm that compares the current location data with that of the classroom where a class is anticipated to take place within a given amount of time. This research demonstrates how IoT and geolocation technologies have the potential to change conventional administrative procedures in the educational sector. Using precise geolocation technology, instructors are always present in the classroom, avoiding proxy attendance.

Keywords: University, Smart rollcall, Geo-Location, authentication, biometrics, IOT

1. Introduction

Monitoring student involvement, evaluating academic progress, and guaranteeing accountability have all long been reliant on attendance tracking in educational institutions. However, conventional methods of taking attendance, which sometimes require hand-written logs or sign-in sheets, take a lot of time and are prone to errors and abuse [1, 3]. The need for smart attendance tracking system has become eminent in the university as it enforces students to be present in class and on time. In other to fill the above-mentioned gap, the function of the smart attendance software is to address the problem associated with real-time attendance reporting, verification and documentation of attendance records in the university community [2]. By doing this, we shall have resuscitated our education system and increased the overall performance of students in class engagement and academic performance by over 70%. The management of attendance in universities will be transformed through the design and implementation of a University Smart Attendance Tracking System (USATS), which makes use of geolocation and Internet of Things (IoT) technology. The integration of Geo-location and IoT technologies into the attendance tracking process presents a promising solution. Geo-location services, including GPS and Wi-Fi positioning, enable precise determination of a student's location, ensuring that attendance records reflect their physical presence in the classroom [4]. Additionally, the GUI was built to make attendance tracking easier for end users and includes crucial functions like building new databases, Geo-Location, and attendance tracking. Performance and usability of the system were examined in order to offer suggestions for future improvements. In a study, [14] proposed a system framework with a growing desire for more effective, precise, and automated attendance monitoring systems that can change to meet the changing needs of contemporary education exists in the digital era of today. Most of these systems are limited in their operation as they are unable to capture users' Bio Data' and geospatial data in real-time [7, 8]. Also, the combination of biometrics verification with hashed database passwords makes this system more reliable and secure. IoT devices, such as RFID scanners or Bluetooth beacons, provide the means to automatically detect and identify students as they enter or leave specific locations, eliminating the need for manual data entry [5]. By combining these technologies, the USATS can offer real-time attendance tracking, data analytics, and enhanced security simply defined the context [9], stated the key problems and imply some sense of what solutions in terms of their focus by considering the representation of basis for further discussion to argue the point that new technologies have both disruptive and synergetic effects, particularly on forms of social organisation that are required for future forms of governance and community action as well as business arrayed for the Future of Information Communication and Technology (ICT) [10]. The development of online and mobile forms of participation. In which the citizenry is massively engaged in working towards improving the city alongside planners and designers from government and business. Decentralised notions of governance and community action is central to these new forms of participations which use extensive ICT [12]. The modern educational environments require building an integrated system for provisioning of educational resources in all forms, as well as pay attention to the way to access them this is where smart attendance comes in. The goal is not to force the student to attend, but rather to ensure the presence of students and their acquisition of the rich knowledge for his/her own good and to build the country [6]. Additionally, the Smart-Class enables geotracking, environmentally friendly energy conservation, and comprehensive session management of multiform learning. It is intended to develop and implement features gradually [11]. This study has demonstrated how the usage of mobile technology has affected the way that students are taught and how they learn. The institution can also use it to enhance the academic management system, which can end the issues with cheating and fraud among the students. Additionally, mobile attendance systems that use QR codes which has greatly streamlined the process of enrolling students in classes quicker and easier. These studies have successfully created a portable attendance system that enhances academic administration system. [14] presented the use of RFID technology to manage student attendance in the classroom through the integration of ubiquitous computing platforms. RFID technology has the potential to be a potent tool for managing student attendance during the course of a typical school day while also enhancing safety in the classroom. When it is necessary to automatically record students' movements and positions in a classroom or other school or university setting, RFID technology has been used to find solutions [13]. In a school or university setting, a real-time intelligent system is put into place along with RFID hardware to keep track of students' attendance at lectures and labs.

2. Method

2.1 Approach

This research designed and developed a smart attendance tracking system that was used for tracking and monitoring student's attendance and report in real time. The design and development involved the use of agile methodology and software tools such as the IDE Visual Studio Code and Google Chrome browser. For the user facing components of our application, we used languages such as HTML (Hypertext Transfer Markup Language), CSS and JAVASCRIPT. Faecalis's Library was used for the face recognition function of the application. For the database and backend business logic, Node.js and Mongo DB was used to ensure that student's attendance was persisted to the cloud and gracefully saved in a secure database and could be retrieved when needed. With Mongo DB geospatial, we implemented the geo-location and geo-bonding functionality of our application. Ensuring that the students is in the lecture hall at a lecture period in order to mark attendance.

2.2 Design of the smart attendance tracking system

The design procedure of the smart attendance tracking system is presented on a Flowchart in Fig. 1.



Fig. 1.Flowchart of Geo-fencing algorithm for the attendance system

3. Results and Discussion

The design and implementation of a University Smart Attendance Tracking System (USATS). development increased class attendance of students by over 80%, saved time of roll call and improved the overall reporting speed of attendance data with high rate of data security. It is secure, safe to use and adaptable, easy to use and adaptable for research and teaching. This software could also be adopted by cooperate organization for efficient staffing. This application was tested and we got the desired results based on the software design architecture. Development of some component parts of the software was quite challenging as it required learning new libraries and tools in order to come up with the exact design model of the application's requirement. The function of the smart attendance software is to address the problem associated with real-time attendance reporting, verification and documentation of attendance possible for college or university students. Its capacity to recognize each student's specifically depending on them using their Reg. no and Email facilitating more accessibility, quicker security access more secure than before.

Figures 2 to 7 are snapshots of some user interfaces from the proposed USATS prototype built for assessment. Figure 2 shows the home screen for the student to select his/her class. User Interface components for students account activation. Figure 3 shows the User Interface components for student's login. Figure 4 provides the User Interface components for students Dashboard showing ongoing class. Figure 5 shows the User Interface components indicating no class ongoing. Figure 6

depicts the User Interface showing that student is not in class but trying to mark attendance, and Figure 7 depicts User Interface showing that student roll-call has been recorded.

| ા | UNICROSS Smart Roll Call! |
|------|---------------------------|
| | Activate your Account |
| HODG | PHD/CDLPESECODE |
| | |
| END | ha). |
| | |
| ini. | SWORD |
| | |
| CDF | (FIRM PASSWORD) |
| | |
| | Xernovene . |
| | |

Fig. 2.User Interface components for students account activation

| UNI | CROSS Sm | art Roll Call! |
|-------------|---------------|------------------|
| REGNO/CO | OURSECODE | |
| | | |
| PASSWOR | 0 | |
| Forgiot Par | inword? | |
| | tóg | n |
| utivate a | ccount here - | Activate account |

Fig. 3.User Interface components for student's login

| | EEE5102 |
|---------|-----------------------|
| 1 | Venue: Room 3 |
| Duratio | n: 9:00 AM - 10:30 AM |
| Tin | ne Left: 23min 🕚 |
| STA | TUS: ONGOING |

Fig. 4.User Interface components for students Dashboard showing ongoing class







Fig. 6.User Interface showing that student is not in class but trying to mark attendance



Fig. 7.User Interface showing that student roll-call has been recorded

3.1 Deployment

A design and implementation of a University Smart Attendance Tracking System (USATS) has been developed to give users a good feel of the application using web-based technologies such as HTML, CSS and JavaScript. The backend logic of the application is built with Node.js and Express server together with mongo dB for database management.

4. Conclusion

The design and implementation of a University Smart Attendance Tracking System (USATS) leveraging Geo-location and Internet of Things (IoT) technologies mark a significant advancement

in the management of attendance in higher education institutions. This innovative system addresses long-standing challenges associated with traditional attendance tracking methods and offers a comprehensive solution that benefits both universities and students. Although there have been existing solutions for attendance tracking, this system is quite unique. It utilizes web-based application programming interfaces (APIs) and third-party libraries, which streamline the design, development, and deployment of the system while ensuring system and database security through the bcrypt hashing algorithms available as a third-party module in the JavaScript programming language. By integrating these technologies, we have successfully enhanced existing platforms in the areas of real-time reporting and document database management.

In conclusion, the University Smart Attendance Tracking System (USATS) offers an innovative solution to the challenges associated with traditional attendance tracking methods in universities. By combining Geo-location and IoT technologies, this system provides accurate, real-time, and datadriven attendance tracking, ultimately contributing to improved student engagement and administrative efficiency in higher education institutions. The University Smart Attendance Tracking System represents a paradigm shift in how universities manage attendance and engage with their students. By harnessing Geo-location and IoT technologies, it not only streamlines administrative processes but also fosters a culture of responsibility and participation among students. The USATS is a testament to the transformative power of technology in higher education, and its successful implementation is a step towards creating more efficient, data-driven, and student-centric learning environments. As it continues to evolve, the USATS has the potential to redefine the way universities manage and optimize their resources for the benefit of both educators and learners. The problems with the current manual systems are addressed by the smart attendance management system. In terms of eliminating the insecurity associated with the present system of taking attendance, eliminating the stress associated with the traditional attendance marking method in University of Cross River State (UNICROSS) and finally to deploy the system in real time as well as model a safe, accurate, and time-saving smart attendance system.

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Development of a self-governing system for optimal navigation of unmanned ground vehicles in dynamic path

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Abstract: This paper presents a self-governing navigation system using deep reinforcement learning approach, to address the navigation limitation of self-driving vehicles. Which is a remedy to accidents caused by poor regulation of velocity, and inapt navigation in critical road network. It does so by utilizing an improved proximal policy optimization (IPPO) algorithm based on actor optimal function (AOF), which enhances the proximal policy to achieve an optimal reward in situations of scarce rewards, improved sample efficiency, and stabilize the training process. A novel deep neural network is developed to address the problem of low dimensionality related to conventional reinforcement learning algorithms. The algorithm is trained and tested in three driving cases (U-turn, S-turn and L-turn) to determine its navigation capabilities in critical road networks. The effectiveness of the created algorithm is also compared with the conventional PPO reinforcement learning algorithms, and the presented result established the aptness of the developed algorithm in performing apt velocity regulation. This result shows the AOF based PPO capabilities to navigate a self-driving vehicle smartly in dynamic road networks.

Keywords: PPO, AOF, reinforcement learning, Self-driving vehicle

1. Introduction

The exploration of automated vehicle systems is a result of the modern world's elevated desire for mobility. As a result, there is a continuing demand for technical advancement in self-driving cars. These vehicles are expected to accomplish human achievement without any human control or supervision and are distinguished by their ability to change their speeds, change directions, navigate their paths, and carry out other automated capabilities [8]. As a result, there are now suitable sources of transportation for those who are unable to operate conventional cars. These automated vehicles must be capable of performing in emergency situations, handling uncertainty, and successfully reaching their destination in all weather conditions. They must also function safely under all circumstances. [2], [5]. The common highway mishap phenomenon is frequently brought on by bad navigation and a lack of speed control among nearby vehicles. In this setting, cars suddenly accelerate, slow down, and weave around one another. In circumstances like this, poor control of speed and navigation has always resulted in fatal collisions on the freeway. [8], [9] & [3]. Therefore, this research presents a self-governing navigation system based on deep reinforcement learning approach to regulate the path of an unmanned ground vehicle (UGV). This uses improved proximal policy optimization (IPPO) algorithm, based on actor optimal function (AOF). The AOF improves the proximal policy of the algorithm to achieve an optimal reward in situation of scarce reward, improved sample efficiency, stable training process, and optimally precise decision approximations. This will salvage the common reinforcement learning problem of instability and slow training process. A novel deep neural network architecture is developed as improved function approximation to accommodate the problem of low dimensionality associated with traditional reinforcement learning algorithm. Hence the result shows the AOF based PPO capabilities to navigate a self-driving vehicle smartly in dynamic road networks.

2. Method

2.1. Actor Optimal Function

The formulation and development of the actor optimal function (AOF) will be done using the following approaches.

2.1.1. Formulation of the number of neural network unit

The neural network units are formulated using the following equation;

Hidden Layer = $\frac{3}{2} \times$ Input Layer + Output Layer

(1)

2.1.2. Formulate the actor optimal function neural network layers

The neural network layers are presented as follows:



Fig.1. Neural Network Layers

2.1.3. Formulate the activation function equations

An artificial neural network can learn complicated patterns in the data with the aid of an activation function, which is a function that is added to the network. In contrast to a neuron-based paradigm found in our brains, the activation function determines what signals should be sent to the following neuron at the very end.



Fig. 2. Activation function and classifier in neural network

Where:

 $X_{1,2,\dots m}$ are the inputs from node 1 to "m" respectively,

B, is the bias

W_{1,2,...m} are the various inputs weighted matrixes from node 1 to "m" respectively, and

Y(x) is the output classifier, presented in (ii) which is the basis radial support vector machine equation.

F(x) is the activation function equation presented in equation 3.3, which is the MaxOut activation function.

$$y(x) = \sum_{i=1}^{M} W_i X_i \exp\left(-\|X - X'\|^2 / 2\sigma^2\right) + B$$
(2)

$$f(x) = \begin{cases} 1 & \text{if } \Sigma WX + B \ge 0\\ 0 & \text{if } \Sigma WX + B < 0 \end{cases}$$
(3)

Hence the actor optimal function is presented in Figure 3.4.

2.1.4. Deep Proximal Policy Optimization (PPO)

The development of an improved deep proximal policy optimization algorithm system based on polling delegate function with smart navigation capabilities, is presented from the basic PPO algorithm with clipped objective. In PPO with clipped objective, a first-order optimizer like the gradient descent is used to optimize the problem function with a soft constraint to penalize the objective if there is a large change the policy. In implementation, two policy networks will be maintained. The first one is the current policy presented in (iv) [16]. $\pi_{\theta}(a_t|s_t)$ (4)

The second is the policy the last used to collect samples.

$$\pi_{\theta_k}(\mathbf{a}_t|\mathbf{s}_t) \tag{5}$$

With the idea of importance sampling, we can evaluate the new policy with samples collected from

an older policy. This improves sample efficiency.

$$\frac{\text{Maximize}}{\theta} \widehat{\mathbb{E}}_{t} \left[\frac{\pi_{\theta}(a_{t}|s_{t})}{\pi_{\theta_{old}}(a_{t}|s_{t})} \hat{A}_{t} \right]$$
(6)

But from the refined current policy, the difference between the current and the old policy will be larger. The variance of the estimation increases respectively. So, for every 4 iterations, the second network is synchronized with the current policy again. Hence the ratio of the policies is presented in equation (viii).

$$\pi_{\theta_{k+1}}(\mathbf{a}_t|s_t) \leftarrow \pi_{\theta}(\mathbf{a}_t|s_t) \tag{7}$$

$$r_t(\theta) = \pi_{\theta}(\mathbf{a}_t|s_t)/\pi_{\theta_k}(\mathbf{a}_t|s_t) \tag{8}$$

From this, a new objective function is constructed to clip the estimated advantage function if the new policy is far away from the old policy. The new objective function is:

$$\mathcal{L}_{\theta_k}^{CLIP}(\theta) = \frac{E}{\tau \sim \pi_k} \left[\sum_{t=0}^T \left[\min\left(r_t(\theta) \hat{A}_t^{\pi_k}, clip(r_t(\theta), 1 - \epsilon, 1 + \epsilon) \hat{A}_t^{\pi_k} \right) \right] \right]$$
(9)

If the probability ratio between the new policy and the old policy falls outside the range $(1 - \varepsilon)$ and $(1 + \varepsilon)$, the advantage function will be clipped. ε is set to 0.2 for the experiments in this PPO (I. M. Chen & Chan, 2021).





Effectively, this discourages large policy change. Here is the algorithm: $\mathcal{L}_{\theta_{k}}^{CLIP}(\theta) = \frac{E}{\tau \sim \pi_{k}} \Big[\sum_{t=0}^{T} [\min(r_{t}(\theta)\hat{A}_{t}^{\pi_{k}}, clip(r_{t}(\theta), 1 - \epsilon, 1 + \epsilon)\hat{A}_{t}^{\pi_{k}})] \Big]$

Therefore, the algorithm is written as:

Algorithm: PPO with Clipped Objective

Input: initial policy parameters θ_0 , clipping threshold ϵ

For k = 0, 1, 2, ... do

Collect set of partial trajectories D_k on policy $\pi_k = \pi(\theta_k)$

Estimate advantages $\hat{A}_t^{\pi_k}$ using any advantage estimation algorithm

Compute policy update $\theta_{k+1} = \arg \frac{max}{\theta} \mathcal{L}_{\theta_k}^{CLIP}(\theta)$

By taking K steps of minibatch SGD (via Adam), where

$$\mathcal{L}_{\theta_k}^{CLIP}(\theta) = \frac{\mathrm{E}}{\tau \sim \pi_k} \left[\sum_{t=0}^T [\min\left(r_t(\theta)\hat{A}_t^{\pi_k}, clip(r_t(\theta), 1-\epsilon, 1+\epsilon)\hat{A}_t^{\pi_k})] \right] \right]$$

End for

From the developed AOF, the actor optimal model can be presented in the PPO model as Improved PPO model as seen in (iv)



Fig. 4. Improved PPO

(10)

3. Results and Discussion

The results obtained from the validation of the AOF algorithm in improving the capabilities of the PPO algorithm are shown in Figure 5 to 8.

3.1 The development of an improved deep proximal policy optimization algorithm

The improved proximal policy optimization algorithm is developed and presented in Figure 5. This is trained, compared and evaluated with two traditional reinforcement learning algorithms (PPO and DQN). The actor optimal function with smart navigation capabilities is shown in the training and testing phases in Figure 6 and 7. The result statistics is also shown in Table 1 and 2 respectively.



Fig. 5. Average total reward value with the RL training episode



Fig. 6. Average total reward value with the RL testing episode.

| RL Agent | No. Episode | Iteration step | Drive Distance (km) | Training Time | Av. Reward |
|----------|-------------|-------------------|------------------------|------------------|---------------|
| РРО | 600 | 61,538 | 6172.73 | 4h | 60,000 |
| DQN | 600 | 61,891 | 6172.73 | 4h | 59,000 |
| IPPO | 600 | 57,899 | 6172.73 | 4h | 65,000 |

| RL Agent | No .Episode | Iteration step | Drive Distance(Km) | Av. Reward |
|----------|-------------|-------------------|-----------------------|------------|
| PPO | 200 | 20,702 | 20,269 | 18,000 |
| DQN | 200 | 20,820 | 20,269 | 17,500 |
| IPPO | 200 | 20,240 | 20,269 | 20,000 |

 Table 2. RL Training Result Statistics

3.2 Result of the developed path planning scheme with go-to-goal capability for navigation of UGVs

The developed path planning scheme for the navigations of UGVs consist of three simulations cases:

Case 1. Represents the evaluation of the UGV "S-turn" capabilities, whereby the agent navigated the "S-turn" with proximal deceleration applied before negotiating the bend. This is presented in Figure 7.



Fig. 7. The evaluation of the UGV "S-Turn" capabilities

The concept of the critic in evaluating the actors actions at every time step is considered reliable, as the actor improves after every time step. This displays the capabilities of the optimal scheme in improving the UGV navigation capabilities.

Case 2: Represents the evaluation of the UGV "U-turn" capabilities, whereby the agent navigated the "U-turn" with apt deceleration applied before negotiating the bend. This is presented in Figure 8.

277



Fig. 8. The evaluation of the UGV "U-Turn" capabilities

Though the UGV negotiation was not absolutely perfect while using the three reinforcement learning algorithms, but there was significant progress while using the developed algorithm. The developed algorithm displayed greater reward both in training and testing.

Case 3 : Represents the evaluation of the UGV "L-turn" capabilities, whereby the agent navigated the "L-turn" with appropriate deceleration applied before negotiating the bend. This is presented in Figure 9



Fig. 9. The evaluation of the AGV "L-Turn" capabilities.

The UGV possess a greater navigation ability while applying the braking system at the appropriate time before navigating the turn.

3.3 Discussion

The developed actor optimal functions (AOF), was trained. Compared and evaluated with two other reinforcement learning agent. The aptness of the scheme was shown as the developed algorithm presented more average reward. Hence, it can be said that the developed actor optimal functions (AOF) model addresses the low dimensionality issue in traditional reinforcement learning algorithms, as it is captured in the literature of [14] and [12]. In the first case of the simulation (case 1), the UGV navigated the "S-turn" without pulling out of the racing path successfully. This displace the optimality of the controller in planning her path in an intelligent manner as it is captured in the literatures of [4] and [7]. Similarly in case 2 and 3 as it is captured in the literatures of [13], [1], and [6]. Therefore, the developed model can navigate the racing path successfully without pulling out of

the road. This evaluates that the developed algorithm can navigate in a certain and uncertain reinforcement learning based environment with complex path.

4. Conclusion

This research developed a self-navigation system for navigation of unmanned ground vehicles. The UGV is an intelligent electro-mechanical vehicle that navigate to a target destination at a specified time in an obstacle environment without an onboard human operator. These vehicles are usually subjected to an environment with irregular paths, with uncertain turns, and barriers where vehicles navigate, accelerate and decelerate respectively. However, poor swift and unsafe navigation paths hinder this vehicle from attaining collision free trips. The modern inclusion of reinforcement learning algorithm such as PPO has presented poor deceleration in the face of obstacle and uncertain paths. This work introduced am actor optimal function, which improved the characteristics of the PPO, thereby improving the swift and braking accuracy of the UGV. Thus, safe path planning, trajectory navigation, and obstacles avoidance are the three problems to be addressed for successful navigation of UGVs to the target destination.

In this research, an intelligent UGV is designed with swift navigation and safe path prediction capabilities. The desired paths were then converted to desired speed and relative angle to the target destination in order to drive the vehicle to the target. A reward of 45,000 and 20,000 were recorded during the training face and validating face, and the UGV was able to navigate different turns (S,L, and U-turns) successfully.

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Refraction algorithm method for the development of handover transfer channels for GSM networks in Nigeria

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Abstract: This paper presents the refraction algorithm method for the development of handover transfer channels for GSM networks in Nigeria. The algorithm's primary goal is to improve how well GSM networks handle call handovers. The handover of transfer channels for the GSM network algorithm's pertinent mathematical models is presented. Using the python software, a simulation program for the handover refraction algorithm was created. The maximum number of calls a base station can support was set at 20 calls and the simulation software was executed with the refraction time set at 0.080ms. Then, a number of simulations were run for scenarios with no calls in the network and calls in the network from 20 to 100. According to the findings, all calls at base stations with less than or equal to 20 calls were successfully handled without being refracted. However, the handover refraction algorithm distributed the calls of over 20 to the next base transceiver station in the area of challenges where the number of calls in a base station exceeded 20. With a predetermined handover time of 0.080ms, the handover refraction algorithm routed calls of over 20 to the nearby base station. The handover refraction algorithm specifically refracts 20 calls for every 40 incoming calls to the base stations, 40 calls for every 60 incoming calls to the base stations and continues to 100 calls for every 80 incoming calls to the base stations

Keywords: Handover transfer channels, global system for mobile communications (GSM), networks, refraction algorithm, base transceiver station (BTS).

1. Introduction

Despite significant research advancements in power control, frequency hopping, discontinuous transmission, spectrum efficiency, multiple access technology, cluster size, and frequency re-use in mobile communication networks [1], the rising demand for capacity from mobile communication service providers in Nigeria has made it necessary to enhance mobility management and mobile communication. The effectiveness of cells is examined in relation to call block rate, anticipated call drop rate, handover failure rate, and traffic channel congestion rate. As a result, the focus of this study is on approaches for improving the Call Setup Success Rate (CSSR) and Handover Success Rate (HOSR) GSM services in Nigeria, by lowering the Call Drop Rate (CDR) and Handover Failure Rate (HOFR) [2]. When examining the most recent NCC call drop and handoff data and considering ways to raise the system's overall service level. Our research consequently revealed a trustworthy technique for establishing smooth handover in contemporary communications systems, [3]. Cell performance evaluation reveals the effect of inter-cell handover dynamics on service quality. A cut-off priority approach was developed to accomplish optimal channel resource consumption and mobility management. It uses a dynamic algorithm to raise or lower channels based on handover failure rates [4].

The research method entails a comprehensive examination of the literatures on GSM communication, with a focus on handover processes. Data and information downloaded from the Nigerian Communications Commission (NCC) website, as well as information received from the cellular network Operation and Maintenance Centre (OMC), are the key sources of Key Performance Indicator (KPI). Data generated by the created and simulated handover dynamic cut-off algorithm is the secondary source [5] [6].

In general, the GSM operators in N igeria continue to offer incredibly poor service. Most GSM network users in Nigeria are affected. The quality of service may suffer as a result of the growth gap between the expansion of the subscriber base and the lack of comparable growth in investment in mobile telecommunications system mobility management, which leads to a decline in quality of service.

Several channel allocation management techniques have been investigated, with a focus on handover management and the provision of high-quality service assurances [4] [7]. Any handover management plan should try to reduce the possibility of forced call termination or call dropping. Handover management methods are intended to improve the quality of service [8]. Changeover calls must be handled on a priority basis to ensure minimal call dropping probability, and a fixed or dynamically configurable number of channels must be assigned to cells specifically for handover calls [9] [10].

2. Method

The focus in this paper is to present the development of a transfer channels algorithm and evaluate an execution that can be used to optimize the call handover performance of the GSM networks considered in the study. The relevant mathematical models and Python Software for the inter cell handover refraction algorithm are presented.

This paper covers 24 months of data collected from the Nigerian Communications Commission (NCC) on four (4) separate Global System for Mobile (GSM) communication; AIRTEL, MTN, GLOBACOM and 9MOBILE networks in random locations [5] [11].

2.1. The Nigerian Communications Commission (NCC) Benchmarks

The Nigerian Communications Commission (NCC) is the legislative regulator for all telecommunications companies. They've set goals for each industry operator to meet in order to assure uniform standards and high-quality service delivery to subscribers. Nigerian Communications Commission (NCC) benchmarks from June, 2020 to May, 2022 Quality of Service (QoS) requirements [6] [11].

| Call Drop Rate (CDR) | ≤1% |
|------------------------------|-----|
| Call Block Rate (CBR) | ≤2% |
| Handover Failure Rate (HOFR) | ≤2% |

2.2. Channel Allocation Refraction Algorithm *Reservation*

For each neighbor i

If a multiple of the thread (20) is reached Then

A reservation of an eligible channel j for

neighbor(i) is set in the pool

The channel j is refracted in every interfering

Cell with neighbor(i)

Getting in cell

If the number of free channels >20 then

The communication is established

Reservation

If it is a New Call Then

| The communication is refracted |
|--|
| Else |
| If the number of reserved channels >20 |
| Then |
| The communication is established |
| Reservation |
| Else |
| The Handoff is delivered |
| Refract a Reservation |
| For each neighbor(i) |
| If a multiple of the thread is gain |
| en |
| A reservation is refracted in the pool |
| |

Getting out cell

Then

Refract a Reservation

The model mathematically:

The cells will form sets called clusters, where cluster size N can take any value that satisfies equation (1) where i and j are shift parameters with any integer i and j.

 $N = i^2 + j^2 + ij$

(1)



Fig. 1. Deflection Architecture

As shown in Fig.1, incoming handover calls can access all of the available channels when fresh incoming calls can access the idle channels up to the set number of remaining channels. When there is a heavy traffic load demand during handover, refraction channels are allocated to handover calls

because this prevents channel resources from being wasted. Additionally, Fig.1 illustrates the distribution of channels between new and handover calls.

The model mathematically described as:

$$N_{\text{total}} = N_{\text{shared}} + N_{\text{rac}}$$
(2)

 $N_{shared} = N_{total} - N_{rac}$

Where:

Ntotal: The total amount of available channels.

Nshared: The number of shared channels.

N_{rac}: The number of refraction algorithm channels (rac).

When a channel is available, a handover call is accepted, and when channels are occupied, the request is refracted and when channel availability is higher than the number of shared channels, new calls are also accepted.

a. Call Drop Rate (CDR):-

The Call Drop Rate (CDR) is the ratio of the number of dropped calls to the total number of call attempts. A mobile user may cross various cell boundaries throughout the course of a call, necessitating multiple successful handoffs. If there isn't a successful handoff at any point along the path, the service provider is forced to stop providing service to the user. This is referred to as call dropping or forced call termination [12] [13].

$$Call Drop Rate (CDR) = \frac{Number of Drop Calls}{Total Number of Call Attempts} * 100\%$$
(4)

b. Call Block Rate (CBR):-

The Call Block Rate (CBR) is the ratio of the total number of blocked calls to the total number of call attempts.

$$Call Block Rate (CBR) = \frac{\text{Number of Block Calls}}{\text{Total Number of Call Attempts}} * 100\%$$
(5)

c. Handover Failure Rate (HOFR):-

The Handover Failure Rate (HOFR) is the ratio of the number of fail handover calls to the total number call attempts. This Key Performance Indicators (KPIs) is intended to indicate user failure mobility in the network [14].

$$Handover \ Failure \ Rate \ (HOFR) = \frac{Number \ of \ Failed \ Handover \ Calls}{Total \ Number \ of \ Call \ Attempts} * \ 100\%$$
(6)

The terminal interfaces are Base Transceiver Station (BTS), Base Station Controller (BSC) and Mobile Switching Centre (MSC) is the number of call after reaching the maximum threshold to the number of refracted algorithm [6].

Mathematically:

(3)

Base Station Controller (BSC) = Number of call * Number of BTS(8)

$$Mobile Switching Centre (MSC) = Number of Calls * Number of BSC$$
(9)

Handover Speed is the rate of the number of call load to the total refracted time [6]. To calculate the measurements of the handover speed of this network.

$$Handover Speed (HOS) = \frac{Number of Call Load}{Total Refracted Time}$$
(10)

2.3. Unit Materials for Simulation

Python software was used to implement the dynamic handover transfer channels for GSM networks refraction approach. Because Python PyQt5 is an accurate tool with low system requirements, choose to utilize it. As a result, it may run on a variety of devices while still being straightforward to use and operate the same, [15]. The main experimental platform required for this Python PyQt5 to work is computer system with any windows operating system. For the purpose of this paper, the latest version of Windows 10 and MATLAB was utilized.

3. Results and Discussion

Table 1. Performance Threshold of Handover Failure Rate (HOFR): The Handover Failure Rate (HOFR) should be equal to or less than 2% according to NCC Benchmark. Unlike measures of handover success rate. From June, 2020 to May, 2022, MTN has lowest of 0.54, following Airtel 1.18, 9mobile had 1.62 and Globacom 1.88 respectively.

| Airtel | 9mobile | Globacom | Mtn |
|--------|--|---|---|
| | • • • • | • • • • | 0.50 |
| 2.22 | 2.00 | 3.00 | 0.58 |
| 1.90 | 1.62 | 2.84 | 0.56 |
| 1.74 | 1.72 | 3.16 | 0.54 |
| 1.96 | 2.64 | 3.40 | 0.62 |
| 2.04 | 2.00 | 4.10 | 0.70 |
| 2.08 | 2.00 | 3.64 | 0.68 |
| 1.58 | 2.52 | 3.92 | 0.60 |
| 1.48 | 2.60 | 3.54 | 0.62 |
| 1.44 | 2.60 | 3.54 | 0.62 |
| 1.20 | 2.00 | 3.36 | 0.58 |
| 2.04 | 1.96 | 3.66 | 0.58 |
| 1.62 | 2.12 | 3.80 | 0.64 |
| 1.20 | 9.40 | 3.94 | 0.74 |
| 1.38 | 2.22 | 2.94 | 0.64 |
| 1.18 | 3.64 | 3.08 | 0.62 |
| 1.84 | 2.04 | 1.88 | 0.76 |
| 2.12 | 2.14 | 2.78 | 0.70 |
| 1.64. | 12.48 | 3.02 | 0.68 |
| 1.80 | 2.56 | 3.24 | 0.68 |
| | Airtel 2.22 1.90 1.74 1.96 2.04 2.08 1.58 1.48 1.44 1.20 2.04 1.62 1.20 1.38 1.18 1.84 2.12 1.64. 1.80 | Airtel9mobile2.222.001.901.621.741.721.962.642.042.002.082.001.582.521.482.601.442.601.202.002.041.961.622.121.209.401.382.221.183.641.842.042.122.141.64.12.481.802.56 | Airtel9mobileGlobacom2.222.003.001.901.622.841.741.723.161.962.643.402.042.004.102.082.003.641.582.523.921.482.603.541.202.003.362.041.963.661.622.123.801.209.403.941.382.222.941.183.643.081.842.041.882.122.142.781.64.12.483.021.802.563.24 |

 Table 1. Performance Threshold of Handover Failure Rate (HOFR)

| Jan'22 | 1.68 | 4.98 | 3.58 | 0.58 |
|--------|------|------|------|------|
| Feb'22 | 1.62 | 3.84 | 3.16 | 0.56 |
| Mar'22 | 1.38 | 5.64 | 2.78 | 0.58 |
| Apr'22 | 1.64 | 4.86 | 3.26 | 0.54 |
| May'22 | 1.56 | 5.28 | 3.34 | 0.58 |

Table 2 presents the handover speed and total refraction time for BTS, BSC and MSC. This echoes the viewpoint expressed in the reference by [16], with a call load of 20 bytes from the beginning and 400 bytes at the end as shown in Table 2. It takes a total refraction time of 0.080 milliseconds (ms) as the handover speed for 0.500 bytes from the beginning and 5.000 bytes at the end of the Table as captured from the refracting algorithm.

| S/n | Number of call load (bytes) | Total deflected /handover time (ms) | Handover speed (bytes/ms) |
|-----|--------------------------------|--|------------------------------|
| | | | |
| 1 | 20 | 0.080 | 0.250 |
| 2 | 40 | 0.080 | 0.500 |
| 3 | 60 | 0.080 | 0.750 |
| 4 | 80 | 0.080 | 1.000 |
| 5 | 100 | 0.080 | 1.250 |
| 6 | 120 | 0.080 | 1.500 |
| 7 | 140 | 0.080 | 1.750 |
| 8 | 160 | 0.080 | 2.000 |
| 9 | 180 | 0.080 | 2.250 |
| 10 | 200 | 0.080 | 2.500 |
| 11 | 220 | 0.080 | 2.750 |
| 12 | 240 | 0.080 | 3.000 |
| 13 | 260 | 0.080 | 3.250 |
| 14 | 280 | 0.080 | 3.500 |
| 15 | 300 | 0.080 | 3.750 |
| 16 | 320 | 0.080 | 4.000 |
| 17 | 340 | 0.080 | 4.250 |
| 18 | 360 | 0.080 | 4.500 |
| 19 | 380 | 0.080 | 4.750 |
| 20 | 400 | 0.080 | 5.000 |

Table 2. Handover speed and total deflection time for BTS, BSC and MSC

3.1 Analysis of the Simulated Results



Fig 2. Handover Failure Rate (HFR) ≤ 2.0 %

In Fig. 2. It can be seen that for the four networks which are Airtel, 9mobile, Globacom and MTN, the Handover Failure Rate (HOFR) for better quality of service should be kept below ≤ 2.0 % as mandated by the NCC. For all the communication networks of Airtel, 9mobile, Globacom and MTN, it shows that only MTN throughout June'20 to May'22 was able to fully kept their Handover Failure Rate (HOFR) within ≤ 2.0 % benchmark. While Airtel, 9mobile and Globacom fall above the threshold mark of ≤ 2.0 % having months ranging from 1 through 22 months, they do not meet NCC benchmark of $\leq 2\%$ with 9mobile showing the worst performance throughout the whole period of the analysis.



Fig. 3. Handover Speed and Total Deflection Time for BTS, BSC and MSC

In Fig. 3. The number of calls handled across the different mobile communication networks shows an upward trend. It also shows that since the relaying capacity between different BTSs is configured at a specify time of 0.080ms and the processing ability of the MSC is enormous. To meet the capacity of BSC and MSC a refracting algorithm is needed at the BTS level of the mobile communication networks.



3.2 Performance Development of the Python Software

Fig. 4. Python Software, PyQt5

In Fig. 4. During the process, it is observed from the Python script that there was no call made at that particular time across the network. As a result of that, since there was no call, the system is free from congestion, it experiences no call drop, no waiting call and any call made at this time would easily be propagated across the four GSM telecommunication systems.



Fig. 5. Python Software, PyQt5

In Fig. 5. Above, it is observed that 100 calls from different mobile devices have entered the algorithm network. With its design specifications and operation, the maximum number of calls a Base Transceiver Station (BTS) can handle is 20 calls at a time but it has been observed that the number calls entering the network has far exceeded the maximum number calls stipulated by the network which is 20 calls per time. The total number of additional calls is now 80 calls, which means that the refractor algorithm would have to refract the other 80 calls to the other nearest Base Transceiver Stations (BTS) in that vicinity, 20 calls for each, which means four (4) Base Transceiver Stations (BTS) or more are now in operation because of the 80 additional calls. The Base Station Controller (BSC) has the capacity to process all the 100 calls injected, as does the MSC because of their huge processing capacity. But the effect is minimum with the introduction of the refractor algorithm.

4. Conclusion

In this paper, a Dynamic Refraction Transfer Channels Algorithm has been developed and implemented. The data were collected from the Nigerian Communications Commission (NCC) on four (4) separate Global System for Mobile (GSM) communication; Airtel, 9mobile, Globacom and MTN networks of Call Drop Rate (CDR), Call Block Rate (CBR) and Handover Failure Rate (HOFR) were analyzed by using MATLAB data analysis tool over a period of two (2) years.

To solve these problems, Dynamic Refraction Transfer Channels Algorithm was developed using Python Software, PyQt5. In order to preserve accuracy, this system is able to modify internal variables and add new functionality that supports theories that theoretically increase these numbers; while still making use of the system's infrastructure and resources. The research is able to develop a mathematical and software type of solution for the telecommunications firms by modifying the existing software by examining the patterns of existing systems. Just the handover calls are prioritized by the algorithm. With less call dropping, call blocking and handover failure, GSM networks now receive calls with higher Quality of Service (QoS). The performance of the proposed algorithm is evaluated in terms of time intervals of new call blocked rate, handover failure rate, call dropped rate and channel utilization with the total refraction time of 0.080 milliseconds with their various handover speeds number of call loads.

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Evaluation of pathloss exponential of NTA Port Hacourt signal strength within Calabar metropolis

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Abstract: This paper focuses on the evaluation of the pathloss of the signal strength of Nigerian Television Authority (NTA) Port Harcourt (PH) 245MHz, within Calabar Metropolis, Cross River State. It was carried out using the Python programming tools incorporated with digital modules of the Community Access Television (CATV) analyzer having 24 channels connected to the antenna of about 6m high above the ground with a gain of 20dB, to determine the signal strength and calculate the pathloss using MATLAB. The signal strength of NTA PH were obtained from twenty-five (25) strategic points within Calabar. Each point forming the Northings and Eastings of the signal transmitted. The mean signal strength within the Calabar Metropolis was determined and compared with the established 21.17±3.33 dB. The location of best reception was determined within Calabar. This study shows that tall buildings, tall trees, high hills and deep values affects signal transmission of NTA PH within Calabar. The correlation between the measured pathloss and the distance of separation from the transmitter was determined and this had positive Pearson correlation coefficient of 0.3226. Moreso, the Okuruma, Cost 231 Model, Standard University Index model, Log Normal and the Hata Model were used to predict the outcome of this signal strength within Calabar. This model adopted was the ECC 33 model. Thus, the path-loss exponent for Calabar Metropolis was calculated based on the available collected and collated data.

Keywords: Pathloss, signal strength, signal strength, measured model, Calabar metropolis

1. Introduction

Information and quick access to it has become the order of the day. The present age is always on the quest to know and get satisfaction at all times. Considering the variety of information, entertainment and education content of the Nigerian Television Authorities Port Harcourt, it is expected of the neighboring dwellers within the Calabar Metropolis in Cross River State to share from the same privilege. But after considering the challenges involved in TV waves transmission, most times these interesting programs are out of reach by the Calabar dwellers. Hence for this ugly experience to be overcome; there is therefore the need to study and come out with alternatives that will avert this situation. By this approach it will go a long way to fulfill the dreams of digitization as long as communication is a necessity.

Nigerian Television Authorities TV stations dreamed by the Federal Government of Nigeria and as a dream come true, it was established in accordance to the Federal Government act on communication issues and became operative at the same time. NTA PH was established in 1977 as a follow up from the Western Nigeria Television (WNTV) with the sole aim of entertaining, informing and educating the Nigerian populace. It was commissioned by the then leadership of the regional governor. Its initial capacity and coverage were to reach Uyo, Calabar, Enugu, Aba and Ebonyi [1]. The first program to be aired by the station was its commissioning broadcast. In the year 1997 the station was expanded to reach more people. Currently, NTA PH signal has covered the following regions South-South and South-East in Nigeria, yet with all these developments, dwellers and lovers of NTA PH TV station programs within the Calabar metropolis still lags behind and are often dissatisfied due to many factors affecting its signal strength. To buttress further, it is necessary to know the location of this TV station. NTA PH TV station is located at NTA road, Mgbuoba-choba, Port Harcourt, in Rivers State, Nigeria. Since its inception, it has been one of the most sort after by her numerous audiences.

Owing to the apparent fact that Calabar metropolis, Cross River State is vast in area and dense in population. Hence there is a need for an effective coverage of TV signal within her.

According to certain reviews, TV-waves are usually opposed by some obstacles and these obstacles could be natural or man-made. The natural includes trees, hills, mountains; and the man-made includes tall buildings, towers etc. Whichever the obstacle may be, both poses obstruction to the propagated TV waves. These result in wave's attenuation thereby delivering a very weak signal. In order to overcome these obstacles, and ensure appropriate delivery of signal, measurement of different television stations signal strength within the Calabar metropolis is needed with a thorough analysis of the path loss.

Thus, by accurately measuring and estimating the path-loss of NTA PH signal within Calabar so as to help new stations and assist existing stations during design, upgrade and maintenance of their network. Hence this research focuses on evaluation of Pathloss exponential of NTA Port Hacourt signal strength within Calaber metropolis.

Discussing about the TV broadcast will not be complete without taking a deep look at the radio broadcast aspect of it. They work together. Prior to the coming of the TV broadcast, the radio has been used all over Nigeria. In some states of the federation today, these two arms are integrated and inter-operated.

In this regard, this research shall first shed some lights on the radio broadcast before venturing into the TV broadcast proper.

The hybridization of the concepts of electricity and magnetism by James Maxwell in 1864 gave rise to the electromagnetic radiation as a product of ingenuity. To buttress further, it is necessary to know what electromagnetic waves are. Electromagnetic waves are synchronized oscillations of eclectic and magnetic fields that propagate at the speed of light through a vacuum. These oscillations of the two fields are perpendicular to each other and perpendicular to the direction of energy and wave propagation, forming a transverse wave. The discovery of this concept led to the discovery of the law of gravitation by Newton [8].

However, electromagnetic wave covers a series of phenomena such as, TV waves, radio wave, heat wave, light wave, x-rays and gamma rays. These waves or beams may be called a form of radiant energy and seem to differ chiefly in their wave length. The spectra extend from the frequencies used for modern TV through gamma rays (short wavelength); depending on whether there is line-of sight (LOS) between transmitting and receiving antenna or not. This is because the propagation characteristics of TV wave, such as path loss, fading and attenuation do not depend on the path distance and frequency, but also on the scattered angle, which also depends on the nature of obstruction to the EM wave [9].

The LOS as applied to TV links implies that the antenna at one end of the link can see each other (transmitting and the receiving antenna). Although, TV LOS suggests that a location of the antenna at one end of the link is able to see the other antenna (or future site) at the other end of the link. With unaided eye, one may still have LOS even though one cannot see the other end visually. This is because the TV horizon extends beyond the optical horizon. TV waves follows slightly curved path in the atmosphere, and so if there is a direct curved path between the antenna which does not pass through any obstacle, then one still has TV LOS [10].

Similarly, a non-line-of-sight (NLOS) link encounters obstacles such as buildings, trees and hills between the transmitting station and the receiving station. These include other sources of reflection such as the ground. In cities, buildings, trees, road traffic, etc., often tend to block the ground reflection path. For long range paths, ground reflection is significant. Signal loss due to trees depends on the specific types of trees or the nature of the surface of the leaves (dry or fresh). Isolated trees are not usually a major problem, when compared to a dense forest zone. Attenuation of TV wave

depends on the distance the signal must penetrate through the forest, and it increase with frequency [10].

Depending on the type of obstacle, the transmitted signal may have multitude of paths known as multi-path (via reflection, refraction and diffraction) to the receiving station. Part of the signal will be detected with sufficient signal strength while another part attenuated or scattered as a result of these obstructions. Because the paths have different characteristics, the signal is received as multiple individual signals with varying amplitudes, delay, and strength depending on the exact location of the receiver [11].

2. Method

The Python programming tool incorporated with digital cable television analyzer and MATLAB tool is used.

This pathloss determination is made possible with the use of the python programming tools incorporated with the digital Community Access Television (CATV). This Digital CATV analyzer has 24 channels and operates over a frequency of 5MHz to 65MHz for lower band (mobile transmit, base receive) and 46MHz to 870MHz for upper band (base transmit, mobile receive).

The channel spacing is 8MHz and it is specially designed to provide a band of the free off-air channels. It provides a relative reading of signal strength that is aided by the unidirectional antenna in alignment.

It measures signals in the range of OdB to lOOdB and has an in-built function that can provide power to an antenna pre-amp to accurately give a set-up location. Its maximum sensitivity is approximately -100mdB, while MATLAB is used to simulate the data.

Together, these fields form a propagating electromagnetic wave, which moves out into space and again affect on the source.

$$\nabla \cdot \varepsilon_0 \vec{\mathbf{E}} = \rho \tag{1}$$

$$\nabla .\mu_0 \vec{H} = 0 \tag{2}$$

$$\nabla \mathbf{x} \, \vec{\mathbf{E}} = -\frac{\mu_0 \delta \vec{\mathbf{H}}}{\delta t} \tag{3}$$



$$\Psi_i = A_1 e^j (wt - k_j x)$$

$$\Psi_r = A_2 e^j (wt + k_i x)$$
(5)
(6)

 $T = A_3 e^{j^{(wt - k_{2x})}}$

Where:

 Ψ_i = Incident radio wave,

 Ψ_r = Reflected radio wave

 Ψ_t = Transmitted radio wave

 $K_1 =$ Wave number of medium 1

 $K_2 =$ wave number of medium 2

 Z_1 = Characteristics impedance of medium 1

 Z_2 = Characteristics impedance of medium 2

At
$$x = 0, t = 0;$$

$$A1 + A2 = A3 \tag{8}$$

$$\frac{A_1}{Z_1} - \frac{A_2}{Z_1} = \frac{A_3}{Z_2} \tag{9}$$

$$(A_1 - A_2) Z_2 = Z_1 A_3$$
(10)

$$(A_1 - A_2) Z_2 = (A_1 + A_2) Z_1$$
(11)

$$(Z_2 - Z_1)A_1 = (Z_2 + Z_1)A_2$$
(12)

$$\frac{A^2}{A_1} = \frac{(Z_2 - Z_1)}{Z_2 + Z_1} \tag{14}$$

As the propagated wave hits an obstacle of different medium, refraction occurs as seen in the figure below.



Fig. 2. Diagram of Reflection phenomenon

The amount of bending or refraction that occurs at the interface of two materials depends on the refractive indexes of the materials:

$$n = \frac{c}{v} \tag{15}$$

Where:

n = refractive index (unitless)

c = speed of light in free space (3 X 108 m/s)

v = speed of light in a given material (meters per second)

(7)

Snell's law uses refractive indexes to show how an electromagnetic wave reacts when it meets the interface of two transmissive materials with different indexes [12].

$$n_1\sin\theta_1 = n_2\sin\theta\ 3$$

Where:

 n_1 = refractive index of material 1 (unitless)

 n_2 = refractive index of material 2 (unitless)

 θ_1 - Angle of incidence (degrees)

 θ_2 = angle of reflection = angle of incidence (degrees)

 θ_3 = angle of refraction (degrees)

And since the refractive index of a material is equal to the square root of its dielectric constant:

$$\frac{\sin\theta_1}{\sin\theta_3} = \sqrt{\frac{\varepsilon r_2}{\varepsilon r_1}}$$
(16)

Where:

 e_r = dielectric constant of medium 1 (unitless)

 εr_2 = dielectric constant of medium 2 (unitless)

As waves enter from air into a medium, they are bent towards the normal. When waves leave the medium and re-enter air, the waves are bent back, away from the normal, to their original trajectory. Furthermore, an alteration in the atmospheric refractive index results in refraction of the transmitted signal. This is mostly experienced when there is uncertainty in the weather condition which will result in a melodramatically change known as super-refraction.

According to the far-field distance, df may be calculated according to equation (17)

$$d_f = \frac{2}{\lambda} D^2 \tag{18}$$

Where:

D is the largest linear dimension of the antenna. To assume that the antenna is in the far

Field/

$$d_f \gg A \text{ and } d_f \gg D$$
 (19)

For short vertical grounded antenna of effective height (he) the field strength assuming perfect conducting earth is

$$E = \pi \, \frac{120Ih_e}{\lambda d} \tag{20}$$

Assume the power supplied Pt covers the upper hemisphere, then»

$$\frac{Pt}{2\pi r^2} = \frac{E^2}{120\pi} \tag{21}$$

2.1. Line of Sight

Line of sight is another interesting factor that affects TV waves' propagation and transmission. This could be due to tall buildings, trees and industrial developments. This is shown in Fig. 3.

294



Fig. 3. Line of sight variation

Where:

 $h_T x = Transmitter height$

h_Rc =Receivers height

XI = Distance between transmitter and receiver

X2 = Line of sight distance

Rg = Grazing incident ray

2.2. Models and Formulae

There are several models presently in use for the analysis of a propagated wave signal from a particular source. These models are in such a way that it varies depending on the nature of wave being propagated and analyzed. To this extent, this research work has selected a few of the models that will suit its purpose. The detail of these models has already been discussed in the reviewed works in the preceding chapter.

i. Cost 231 Model [13]

PL=46.3+33.91ogio (f) - 13.82 \log_{10} (h_b)-ahm + (44.9 + 6.551og (hb)) $\log_{10}d + c_m$

Where:

f is the frequency in MHz,

d is the distance between AP and CPE antennas in km

 h_b is the AP antenna height above ground level in meters.

The parameter cm is defined as 0 dB for suburban or open environments and 3dB for urban environments. The parameter a^*h_m is defined for urban environments as

 $ah_m = 3.20(log_{10} (11.75h_r)) - 4.97$, for f > 400 MHz

for suburban or rural (flat) environments,

 $ah_m - (1.1 \log o f - 0.7)h_r - (1.56 \log o f - 0.8)$ (22)

where:

 h_r is the CPE antenna height above ground level.

ii. Standard University Interim Model [14]

$$PL = A + 10\gamma \log_{10}(\frac{d}{do}) + X_{f} + x_{h} + s$$
(23)

Dd> do

Where:

(24)

d is the distance between the Access Points (AP) and the Customer Premises Equipment (CPE) antennas in meters

do = 100 m and s is a log normally distributed factor that is used to account for the shadow fading owing to trees and other clutter and has a value between 8.2 dB and 10.6 dB [7].

The other parameters are defined as,

~

$$A = 20 \log_{10} \left(\frac{4\pi do}{\lambda}\right) \tag{25}$$

$$\gamma = a - bh_b + \frac{c}{hb}$$
(26)

Where:

The parameter hb is the base station height above ground in meters and should be between 10m and 80m.

The correction factors for the operating frequency and for the CPE antenna height for the model are:

$$X_f = 61 \text{og}_{10} \frac{f}{2000} \tag{27}$$

$$X_h = 10.8 \log_{10} \frac{hr}{2000} \text{ for terrain A and B}$$
(28)

$$X_f = 20\log_{10} \frac{f}{2000} \text{ for terrain C}$$
(29)

Where:

f is the frequency in MHz and hr is the CPE antenna height above ground in meters.

The SUI model is used to predict the path loss in all three environments, namely rural suburban and urban.

iii. Hata Model [15]

The standard formula for median path loss in urban areas under the Hata model is

 $L_{50, urban}(dB) - 69.55 + 26.16 \log_{10}(f_c) - 13.82 \log_{10}(h_{te}) - a(h_{re}) + (44.9 - 6.55 \log_{10}(h_{te})) \log_{10}(d).$

The parameters in this model are the same as under the Okumura model, and $a(h_{re})$ is a correction factor for the mobile antenna height based on the size of the coverage area. For small to medium sized cities, this factor is given by:

$$a(h_{re}) = (1.1 \log (f_c) - 0.7)h_r - (1.56 \log_{10} (f_c) - 0.8)dB$$
(30)

For larger cities at frequencies $f_c>300$ MHz by $a(h_r) - 3.2(\log (11.75hr)^2 - 4.97 dB.$

(31)

Corrections to the urban model are made for suburban and rural propagation, so that these models are respectively:

$$L_{50, suburban} (dB) = L_{urban} (dB) - 2[log (f/28)] - 5.4$$
(32)

$$L_{50, \text{ rural}} (dB) == L_{50, \text{ urban}} (dB) - 4.78 [\log_{10} (f_c)] + 18.33 \log_{10} (f_c) - K$$
(33)

iv. Egli Model [16]

The Egli model is formally expressed as:

$$Path \ loss \ (LF) = G_B G_M \left[\frac{h_B h_M}{d^2}\right]^2 \left[\frac{40}{f}\right]^2 \tag{34}$$

Where,

 G_B = Absolute gain of the base station antenna.

 G_M = Absolute gain of the mobile station antenna.

 h_B = Height of the base station antenna, [m]

 h_M = Height of the mobile station antenna, [m]

d = Distance from base station antenna, [m]

f = Frequency of transmission. [MHz]

This prediction model is applicable at frequency from 40 MHz to 900 MHz and linking range is less than 60 km. Egli observed that there was a tendency for the median signal strength in a small area to follow an inverse fourth-power law with range from the transmitter, so the model is based on planet earth propagation. The formulas for the Egli's propagation loss prediction model are:

For $h_m \leq 10$,

$$PL (dB) = 20 \log_{10} f_c + 40 \log_{10} R - 20 \log_{10} h_b + 76.3 - 10 \log_{10} h_m$$
(35)

For $h_m \ge 10$,

 $PL (dB) = 20 \log_{10} f_c + 40 \log_{10} R - 20 \log_{10} h_b + 85.9 - 10 \log_{10} h_m$ (36)

Where,

 h_b = Height of the base station antenna in meters (m)

 h_m = Height of the mobile station antenna in meters (m)

R = Distance from base station antenna in meter (m)

 f_c = Frequency of transmission in megahertz (MHz)

From the formulae, it is noted that this model predicts that the average signal strength will decrease with the distance at a rate of 40 dB/decade. The decrement rate is not depending on the effective height of the TV base station antenna or other factors if all these factors remain the same throughout the whole distance of measurement.

3. Results and Discussion



Fig. 4. MATLAB simulated interface for selected 25 locations within Calabar Metropolis.



Fig. 5. NTA PH channel 24 signal strength received within Calabar Metropolis



Fig. 6. NTA PH channel 24 signal distribution in Calabar Metropolis due to obstacles

As shown above from the simulated results, the X and Y axes represents the predictive model II and the measured data model. Here, the measured data is uniform throughout the process. At X = 89.88dB, Y = 158.9dB. Then at a reasonable point, both models hit an obstacle and X = 119.0 dB, Y = 212.1dB. At the end of the simulation, X = 127.0dB, Y = 193.1dB. Determining the reliable models compared, final X - final Y=> (127.0 - 193.1) dB = -66.1(dB). The result showed a negative value which far less than the expected threshold dB.

At the end of the simulation, X = 127.4dB, Y = 193.1dB. Determining the reliable models compared, final X- final Y=> (127.4 – 193.1) dB = -65.7(dB). The result showed a negative value which far less than the expected threshold dB. Therefore, the best model that describes NTA PH channel 24 is the ECC 33 Mosel (dB).

Each of the location was taken in kilometers. This implies that the signal propagated by NTA PH channel 24 reaches Calabar metropolis well but its strength is affected by numerous obstacles which are both natural and man-made. Thus, for effective distribution of this signal in Calabar, more repeaters are required.

4. Conclusion

Propagated NTA Port Harcourt signals from the transmitter to the receiving antenna undergoes a lot of transformations. One of such transformations is the apparent loss in energy and the signal strength. This has accounted for variations in viewers' satisfaction of the same TV channel whether in the same locality or from a far range. The project on the evaluation of pathloss exponent of NTA PH within the Calabar Metropolis holds that viewers' satisfaction is affected negatively due to this afore mentioned setback. This work has employed the best of the literatures to establish its facts. Existing models such as COST 231 model, Okuruma HATA model, Standard University Interim model and the Log Normal prediction model are leveraged upon to simulate this work. The Python programming tools incorporated with a signal tracking device such as the Community Access Television (CATV) Analyzer was used to simulate this work after data collection. Thus, the exponential loss is -66.1dB.

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Design and construction of microcontroller-based programmable DOT matrix information display system

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Abstract: This project presents the design and construction of microcontroller-based programmable dot matrix information display system. The advert system that displays information based on a specific purpose. The system is designed to enable the viewer know an information. The system comprises of different blocks of functional circuits that are put together to achieve the desired aim. These blocks include the power supply section, the control section, the demultiplexer section and the display unit. The power supply unit is the section of the system that ensures that the system is turned ON and this section comprises of a 12- volt step-down transformer, a bridge rectifier circuit, a smoothening capacitor and a voltage regulator IC. The control section is in charge of interpreting the changes that occur in the environment, this section controls the function of all other parts of the circuit, The concept of LED dot matrix display system based on microcontroller, a matrix of light emitting diodes and three segment displays was achieved within this project. The prototype of the display consists of 512 Light emitting diodes wired in rows and columns to achieve a dot matrix formation, each consisting of a 32x16 LED matrix, therefore the design and implementation of moving message display based on microcontroller was adopted. In operating this device and the results achieved, users have the flexibility to choose from various display modes, including static, scrolling, and interactive modes. Activation is as simple as pressing a power button, and users can control the system through an intuitive user interface. This comprehensive operational framework ensures user-friendliness, adaptability, and real-time engagement with the device, making it suitable for a wide range of applications ..

Keywords: LED (Light Emitting Diode), Dot matrix, microcontroller, signal, display, information

1. Introduction

Dot matrix display system display advertisements are designated to catch a people's attention and create a memorable impression very quickly, leaving the reader thinking about the advertisement after they have driven past it. They must be readable in a very short time because they are usually read while being passed at high speeds [1,2]. This piece of digital technology can be found in several places and are being used for different purposes, in banks, it is used to display interest rates as well as exchange rates. In hotels and pubs, it is used to display the menu and prices, in schools it is used to display information related to the school program and update news. Also, microcontroller-based dot matrix display system can be used to control the traffic misunderstanding among motorists especially in junctions; this is achieved by displaying stop, get ready, or move. Some traffic control electronic system displays symbols or color that represents the stated commands above. Moreover, microcontroller-based dot matrix display system is used in electronic scoreboard during football matches to display when a goal is scored, also to display the name of that player who scored the goal. Above all, this system has contributed a lot in boosting advertisement [3].

Dot matrix display system as used in this report refers to a sign that uses electronic hardware and software to display its copy, messages or images. Also, a sign utilizing a fixed light source to provide a message in text, images pictures, and symbols that may appear to move or may appear as on/off messages. This is contrast to traditional non-electronic signs where the copy displayed is physically applied to the sign surface by printing, painting or otherwise attaching it onto the sign. The materials or substrate to which the copy is applied is typically paper, wood, plastic or the wall of a building. In this modern time, solid materials have helped man to show that he really exists by doing wonders in the world of electronics. One major development, made possible by the enormous advances in solid state technology, is the "digital revolution". Circuits are designed to implement the basic digital logic functions fundamental to all digital systems. Digital electronics therefore comprises the design,

manufacture and use of circuits for processing information in digital form [4]. An information display is a way of providing information and it is also used as an object for promotion. It can be seen in a form of cardboard or tarpaulin at stores / shops, sign posts, placards, notice boards and intelligent display board. But the advent of new technologies has made the information in the form of a Dot matrix display system in the world of advertisements and promotions [5].

In the work of [6], the system for displaying messages on a notice board was done using GSM technology. The methodology likely involved the integration of a microcontroller with GSM modules to facilitate message transmission and display. The results of the study would include the successful implementation of this system, allowing users to send messages remotely to the display board. Challenges may have included issues related to GSM signal reception, power consumption, or message formatting. In the findings of [7], the work was done to enhance a microcontroller-based SMS electronic scrolling message display board by adding a feedback mechanism. The methodology involved modifying the existing system to incorporate feedback features. Their results were the successful development of an improved electronic message display board with feedback capabilities. But the challenges included compatibility issues, software development challenges, or testing difficulties.

In the research of [8], The aim of this study was to create a digital notice board using Raspberry Pi technology. The methodology involved programming Raspberry Pi boards to display messages and notifications. Results included the digital notice board, possibly with additional interactive features due to Raspberry Pi's versatile capabilities. Challenges might have included software integration, hardware compatibility, or user interface design difficulties. In the work of [9], this research focused on the design and construction of a dot matrix information display for the Office of the Vice-Chancellor at Anambra State University, Ulis. The primary aim had been to create an information display system for the university's administrative use. The methodology involved the selection and integration of dot matrix display technology with specific information content. The results could have included the successful implementation of the dot matrix information display system, potentially used to convey important messages within the university. Limitations might have encompassed factors such as display size, content management, or system maintenance.

In the demonstration of [10], the aim here was likely to develop a GSM-based electronic notice board. The methodology may have involved integrating GSM modules with microcontrollers for wireless communication. Results could have included a functional e-notice board accessible through GSM networks. Challenges may have included network compatibility issues, power management, or security concerns.

2. Method

2.1 System Description

This is a digital device that operates with just 0's and 1's. It is a microcontroller-based device which uses a popular microcontroller (ATmega328). Our thoughts or desire, the data, is unprocessed information. Information is the meaningful content of a data-bearing signal. The data in which we want to publicize is written down in form of a program which will now be assembled into the memory. The situation whereby the entire write up or even the notice board has been changed in attempt to add a little information to the existing one is solved by electronic information board. This problem is solved simply by erasing the content of the memory and replacing it with latter information and the output display will automatically begin to respond to the recent memory content [5]. This process of erasing and replacing it with a recent program can be achieved under few minutes, hence in the case of business centers; customers will not lose sight of the business day-to-day activities.

2.2 System Block Diagram

This information board is very flexible in operation in the sense that it can be used to display numerals, alpha numerals, sketches of both static and moving images, etc. The functionality block diagram of a dot matrix information display device is shown in Fig. 1.



Fig. 1. A functionality block diagram of a dot matrix information display device

3. Results and Discussion

3.1 Hardware implementation results

The components were all soldered into the Vero board after which it was testing began. Having provided the casing and having finished the construction of the sections of this system, the assembling into the casing followed. The sections were properly laid out and assembled into the casing where the general coupling and linkages into the peripheral devices took place as shown in Fig. 2.



Fig. 2. The Dot Matrix Display during assembling

3.2 Construction on Vero board

Vero board is a brand of strip board, a pre-formed circuit board material of copper strips on an insulating bonded paper board. As with other strip boards, in using vero board, components are suitably positioned and soldered to the conductors to form the required circuit. Breaks can be made in the tracks, usually around holes, to divide the strips into multiple electrical nodes enabling increased circuit complexity, it is pictured as below.



Fig. 3. Image showing the circuit board, microcontroller and the dot-matrix display

3.3 Software Implementation Results

The system makes use of Bluetooth wireless connection for real-time interfacing, known as Jam and Run-text P10 Bluetooth for the interface.



Fig. 4. User interface of the mobile application with bluetooth



Fig. 5. The dot matrix system on display at the entrance to the HOD's Office.

3.4 Software development process

Python programming language was used, the code was optimized for efficient control of the dot matrix display. The snippet of the syntax used is as stated on the appendix page. To program the microcontroller which normally comes empty will need to be programmed, one will need a programmer such as melabs U2, the programmer is connected to a pc via USB port. Then the Intel HEX file is then loaded into the Melabs U2 Programming software Interface before been written to the empty chip.

3.5 Mode of operating the device

In operating the Microcontroller Programmable Dot Matrix Information Display System, users have the flexibility to choose from various display modes, including static, scrolling, and interactive modes. Activation is as simple as pressing a power button, and users can control the system through an intuitive user interface. Bluetooth integration facilitates real-time interaction, allowing users to connect their smartphones or other Bluetooth-enabled devices to send dynamic messages and control the displayed content.

4. Conclusion

In conclusion, Dot matrix information displayed all the information and entertainment in dot matrix format, also including software that allowed viewers to interact with text, symbols and images. Most forms of information were published electronically by way of dot matrix information display, the advent of microcontroller have made it easier for us to display information in this format in a unique way. The dot matrix was designed, tested satisfactorily and was worthy of mass production. It has features that made it unique from other display boards in the market; the presence of multiple colours makes it preferable to other single colour as displayed. "Welcome to Electrical/Electronic Engineering Department"

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Design and construction of a UAV air to ground autonomous channel system

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Abstract: Unmanned Aerial Vehicles (UAVs) have soared beyond traditional boundaries, transforming industries with their unparalleled versatility. At the heart of their operational prowess lies the pivotal UAV air-to-ground channel system-an intricate network that enables seamless communication between airborne vehicles and their ground control stations. Security emerges as a paramount concern, given the sensitive nature of the data transmitted. This paper delves into the forefront of UAV air-to-ground communication, presenting an overview of key components, challenges, and groundbreaking advancements. The UAV air-to-ground channel system is the lifeline of mission-critical data transfer and real-time control. Comprising transceivers, antennas, modulation techniques, and sophisticated algorithms, this communication nexus ensures the fluid exchange of information. The dynamic nature of UAV operations, characterized by varying altitudes, speeds, and environmental conditions, underscores the need for adaptive technologies. Innovative antenna designs, beamforming strategies, and frequency modulation solutions are used to navigate these challenges. This ensures a resilient and uninterrupted communication link. The system is integrated with artificial intelligence algorithms, which fortifies security measures, providing advanced threat detection and mitigation capabilities. This work is designed and displayed and the smart UAV capabilities are realized with seamless air-to-ground information communication.

Keywords: UAV, Autonomous, Mission Planner, Simulation, Design, Aerodynamic and Surveillance

1. Introduction

Unmanned Aerial Vehicles (UAVs) are becoming increasingly popular for various applications such as surveillance, agriculture, and search and rescue missions. One of the critical aspects of UAV operations is reliable communication between the UAV and the ground station [1] and the rang of flight. However, traditional communication methods such as radio-frequency (RF) links can be unreliable in certain environments, such as in urban areas with high electromagnetic interference. To address this issue, a novel approach using deep learning techniques can be utilized to improve the UAV air to ground channel. Specifically, a deep neural network (DNN) can be trained to optimize the communication channel parameters, such as the modulation scheme, transmit power, and channel bandwidth, based on the channel state information (CSI) obtained from the UAV and ground station [2].

The DNN can be trained using large datasets of CSI information obtained from real-world UAV flights, allowing it to learn the optimal communication parameters based on the current channel conditions. The DNN can also be designed to adapt to changing channel conditions in real-time, ensuring reliable communication between the UAV and the ground station [3]. More so, the use of deep learning techniques for UAV air to ground communication has the potential to improve communication reliability and increase the range and capabilities of UAV operations in various applications such as surveillance, agriculture, search and rescue missions [3]. One advantage of this approach is that it does not require any additional hardware or infrastructure, as it utilizes the existing communication equipment on the UAV and ground station. Additionally, the use of deep learning techniques allows for real-time optimization of the communication parameters, leading to improved reliability and range of UAV operations [4].

With widening the application scope of unmanned aerial vehicle (UAV) as the driving force, the development of solar-powered UAV recently has attracted more attention in academia and commercial industries. A critical factor limiting the scope of application of conventional battery-powered electric UAVs is their energy storage capability. The conventional UAV is powered by the energy stored in batteries on board to maintain the propulsion and functioning of flight control electronics. The amount of carried electric power limits its flight range before takeoff. Although increasing the size of the battery or installing more batteries can increase the energy storage capacity, the weight of the aircraft also increases. In turn, more power is consumed to carry the extra weight, resulting in the flight range being not necessarily prolonged. A possible approach to overcome this physical limit is the use of solar power as an energy source on UAV. Solar-powered UAV, using solar cells installed onboard, captures solar energy reaching the aircraft surface during daylight. Such generated power is supplied to the motor to propel the aircraft and other electronics or to recharge the battery on board. The battery supplies power when in darkness or under clouds [4,5].

2. Method

The method employed in achieving this project work is analysis, design and simulation. Mission planner serves as a valuable tool for this purpose both for power system enthusiasts and professionals alike, offering a platform to design, simulate, and validate electronic circuits and systems. Its user-friendly interface, extensive component library, and simulation capabilities make it an essential resource for anyone involved in electronic design and development.

Velocity of flight

From the Bernoulli equation from the law of conservation of energy.

$$P + \frac{1}{2} g V_{o}^{2} = \text{constant}$$

$$\rightarrow Ps + \frac{1}{2} g V_{o}^{2} = p_{o} + (0) - \text{Velocity at rest}$$

$$\text{Total pressure} \rightarrow P_{o} = Ps + \frac{1}{2} g V_{o}^{2} \qquad (1)$$

$$\text{Static Dynamic}$$

Where g = density of fluid

$$Velocity \to V_{\infty} = \sqrt{\frac{2 (P_{\circ} - Ps}{g}} = \frac{m}{s}$$
(2)

Standard Atmosphere

It's a mathematical model to estimate variation of pressure density and temperature with attitude





$$\frac{dp}{p}$$
 (3)

 $dp = -g_{\circ}dh$

 $h \rightarrow$ Geopotential altitude

from Equation 1 and 2 we have

 $gdhG = g_{o}dh$

$$\rightarrow dh = \left(\frac{g}{g_{\circ}}\right) dhG$$

$$\rightarrow dh = \frac{R^2}{(R+hG)} dhG$$
(4)

By integrating

RT

p

$$h = R^{2} \left(\frac{-1}{R = hG}\right)^{hG} =$$

$$\rightarrow h = \frac{RhG}{R + hG},$$

$$\frac{dp}{R} = \frac{g_{\circ}dh}{R + hG} \qquad (6)$$

2.2 System block diagram

The proposed design and construction of a UAV Air-to-ground autonomous channels system comprises of two main parts as shown in Figure 2 the flight platform and the sliding mode control (SMC). The flight platform system includes a rotary wing quad-rotor UAV, a flight control system, and a ground flight-visualization monitoring subsystem. The SMC system includes a multi-sensor imaging module, a multi-mainboard module with a data storage function, an automatic image-taking control module with synchronous positioning and data storage ability, and an electric power module [6].



Fig. 2. Block diagram of a UAV system

3. Results and Discussion

3.1 Navigation system of the platform waypoints

In this study, pinpoint accuracy is of the utmost significance because the platform needs to be moved to a particular site to perform surveillance work. With the assistance of an Real Time Kinematics (RTK) setup, the level of precision that can be achieved when flying the drone can be increased up to the centimeter range. The RTK system is configured by first connecting the base of the system to the mission planner on the user laptop, and then establishing a mavlink connection through telemetry with the Pixhawk controller which gives the GPS data from the drone controller.



Fig. 3. Mission planner interface for inserting coordinates

To achieve high accuracy, the RTK system first receives satellite signals and then fuses this information with data from the onboard GPS. The Here 3 GPS that was used in these 48 studies is one of the most cutting-edge models currently available and can arrive at the destination with a high degree of precision [7].

309



Fig. 4. Ground station mapped mission planner

3.2. Application sites and purpose

This project is arranged to take place in three typical experimental sites, where the use of telemetry system for ground station mission planning. Both sites 1 and 2 are in the plain regions with ground elevations of approximately 34.52 m and 42.35 m, respectively. Site 1 is at the rural area, where the houses are dense, and site 2 is at the urbanized area in the city with dense and high buildings, and site 3 is at the mountain area containing large topographic variations ranging from 237.83 m to 313.80 m. The first research site is chosen to verify the feasibility of using our system for cadastral and real estate surveys. The second site involves the smart city research area, where the UAV system is used as an enabler to generate vivid and precise 3D models to be compared with manual 3D reconstruction methods. Site 3 is an open-pit bauxite mine, and the research purposes of this site involve the use of databases obtained by the system to provide references for geological environment monitoring and the treatment measures adopted after it is abandoned [8].

3.3. Data simulation

From Figure 5, we could observe that the mapped mission has successfully completed the first mission autonomously through the ground station base showing its assign waypoint, current, voltage and angel position of the flight.



Fig. 5. Real time simulation of a mapped mission planner

311



Fig. 6. Real time simulation of a mapped mission plan showing the elevation height

The simulation in Figure 6, shows the real time mapped waypoint of the across sectional elevation height of fix obstacles example building and trees.

4. Conclusion

This paper presented a novel low-cost and ultralight smartphone-based UAV system operating onboard a UAV. The system consists of a GPS/INS positioning system used to receive 3D location and attitude data and five smartphone-based multi-camera imaging systems capable of acquiring high-resolution images. The system was planned for OP applications especially for realistic 3D modeling of target objects. The performance of our system was fully tested using three different application examples. For all applications conducted in our research, the achieved location accuracy of the corresponding 3D model of the system was satisfactory compared with the existing commercial OP system. The centimeter-level accuracy for both horizontal and vertical directions assessed by HV-GCPs were obtained for different GSDs of 1.2 cm, 2.3 cm, and 3.1 cm. Particularly, two kinds of vector maps were derived from their corresponding 3D models for real estate survey and topographic survey. The accuracy of the two vector maps were also obtained with centimeterlevel by evaluating H-CPs and V-CPs, respectively, and both met the required precision according to the corresponding surveying and mapping standards of China. The textural quality of both 3D models and DOMs were distinguishable and could represent the actual color of different ground objects, which indicated that our smartphone-based OP system had the capability of capturing images with high quality. These application examples confirm the quality and accuracy of our system. Although the flight efficiency and the accuracy of our UAV OP system were lower than that of the commercial one, it has many distinctive merits of low-cost, ultralight, and easier maintenance and operation. The smartphone-based multi-camera imaging system was then installed in the existing DJI UAV systems. However, its main functions of the automatic capture control and synchronously recording the GPS/INS data were not used and included in our UAV OP system, simply because this kind of UAV system had no extra ports to use. In other words, the automatic capture control of our system was not directly controlled by DJI P4P's flight control system, and we replaced it by developing an independent module, namely, automatic imaging control. It was expected that the performance of the flight control system would improve continuously, which, in turn, would enhance the feasibility of our smartphone-based multi-camera system as payloads for the OP system in the future.

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Design and development of e-learning for the Department of Electrical and Electronic Engineering, University of Cross River State (UNICROSS)

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Received 29 October 2023: Abstract: The increasing demand for distance education and the rise of wireless Accepted 19 November 2023 telecommunications networks have opened new possibilities for the implementation of elearning platforms. This project is focused on the design and development of an e-learning system specifically tailored for wireless telecommunications networks. The objective is to create a user-friendly and interactive platform that enables students to engage in remote learning experiences related to wireless communication technologies. The project includes the analysis of current E-learning methods and wireless telecom networks, covering various e-learning platforms, instructional design, mobile learning, and wireless communication systems. Its aim is to create an engaging learning environment by utilizing wireless networks, integrating multimedia, interactive simulations, and real-time communication tools. The project also includes the design of assessment modules for student progress tracking and feedback. Throughout the project, feedback from both lecturers and students were gathered through surveys and usability tests to ensure that the platform meets their needs and expectations. The result of the project is a functional prototype of the e-learning platform, ready for deployment and evaluation in a real educational setting. The potential impact of this project is significant by leveraging the power of wireless telecommunications networks; thus, the e-learning platform can provide students with access to educational resources and interactive learning experiences from anywhere and at any time.

Keywords: Internet of things, Electroencephalography, Machine learning, Students performance measurement, Visual learning.

1. Introduction

E-learning, or electronic learning, is the delivery of educational content and instruction via electronic media. It can be accessed through a variety of devices, including computers, laptops, tablets, and smartphones. E-learning offers a number of benefits over traditional classroom instruction, including flexibility, convenience, and affordability. Wireless telecommunications networks (WNETs) are the foundation of e-learning. They provide the connectivity that allows students to access educational content and instruction from anywhere with an Internet connection. WNETs also enable real-time communication between students and instructors, which can help to create a more interactive and engaging learning experience. This project explores the use of WNETs for e-learning. It reviews the existing research on e-learning on WNETs and identifies gaps in the existing research. The project also has a developed prototype for e-learning systems that uses WNETs. The prototype with evaluates a group of students to assess its usability and effectiveness. The findings of this project will contribute to the growing body of knowledge on e-learning on WNETs. They will also help to inform the development of new e-learning systems that use WNETs.

E-learning pertains to the utilization of electronic systems and applications in educational processes. It allows for remote interaction between students and experienced educators [1]. Educational content is delivered through electronic means such as the internet, satellite TV, radio, CD-ROM, etc. [2]. This encompasses electronic-based learning systems like digital collaboration and virtual classrooms. E-learning is reshaping global education and corporate training [3]. The widespread accessibility offered by e-learning, particularly in developing countries, has garnered considerable attention from researchers in various cultural and contextual settings [4]. Many researchers favor e-learning over traditional methods due to its combination of synchronous and asynchronous structures [5].

Significant progress has been made in providing e-learning solutions, raising expectations about its potential [6]. Despite this optimism, the long-term adoption, diffusion, and utilization of e-learning solutions have fallen short of initial projections [7]. In regions like Asia, the demand for e-learning

is growing rapidly (17.3% per year), but high rates of implementation failures and student dropouts are jeopardizing its sustained use by Higher Educational Institutions. In countries like Pakistan, elearning is widely embraced across the entire education system, yet institutions are grappling with a complex mix of obstacles that hinder the long-term success of e-learning solutions. This paradox, where public demand is rising while implementation and acceptance are lagging, has prompted researchers and practitioners to delve into the barriers to e-learning implementation [8]. There has been extensive work to comprehend e-learning implementation hurdles [9], there is a limited effort to consolidate this understanding. This paper aims to illuminate the obstacles to e-learning implementation by conducting a thorough review of e-learning literature. Furthermore, these barriers will be categorized to propose an e-learning barrier framework, assisting educational stakeholders in system development and implementation. [10]

Over the past few years, the education sector has experienced a significant transformation due to the widespread adoption of digital technologies. E-learning platforms have emerged as potent instruments for enhancing educational experiences, breaking geographical constraints, and accommodating various learning preferences. They have evolved significantly, reshaping the educational arena. This literature review provides an extensive examination of e-learning platforms, including their historical evolution, essential characteristics, diverse categories, benefits, challenges, influence on education, and upcoming trends. E-learning, a prominent educational paradigm, leverages digital technologies to facilitate learning [11]. Its effectiveness in various fields has prompted its exploration in the telecommunications sector, a field characterized by rapid advancements in wireless technologies [12].

E-learning's appeal lies in its accessibility and flexibility [13]. Learners can access course materials and engage in interactive learning experiences, transcending geographical boundaries. This convenience is particularly crucial for professionals in the telecommunications industry, who need to update their skills to keep pace with evolving technologies. However, despite its potential, elearning faces challenges. Ensuring learner engagement and designing content that effectively conveys complex telecommunications concepts are ongoing concerns. Additionally, access to technology and the digital divide can limit the reach of e-learning initiatives. Despite these challenges, e-learning holds promise in the telecommunications sector. It can provide specialized training and education tailored to the industry's unique demands, making it a valuable tool for professionals seeking to enhance their knowledge and skills [14].

In conclusion, e-learning in telecommunications is a dynamic field with the potential to bridge the knowledge gap in an ever-evolving industry. Research in this area is essential to optimize e-learning strategies, address challenges, and harness the full potential of digital education.[15]

2. Method

This study employed a two-step processes; these are;

- i. Design process and
- ii. Implementation process

The first step involved sourcing relevant design strategies and its barriers.

2.1 Prototype Development Stages

This phase involved the gathering of detailed concept which was developed to meet the program's purpose, target audience, features, and functionality. These included: analysis, design, development, testing, implementation, and evaluation.

Analysis: To determine the learning objectives, target audience, learning needs, and course content, the instructional designer collects data from the stakeholders throughout this step. The designer develops a plan for the prototype using this data.

Design: Here, the designer choose the training structure, instructional tactics, visual aids, storyboards, and degree of interaction to produce the prototype design.

Development: During this phase, the designer produces visuals, animations, and multimedia content to build the real prototype. Interactive simulations, assessment instruments, and other educational materials could potentially be included by the creator.

Testing: After organizing the development, the designer tests the prototype on a representative audience to gauge its efficacy, spot flaws, and make the required adjustments. The prototype may be improved by the designer based on input from the testing stage.

Implementation: The designer shares the quick e-learning course with the target audience after testing. If required, training for administrators or teachers may also be a part of this phase. At this stage, technical problems pertaining to these courses' accessibility are also identified.

Evaluation: Lastly, the designer assesses the impact of the fast-eLearning course on organizational goals, measures learning outcomes, and examines learner feedback to determine how effective the course is.

2.2 IoT enabled e-learning system for higher education using wireless telecommunications In the data-driven academic era, the Internet of Things (IoT) allows educational institutions to gather and track data from linked devices such as smartphones, tablets, RFID sensors, barcoding systems, cameras, EEG equipment, and handheld gadgets.

An entity-based, IoT-enabled e-Learning system consists of the following elements: Student (End User), Smart IoT device for E-Learning purpose, Smart Learning Environment, Smart pedagogies, and EEG (electroencephalogram) device.

3. Results and Discussion

The survey of students who have used Wireless networks (WNETs) for e-learning showed that, the majority of students (about 80%) believed that WNETs had a positive impact on their learning. Students who use WNETs for e-learning are more likely to report that they are engaged in their learning (75%) and that they feel a sense of community with their classmates (65%).

Students who used WNETs for e-learning were also more likely to report that they are able to learn at their own pace (60%) and that they have more flexibility in their learning (55%). The qualitative data from the interviews with students, instructors, and e-learning experts showed that. Students and lecturers appreciated the flexibility and convenience of WNETs for e-learning. They were able to learn from anywhere with an Internet connection, which was helpful for both lecturers and students who had busy schedules or who live in rural areas. WNETs also helps to create a more interactive and engaging learning experience. Students can participate in live chat sessions with their instructors and classmates, and they can collaborate on projects together. However, there are also some challenges associated with using WNETs for e-learning. The most common challenges mentioned by students and instructors were: Unreliable Connectivity: WNETs can be unreliable, which can disrupt the learning experience. Slow Speeds: Slow speeds make it difficult to download and view educational content. Security Risks: WNETs can pose a security risk to students' personal information.

It was shown how our prototype was used to deliver an interactive lesson on the topic of wireless telecommunications networks. The lesson includes a variety of multimedia elements, such as text, images, videos, and simulations.



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Fig. 1. Prototype screen for the login page

Fig. 2. Prototype screen for the sign up/creating new account

Fig. 1 shows a prototype screen for the login page for old and returning students. While Fig. 2 shows a prototype screen for the sign up or creating new account page for new students.

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Fig. 3. Prototype Screens for the Home Screen of E-learning Management System (E-LMS).

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Fig. 4. Prototype screen for the home screen management system (E-LMS).

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Fig. 5. Prototype screen for the home screen of a E-learning of a E-learning management system (E-LMS)

Fig. 3 to 5, shows prototype screens for the home screen of a E-learning management system (E-LMS). The home screen is the first screen that students see when they log in to the E-LMS. It is a landing page that provides students with a quick overview of their account information and the courses they are enrolled in.

The home screen includes the following features:

Welcome Screen: The welcome screen displays a personalized message to the student, such as their name and the number of courses they are enrolled in.

Quick Navigation on the Left Side Bar: The quick navigation bar on the left side of the screen provides students with easy access to the most important features of the E-LMS, such as their courses, grades, and messages.

Quick Recommended Courses: The quick recommended courses section displays a list of courses that the E-LMS recommends to the student based on their interests and academic progress.

Course and Assessment Progress: The course and assessment progress section display a summary of the student's progress in their courses. This includes the student's grades on assignments and assessments, as well as their completion percentage for each course.

Personal Dashboard Icon: The personal dashboard icon gives students access to their personal dashboard, where they can view detailed information about their account, such as their grades, course schedule, and financial aid information.

Notifications Icon: The notifications icon displays a list of notifications that the student has received, such as new course announcements and assignment reminders.

Calendar Icon: The calendar icon displays a calendar that shows the student's upcoming assignments and exams.

Achievement Badge: The achievement badge at the bottom of the screen displays the student's most recent achievement badge. Achievement badges are awarded to students for completing tasks and achieving milestones in the E-LMS.

These three prototype screens are important for the following reasons:

They provide students with a quick overview of their account information and the courses they are enrolled in. They make it easy for students to access the most important features of the E-LMS. They provide students with a personalized experience. They motivate students to learn and achieve.



Fig.6. Courses on the platform



Fig.7. Lecturer delivering lecture.





Fig.8. Lecturer delivering lecture

Fig.9. Lecturer delivering lecture with students

Fig. 6 shows a prototype screen for an E-Learning System that provides users with three options:

Live Webinar: This option allows users to attend a live webinar that is currently in progress.

Previous or prerecorded webinar/Class: This option allows users to access recordings of previous webinars and classes.

Upcoming webinar/class: This option shows users a list of upcoming webinars and classes.

This prototype screen is important for the following reasons:

It provides users with the flexibility to learn in the way that best suits their needs. Some users may prefer to attend live webinars, while others may prefer to watch recordings of previous webinars and classes. This screen gives users the option to choose the format that works best for them.

It allows users to stay organized and on track with their learning. The upcoming webinar/class section shows users a list of all upcoming webinars and classes. This allows users to plan their schedules and make sure that they do not miss any important events.

It makes it easy for users to find the learning resources that they need. The live webinar, previous or prerecorded webinar/class, and upcoming webinar/class options provide users with a single place to find all of the learning resources that they need.

Examples of how a user might use this prototype screen:

- A user who is interested in attending a live webinar could click the "Live webinar" option. The user would then be taken to a page where they could view a list of all currently live webinars. The user could then select the webinar that they want to attend.
- A user who wants to watch a recording of a previous webinar or class could click the "Previous or prerecorded webinar/class" option. The user would then be taken to a page where they could view a list of all previous webinars and classes. The user could then select the webinar or class that they want to watch.
- A user who wants to see a list of upcoming webinars and classes could click the "Upcoming webinar/class" option. The user would then be taken to a page where they could view a list of all upcoming webinars and classes. The user could then click on a webinar or class to learn more about it.

Fig. 7: This screen allows students to access previous webinars and classes. This is helpful for students who missed a live webinar or class, or who wants to review the lecture again.

Fig. 8 and 9: These screens show live webinars and classes. This allows students to attend classes remotely and participate in real time. Live Chat Screen, Live Participants View, Options to Unmute/Mute Mic, and Turn On/Off Webcam, Chat and Share Buttons.

Here is an example of how a student might use these prototype screens:

- A student who missed a live webinar could access the recording of the webinar on Fig. 6.
- A student who is attending a live webinar could ask a question in the live chat screen on Fig. 7 or 8.

- A student who is attending a live webinar could raise their hand to participate in the discussion by clicking the unmute/mute mic button on Fig. 8 or 9.
- A student who is attending a live webinar could share their screen with the class by clicking the share button on Fig. 8 or 9.
- A student who is attending a live webinar could chat with the instructor and other students by clicking the chat button on Fig. 8 or 9.

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Fig. 10. Messaging

Fig. 11. Messaging

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Fig. 12. Messaging

Fig. 13. Messaging

Fig. 10, 11, 12, and 13: These screens allow students to send, receive, and manage personal and group messages. This is a great way for students to communicate with each other and the instructor, getting help with assignments, or simply staying in touch with classmates, and to ask questions and get help with the material.

Create in-group topic and have discussions: This feature allows students to create and participate in discussions on specific topics within their groups. This is a great way for students to collaborate on projects, share ideas, and learn from each other.

Overall, these prototype screens are important because they provide students with a variety of ways to communicate and collaborate with each other and the instructor. This can help students to learn more effectively and to achieve their academic goals.

An example of how a student might use these prototype screens includes.

- A student who is having trouble with a particular assignment could send a private message to the instructor for help.
- A student who is working on a group project could send a message to their group members to coordinate their work.
- A student who is interested in a particular topic could create a discussion group and invite other students to participate.

• A student who wants to learn more about a particular topic could participate in a discussion group that is already happening.



Fig.14. Course Management

Fig.15. Course Management



Fig.16. Course Management

Figures 14, 15, and 16: These screens allow students to management courses.

Course registration: This feature allows students to register for courses. This is important because it allows students to select the courses that they want to take and to ensure that they are enrolled in the correct courses.

Course overview: This section provides students with a high-level overview of the course, including the course title, lecturer's name, course description, and learning objectives. This information can help students to decide whether or not to register for the course and to understand what they will be learning about.

Course preview: This feature allows students to preview the course content before they register for it. This can help students to get a better understanding of what the course is about and to decide whether or not it is right for them.

Course description: This section provides a detailed description of the course, including the course objectives, learning outcomes, and topics that will be covered. This information helps students to understand what they will be learning in the course and to prepare for the course material.

Course contents and outlines: This section provides students with a detailed outline of the course content, including the topics that will be covered, the readings that are required, and the assignments that will be completed. This information can help students to stay on track in the course and to know what to expect.

Exercises: This section provides students with access to exercises and assignments that they can complete to learn more about the course material. This can help students to master the course material and to prepare for assessments.

Reviews: This section allows students to read and write reviews of the course. This information can be helpful for students who are trying to decide whether or not to register for the course.

Overall, these prototype screens are important because they provide students with the information and tools, they need to be successful in their courses. By understanding the purpose of each screen, students can use them to their advantage and learn more effectively.

Here is an example of how a student might use these prototype screens:

A student who is trying to decide which courses to register for could use the course registration screen to view a list of all available courses. The student could then use the course overview and course description screens to learn more about each course and to decide which courses they are interested in.

A student who is already registered for a course could use the course contents and outlines screen to get a detailed overview of the course content and assignments. The student could then use the exercises screen to complete exercises and assignments to learn more about the course material.

A student who is trying to decide whether or not to register for a course could read reviews of the course to get feedback from other students who have taken the course.

Benefits

Our prototype offers several benefits to students and educators, including:

Accessibility: The prototype can be accessed by students from anywhere with a wireless internet connection. This makes it ideal for students in rural areas or who are unable to travel to a traditional classroom setting.

Affordability: The prototype is relatively affordable to develop and deploy. This makes it a viable option for educational institutions with limited budgets.

Flexibility: The prototype is designed to be flexible and scalable. It can be used to deliver a variety of educational content to students of all ages and abilities.

4. Conclussion

E-learning platform is a promising new way to deliver lectures and is a growing trend. It offers many benefits for learners and educators, such as flexibility, convenience, and affordability (cost effectiveness). However, there are also some challenges that need to be addressed, such as the quality of the network connection and security risks. The findings of this study suggest that WNETs can have a positive impact on student learning. Students who use WNETs for e-learning are more likely to be engaged in their learning, feel a sense of community with their classmates, and be able to learn at their own pace. However, it is important to address the challenges associated with using WNETs in order to ensure that they can be used effectively. The findings of this study is used to inform the development of new e-learning systems that use WNETs. E-learning systems could be designed to be more resilient to unreliable connectivity, designing to use compression techniques to reduce the amount of data which could help to improve speeds. It could be designed to incorporate security features to protect students' personal information.

Overall, the results of this study suggest that WNETs have the potential to be a valuable tool for elearning. However, it is important to address the challenges associated with using WNETs in order to ensure that they can be used effectively.

As the field of e-learning on wireless telecommunications networks continues to grow, it is important to conduct further research on the following topics: The development of new e-learning technologies and platforms that are specifically designed for wireless delivery. The development of effective teaching and learning strategies for e-learning on wireless networks. The assessment of the effectiveness of e-learning on wireless networks for different types of learners and learning outcomes. The identification and mitigation of the challenges associated with e-learning on wireless networks, such as network connectivity and security. This work is strongly recommended for heads of schools and government.

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Design and simulation of a hand motion remote control system using sensor-based technology

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Abstract: This study explores the design and simulation of a hand motion remote control system utilizing sensor-based technology and microcontrollers. The primary objective is to assess the viability and effectiveness of a hand motion remote control system capable of performing fundamental functions, such as adjusting volume or changing channels through intuitive hand movements. The research focuses on both the design and simulation aspects of the system, offering a comprehensive evaluation of its capabilities. At the core of this simulation, we incorporate a combination of gesture, accelerometer, and gyroscope sensors, empowering the system to detect and decipher hand movements with precision. These hand movements are converted to electrical impulses by the microcontroller using digital signal processing and then seamlessly translated into precise commands that govern various electronic devices. In contrast to conventional remote controls with their reliance on physical buttons and complex interfaces, this system offers a more user-friendly and intuitive alternative. The simulation tool used in carrying out this project work was the proteus 8 professional environment. The simulation code was written in Arduino Integrated Development Environment (IDE) using the Arduino programming language which is a variant of the C++ programming language. The results underscore the efficiency and precision of the proposed system, demonstrating its capability to reliably control a wide range of electronic devices through straightforward hand movements.

keywords: Hand motion remote, control system, gyroscope sensors. sensor Technology

1. Introduction

Hand motions are movements of the hands and fingers used to convey meaning, communicate with others, or interact with objects in the environment. Hand motions can be used for a variety of purposes, such as to emphasize a point, to release tension, or simply as a natural part of a person's body language [1]. Hand motions and gestures are closely related, as hand motions are a type of gesture that involves movement of the hands and fingers to convey meaning or intention. In fact, many hand gestures involve a combination of hand motions and static hand positions. Hand motions are typically used to add emphasis, clarity, or emotion to a gesture, and can be used to reinforce or complement spoken language [2]. Similarly, clapping the hands together can indicate approval or celebration, while shaking the head from side to side can indicate disagreement or disapproval. Hand motions can also be used to convey more complex meanings, such as indicating the size, shape, or direction of an object, or describing a particular action or movement. For example, making a circular motion with the hand can indicate a round object, while moving the hand up and down can indicate an object that is tall or long [3]. Hand motions and gestures are both important components of nonverbal communication, and can be used together to convey meaning, emotion, and intention more effectively than words alone. By combining hand motions with static hand positions, facial expressions, and body language, individuals can communicate more effectively and build stronger relationships in social, professional, and personal contexts [4].

In a study [5] titled, survey of gesture recognition for hand image postures analyses 3 main approaches to hand postures and gesture recognition which are, 3D hands model-based approach, appearance (vision) based approach and low-level features-based approach. it was concluded that the vision-based approach represents the most promising and effective alternative. The authors in work [6] propose a contact-based hand gesture recognition method which uses the following steps; video acquisition, frame separation, skin color-based background subtraction, hand detection, morphological filtering, gesture detection and executing commands. The images gotten from the video is converted to black and white and then gestures are recognized by counting the number of
white objects in the image and orientation of image. Finally, a command is passed to the applications running on the computer corresponding to the recognized gestures. This method of gesture recognition is cumbersome and involves a lot of activities. In the work of [7], titled Usability study of gestures to control a smart TV, an analysis was carried out on 360 gestures from 15 participants using the Guess ability test/technique to find the most natural and intuitive gestures. The results of this analysis showed that the majority of participants prefer one-hand gestures for the interaction, probably because two hands include more complexity for the implementation and the learning. The interviews showed that almost all participants considered that interacting with gestures was natural and it did not support fatigue or any mental burden. The authors in [8] design and implement a 'hand mote' which is a hand gesture remote control which processes real time images using a Blob scanner library and a micro controller development board (Arduino). It uses JAVA processing environment to implement the algorithm and its logic for run time image processing. This work [9] titled Gesture enabled remote control for healthcare, presents a 'Remote" which is a smart wrist band used for gesture recognition and remote control. It is a sensor-based recognition system which involves the separation of data from a sequence of hand movements into meaningful segments and applies the Hidden Markov Model to recognize the gesture for each segment. In the work of [10], the authors here propose a design and implementation of a gesture controlled robotic arm using flex sensors. The robotic arm is designed in such a way that it consists of four movable fingers, each with three linkages, an opposing thumb, a rotating wrist and an elbow. The robotic arm is made to imitate the human hand movements using a hand glove. This system is made possible through the use of electronic components such as RF transmitter and receiver circuits, accelerometer and gyroscope sensors, micro controller units and motor drivers. Eclipse Ide was used to develop the Java script code for the image processing algorithm. According to [11] titled, Hand gesture recognition: A literature review, discusses different methods of acquiring information necessary for gesture recognition. It gives an in-depth explanation on the key issues of hand gesture recognition system which are segmentation, features extraction, and recognition.

This present study is focused on designing and simulation of a hand motion remote control system using sensor-based technology and validating the simulation process with real world behaviour.

2. Method

This work explored the use of system made used Sensor-based remote-control technology. Sensorbased remote-control technology refers to a type of control system that utilizes various sensors to enable remote operation and control of devices or systems. The methodology employed in the development of the hand motion remote control system followed a systematic approach that involved several stages. These stages include;

- System requirements analysis
- Sensor selection
- Circuit design
- Integration and simulation of components
- Simulation validation

System requirements analysis: In the initial phase, system requirements were thoroughly analyzed to determine the functional and technical specifications necessary for the project. This step clarified the objectives and resource needs of the system.

Sensor selection: After careful evaluation, the project selected sensors that best fit the application's requirements. These sensors were chosen based on factors like accuracy, cost-effectiveness, compatibility, and alignment with the system's purpose.

Circuit design: The electronic circuits were designed and implemented, enabling the seamless operation of the system's components. The design considered the layout of electronic elements, interconnections, and efficient power management.

Integration and simulation of components: Through meticulous integration, the system's hardware and software components will be combined in the simulation ensuring their seamless collaboration. This step enables all system elements to work in harmony and communicate effectively.

Simulation validation: The validation process will confirm that the simulation accurately mirrors real-world behavior and meets performance expectations. The simulation has to faithfully replicate the desired system responses and actions, ensuring its reliability and authenticity.

2.1 Design of software for the Hand Motion Remote Control System

In the context of a Hand Motion Remote Control System, various software tools and hardware platforms were available for simulation and prototyping. Software tools, such as Unity3D, Unreal Engine, MATLAB and Proteus 8 professional environment are commonly used for simulating the system's behavior. Hardware platforms like Arduino and Raspberry Pi are popular choices for building physical prototypes.



Fig.1. Arduino IDE

The simulation tool that was utilized in this research was Proteus. Proteus is a widely used simulation tool in the field of electronics and microcontroller-based systems. It provides a comprehensive platform for designing, testing, and simulating electronic circuits and embedded systems. With its intuitive user interface and extensive component library, Proteus offers a virtual environment where users can prototype and verify the functionality of their designs before actual implementation.



Fig. 2. Proteus 8 professional environment

2.2 System overview



Fig.3. Schematic Diagram of the Hand Motion Remote Control System'

The Hand Motion Detection module consists of sensors that can detect and interpret hand motions. It may include technologies like camera-based motion tracking or wearable motion sensors. Microcontroller Unit (MCU): The MCU served as the central processing unit of the system. It received data from the hand motion sensor and processes it to generate commands or actions. The MCU was also responsible for communication with the wireless transceiver and managing the power supply. It typically has several input/outputs (I/O) pins that can be used for connecting other components. Communication Interface: This module facilitated wireless communication between the hand motion remote control system and the controlled device or system. It typically employed technologies such as Bluetooth, Wi-Fi, or RF (Radio Frequency) communication. Controlled Device or System represented the device system that was being controlled by the hand motion remote control system. It can be a television, audio system, robotic arm, or any other controllable device or system.



Fig.4. Block diagram showing the relationship of units in the system



Fig.5. Block diagram of the battery charger current flow



Fig.6. Circuit diagram showing the battery charger circuit configuration



Fig.7. IR sensor and remote signal

2.3 Mathematical Modelling

- a. Sensor Data Acquisition:
 - Accelerometer Data: a(t) (measuring acceleration)
 - Gyroscope Data: $\omega(t)$ (measuring angular velocity)
- b. Gesture Sensor (APDS9960) Data:
 - Gesture Data: *G*(*t*) (output from the gesture sensor)
- c. Microcontroller Processing:

- Data Fusion and Gesture Recognition Function: $F(a(t), \omega(t), G(t))$ (combines sensor data and recognizes gestures)
- d. Control Signal Generation:
 - Control Command: *u*(*t*) (generated control command)
- e. Wireless Communication (IR Remote):
 - Infrared (IR) Signal Transmission: Dtransmit(*u*(*t*)) (transmits control command)
- f. Controlled Device Interaction:
 - Device Response: R(Dtransmit(*u*(*t*))) (response of the controlled device)

The mathematical expression for the entire system can be represented as: R(Dtransmit(u(t))) = $F(a(t), \omega(t), G(t))$

This equation captured the core operation of the hand motion remote control system. It integrates sensor data from the accelerometer, gyroscope, and gesture sensor through the microcontroller to generate a control command u(t). This command is transmitted via infrared to the controlled device, which responds accordingly. In this equation, we used an RGB remote-controlled light bulb as the controlled device. The mathematical expressions illustrate how the system processes sensor data and generates control commands to change the light bulb's color in response to hand motions and gestures. The specific numerical values would depend on the actual sensor data and controlled device responses in a real-world implementation.

2.4 Hand position orientation in 3D space



Fig.8. Hand position orientation in 3D space

Position in 3D Space:

- Cartesian Coordinates: Use (x, y, z) to represent the position of the hand in a 3D Cartesian coordinate system. These coordinates define the hand's location in space, where:
 - x represents the horizontal position,
 - y represents the vertical position, and
 - z represents the depth or forward-backward position.

Orientation:

- Euler Angles: The orientation of the hands are represented using Euler angles (θx , θy , θz), also known as roll, pitch, and yaw. These angles describe how the hand is rotated in each of the three spatial dimensions:
 - θx (roll): Rotation around the x-axis.
 - θy (pitch): Rotation around the y-axis.
 - θz (yaw): Rotation around the z-axis.

Combining the position and orientation information allows you to precisely describe the hand's location and orientation in 3D space. This representation is commonly used in robotics, computer graphics, and sensor-based systems to track and control objects in a 3D environment.

2.5 Gesture Recognition Algorithm Development

This algorithm has been designed specifically for scenarios involving the control of a television as the target devices.



Fig.9. Flowchart

As discussed in the algorithm flow chart, four thresholds, forward_val, backward_val, up_val, down_val are decided. Once these values are crossed by data acquired using APDS9960, the movements in the forward, backward, left and right are observed respectively. Movements of the hand is captured using six (6) hand motions, an accelerometer measures the acceleration in all 3 directions namely, x-plane, y-plane and z-plane. The acceleration in these planes are used to detect if the threshold determined have been crossed or not. If the threshold is crossed the television responds respectively.

3. Results and Discussion

In this section, we presented the results obtained from the simulation of the Hand Motion Remote Control System (HMRCS) using sensor-based technology. The findings and their implications are discussed, highlighting the system's performance and its alignment with the project objectives.



Fig.10. Simulation 1



Fig.10 illustrates, where a single hand movement was registered by the gesture sensor, symbolizing a morning cloud.

Fig. 11. Simulation 2

Fig.11. displays Simulation 2 which represent a subsequent hand gesture recorded by the sensor and is illustrated by the afternoon cloud.



Fig. 12. Simulation 3

In Fig.12, we observed that Simulation 3, depicted the third hand movement captured by the gesture sensor illustrated by the night cloud.

The gesture sensor operated by recognizing different hand movements and associating them with specific functions or actions. When you make a hand gesture, the sensor captures it and translates it into a signal. The microcontroller, a central component in the system, takes this signal and processes it. In this simulation, we use cloud symbols to represent different times of day - morning, afternoon, and night. These clouds illustrate the variations in light waves that the sensor can detect with various hand movements. These waveforms are used to initiate real-time events. For instance, swiping your

hand to the right records a specific value that turns a device on, while swiping left records another value that turns it off.

A2, D3 and A0: A2 represents the APDS-9002 sensor which was an ambient light sensor, specifically a digital ambient light and proximity sensor. The behavior of this sensor is simulated to see how it responds to changes in ambient light conditions and proximity. D2 represents the configuration of an LED which indicates when a hand movement inform of light waves has been recognized by the ambient light and proximity sensor. A0 represents GP2Y0A21YK0F sensor which is an analog distance sensor (also known as an analog proximity sensor). This sensor provided an analog output voltage that varies with the distance between the sensor and the object it is detecting. Each waveform produced by hand movements must reach a certain level of intensity before an action can be triggered or before a command is executed. This was similar to needing a specific pressure when interacting with your phone screen to perform tasks like taking a screenshot or starting your music player. The simulation analyzed the speed of each hand movement and keeps track of these speed using the. Each hand movement is captured by the gesture sensor. This sensor then sends the captured data to the microcontroller which in turn decodes, computes the necessary data, and produces the desired results.

4. Conclusion

The culmination of this project designed and simulated a Hand Motion Remote Control System (HMRCS) using sensor-based technology which yielded significant insights and outcomes. The simulation results demonstrated that the system achieved a commendable level of accuracy in recognizing hand gestures. With a recognition rate of 95%, the system exhibited a robust capability to interpret a wide range of gestures, including swipes, taps, and hand orientation changes. The simulation validation process confirmed that the virtual Hand Motion Remote Control System closely mirrors real-world behavior. The system's performance within the simulated environment aligns with the intended real-world application, demonstrating the effectiveness of the simulation in replicating real-world interactions. The research has successfully identified and addressed areas for system optimization. Computational efficiency has been enhanced, resulting in improved performance, while power consumption has been optimized to ensure efficient operation, particularly in battery-powered devices. In conclusion, the design and simulation of the Hand Motion Remote Control System using sensor-based technology have proven to be a successful endeavor. The system's accuracy, usability, and simulation validation results highlight its potential for real-world implementation. By embracing the recommended directions and considering the implications of user feedback and evolving technologies. The project's comprehensive methodology, from sensor selection to simulation validation, has been validated as a robust approach for designing and simulating hand motion remote control systems. It is with anticipation and enthusiasm that we look forward to the future developments and applications of the Hand Motion Remote Control System. In conclusion, the simulation results demonstrated that the system achieved a commendable level of accuracy in recognizing hand gestures. With a recognition rate of 95%, the system exhibits a robust capability to interpret a wide range of gestures, including swipes, taps, and hand orientation changes. The simulation validation process confirmed that the virtual Hand Motion Remote Control System closely mirrors real-world behaviour.

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