THE ASSOCIATION FOR CONSULTING ENGINEERING IN NIGERIA (ACEN)

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FROM THE EDITORIAL SUITE

Engr. Ademola Adeboya, MNSE

Can we say: "There is light at the end of the tunnel in Nigeria?"

This edition of our popular magazine is about electricity which provides light and power. Specifically, it is published on the theme: "Electrical Power Generation and Distribution". In keeping with the usual outstanding educative value of our magazine, this edition will illuminate the minds of readers just as electricity illuminates the environment through electric bulbs and lamps.

The first article is entitled: "Operations of Nigeria's National Grid, Challenges and Solutions" by Dr. Peter Olabisi Oluseyi, Associate Professor of Electrical Power & Energy Systems, Department of Electrical & Electronics Engineering, University of Lagos. Dr. Oluseyi is an expert on Power Systems. Readers will discover the answer to the country's national grid problems in Dr. Oluseyi's treatise.

Other articles are presented by experts as follows:

i. Execution of Solar Electricity Projects by Engr. Curtis Uwuigbe, C.Eng, MNSE, MNSChE, MAIChE, MPE (CEO, Curtis Energy Ltd) & Engr. Anthony Ogheneovo, MNSE, FNSChE (Chairman, Sharetech Consulting Ltd)
ii. Design and Execution of an Electricity Substation Project by Engr. Sam Otenaike, FNSE (Principal Partner/CEO, Samabot & Associates Ltd and Engr. Olawunmi Abolarin, MNSE (Chief Engineer/Head, Electrical Services)
iii. Policy on Mini-Grids, Rural Electricity Access and Implementation in Nigeria by Dr. Ibukun D. Fajuke, Deng (Power Energy Machine and Drive Research Group Department of Electrical and Electronic Engineering, Faculty of Technology, University of Ibadan)
iv. Hydroelectric Power Generation by Engr. Aminu Musa (Principal Manager, Mechanical, Shiroro Hydroelectric Power Plant)

ACEN carried out some activities in pursuit of the vision of the Association. These activities are shared with the reading public in memorable pictures. They include FIDIC Training, Business Evening and 2024 ACEN EGM. Check them out inside.

This edition gives special recognition to Actolog Solutions Limited, a prominent firm in the Electricity Industry. Under the visionary leadership of Mr. John Akadu, Managing Director of Actolog Solutions Limited, the company has come up with sustainable integrated renewable energy solutions that meet a variety of needs of small and large scale consumers. This is exactly what Nigeria and other countries need in this era of climate change concerns.

Also in the Special Supplement section, we have featured IEC Group Company Limited, an outstanding player in Nigeria's Electricity Industry with numerous flagship projects to its credit. We congratulate Engr. Hassan Odediran, MD/CEO, Interactive Engineering Consult Limited for the meritorious achievements.

In the personality profile section, we present Engr. Adewale Adereti, Managing Director, FixonTime Electric Limited. He is a seasoned Electrical Engineer whose meteoric rise to iconic status in a short span of time in engineering practice is a feat that young engineers should emulate.

In this edition, we are also presenting news on an outstanding company, MicCom Cables and Wires Limited where Mrs. Olubukola Adubi serves as the Chief Executive Officer. One may wonder how an organization producing electric cables and wires is headed by a Pharmacist. Her phenomenal success can be attributed to being versatile, vision-driven in addition to other positive attributes. You can imagine Bukola Adubi on a visit to the factory floor beaming in feminine radiance, filled with a sense of satisfaction and fulfilment as she observes MicCom cables and wires of international standard being churned out from the production facilities. Her competence in the industry has earned her the election to the post of the President of the Cable Manufacturers Association of Nigeria.

Engr. Enefiok Ubom, in his Tit-Bits Column, takes readers to the basics about Electricity with such terms like ampere, ohm and others under the title: "Reminiscences of Electricity Lesson" in a Physics Class. Check for these and more.

The contributors to this edition have done extremely well. We value their partnership and contributions and appreciate them greatly.

Enjoy your reading.

Engr. Ademola Adeboya
(Chairman, Editorial Board)

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THE ASSOCIATION FOR CONSULTING ENGINEERING IN NIGERIA (ACEN)

The Association for Consulting Engineering in Nigeria, ACEN, was founded in 1971 and registered in 1979. ACEN is a body of registered independent private engineering consultancy firms and the voice of the profession in Nigeria.

MISSION STATEMENT

""ACEN shall build a strong membership that fosters equal opportunities, creates competitive advantage through increased visibility with strategic partners, and improves the standards of consulting engineering in line with international best practice."

VISION STATEMENT

"To remain the ultimate reference business association of choice for organisations providing professional engineering consultancy services in Nigeria."

FUNDAMENTAL OBJECTIVES

- Ensure that the highest level of technical competence and business ethics are brought to bear on the practice of the profession in Nigeria.
- Ensure that every State has the highest level of Consulting Engineering practice by having members in every state of the federation and the federal capital.
- Increase the number of engineering firms in the country relative to the size of the nation.
- Ensure that stakeholders in the built environment get maximum value for their investments by monitoring standards of practice within the industry.
- Grow the industry by promoting the growth of large consulting engineering firms.

ACEN MEMBERSHIP

Prior to December 2007, ACEN membership was open to individual and firm members, who possessed the required experience and professional integrity. At the 2007 AGM, a motion was passed limiting ACEN membership to firms. This was to further emphasize the business nature and focus of the association. Membership is therefore now open to Consulting Engineering firms with the adequate experience and commitment to continuous improvement in technical and business integrity. Today, ACEN's member firms numbering about 300 are located in the 6 geo-political zones and the FCT.

ACEN & COREN

The Council for the Regulation of Engineering in Nigeria is the statutory body responsible for the regulation of all Engineering activities in Nigeria. It is empowered to keep a register of all Engineering craftsmen, technicians, technologists, Engineers and Consulting Engineering Firms who wish to practice in the country. No individual or organization is allowed to practice Engineering in Nigeria without the approval of COREN. Thus all member firms of ACEN must be registered with COREN and the members of such firms must also be individually registered by COREN. ACEN has just recently been mandated by COREN to register on its behalf all consulting engineering firms in the country. Furthermore, ACEN President now seats on the Council of COREN. Thus, ACEN is now better positioned within the built industry.

ACEN & NSE

The Nigerian Society of Engineers is the umbrella association of all graduate Engineers in Nigeria and all Engineers employed in ACEN member firms are members of NSE. Conversely, most members of NSE with an interest in Consulting Engineering practice are members of ACEN. ACEN focuses only on the business interest of Consulting Engineering Firms and her interest is, therefore, specific and complementary to the scope of COREN and NSE.

ACEN & FIDIC

The International Federation of Consulting Engineers is a 100-member organisation that provides the strongest platform for our international activities. FIDIC is the voice of Consulting Engineering all over the world, and this it does through seven major focus areas: Representation, Business Practice, Ethics/Integrity, Image, Sustainability, Globalization and Quality.

FIDIC is perhaps best known for its contract documents, which are used all over the world, especially for international projects in the third world. The documents are used extensively by the Nigerian Federal Ministry of Works. In addition, FIDIC has Manuals on a Guide to Practice that teaches best practice in Consulting Engineering, Business Integrity Management, and Quality Management amongst several others.

Two (2) ACEN members, Engr. J.I. Folayan and Engr. Bayo Adeola have served on the FIDIC Executive Committee, the highest level of the organization. Other ACEN members have served on committees and task forces of the organization, and members attend the yearly annual conferences in large numbers regularly.

ACEN & FIDIC Africa

FIDIC Africa is the FIDIC Group of African Member Associations which addresses specifically, African concerns. FIDIC Africa currently has 14 members, holds regular annual conferences and AGMs, and promotes networking among its members. Nigeria played a very active role in the formation of FIDIC Africa and has continued to be very active in the Association.

ACEN Past President, Engr. (Mrs.) Mayen Adetiba, was once Chairman of FIDIC Africa while several ACEN members have served on the Executive Committee including ACEN's past Presidents, Engr. Charles 'Yele Akindayomi and Engr. George C. Okoroma (JP), who are members, presently, of the FIDIC Africa Executive Committee.

ACEN ACTIVITIES

ACEN provides a series of activities tailored to deliver service and benefits to our members in these key areas:

- Training through the ACEN School of Consulting Engineering.
- AGM & EGM for effective dissemination of information to members.
- Attending International Conferences.
- Membership / Certifying Standards.
- Advocacy.
- Quarterly Business Evening meetings to discuss topical issues affecting members.
- The Young Professionals Forum.
- Triannual publication of "The Consulting Engineer" magazine.
- Monitoring and follow-up on policies and bills relating to matters of engineering practice.
- Legal retainership program to advise members on legal issues.
- Advancing the practice of consulting engineering for favourable business environment for members.
- Setting up of Special Task Forces on:
  The collapse of buildings, conditions of engagement/ scale of consultancy remunerations, quackery, Industry study, formation of built industry transparency initiative, local content for the construction industry, etc.

CHALLENGES OF ACEN

Despite the fact that ACEN has been in existence for fifty-three (53) years, some of the challenges leading to its formation have remained while new ones have emerged. The most notable current challenges are as follows:

- Unfavourable Government procurement policies especially in the states.
- Private sector perception.
- Loss of Engineers to other sectors due to low remunerations.
- Number, size and scope of ACEN Member firms.
- Delayed payments to members.
- Limited awareness and knowledge of the savings consultants contribute to the overall cost of projects if employed by governments and entrepreneurs.
- Inadequate corporate sponsorship to enhance smooth operations of the organisation.

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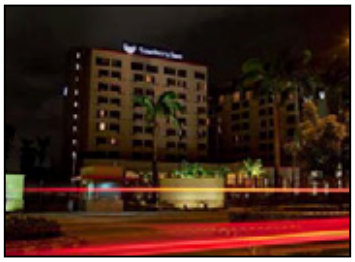

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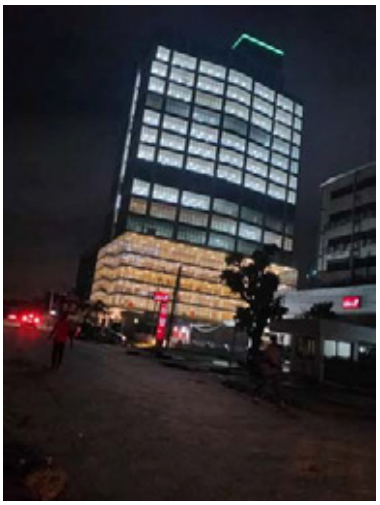

Greystone Towers, Lagos, Nigeria

Twin Lakes Estate, Lekki, Lagos, Nigeria - Civil Infrastructure

OPERATIONS OF NIGERIA'S NATIONAL GRID, CHALLENGES AND SOLUTIONS

ABSTRACT

There have been unabated comments that the integrity and grid capacity are inadequate to support the available generation capacity. This has been associated with the system collapses recorded by the grid. This incidence is not unexpected because of the huge geographical landscape/coverage of Nigeria. According to the Nigerian Electricity Regulatory Commission (NERC), the Transmission Company of Nigeria (TCN) manages about 20,000km of the conglomerate of the 330kV and 132kV transmission lines and several substations. Nigeria's grid is interconnected with 27 generation companies in different locations interspersed with 11 distribution companies across a land area of 910,800 square kilometers. Within this land space is an electricity infrastructure that has above 840 transmission-distribution interfaces. Under this scenario, some technical difficulties facing the system operation were analyzed. In the same vein, analytical approach to overcoming these obstacles were enumerated. It is expected that with commitment to some of the ongoing policies of the governments at various levels, the challenges of the transmission network would be eliminated especially through efficient adoption and implementation of the national energy transition policy with emphasis on the Electricity Act 2023.

Dr. Peter Olabisi Oluseyi, *Associate Professor of Electrical Power & Energy Systems, Department of Electrical & Electronics Engineering University of Lagos, Akoka, Lagos.*

1.0 INTRODUCTION

Electricity is crucial to all spheres of human existence and it plays an important role in the technological and political economies of every nation. It is the hub for industrial prosperity and revolution. An appraisal of the social landscape of various communities leads to the conclusion that it would be impracticable to achieve a handful of United Nations Sustainable Development Goals (SDGs) without clean, affordable and accessible energy (i.e., SDG-1). For instance, the following SDGs are closely linked with adequate and accessible energy: SDG-1, SDG-3, SDG-5, SDG-6, SDG-8 and SDG-13.

2.0 ELECTRICITY TRANSMISSION SYSTEM

Electricity production process relies on three major balances. Any form of disruption in any of these will result in the failure of the whole production system. These are the generation, transmission and distribution systems. However, the focus of this discourse is the transmission system. Transmission is the only one that the government is directly involved in its operational activities. As a follow-up to the Electric Power Sector Reform (EPSR) Act 2005 which was signed into law in March 2005, it unbundled the vertically integrated utility that was responsible for electricity supply into 18 companies. This was expected to improve the electricity reliability and efficiency.

However, Nigeria's vertically integrated power utility was later unbundled in the Year 2019 by splitting the Power Holding Company of Nigeria (PHCN) into 18 utility firms. These consist of 6 generating companies, 1 transmission company and 11 distribution companies (DISCOs). The government sold these at a whopping cost of US$2.5 billion. As the company saddled with the operation of the transmission infrastructure, the Transmission Company of Nigeria (TCN) was issued a license of operation on July 1, 2006 with the responsibility to transport power supply at high voltage while operating as both system operator and market operator. There have been several arguments in many quarters for and against the splitting of these two functions into

"...Transmission Company of Nigeria (TCN) manages about 20,000km of the conglomerate of the 330kV and 132kV transmission lines and several substations."

distinct subsectors. In the current circumstance, how this will influence the efficiency of operation is still a matter of further interrogation.

According to the Nigerian Electricity Regulation Commission (NERC), the infrastructural audit of the transmission facilities in Nigeria estimated the total length of the transmission lines as 20,000km with the current wheeling capacity of 5,700MW (as at 2021). This value is nominally higher than the total operational generation capacity of less than 4,000MW. With the highest Nigeria's transmission support being granted to the total capacity of 5,420MW being recorded in 2020 ("Nigeria's Electricity Transmission", 2020). Through the activities of Nigerian Electricity Grid Maintenance Expansion and Rehabilitation program (NEGMERP), this wheeling capacity increased to 7,500MW in 2022 ("Power Supply-FG to increase transmission capacity", 2022). This has further increased to 8,100MW in the first quarter of 2023 ("Electricity-TCN boosts wheeling capacity", 2023).

The wheeling of the generated electricity to the consumers has been further threatened by the radial configuration of the entire transmission infrastructure. Though with the current transmission expansion exercise, the possibility of making the circuit ring in nature is a matter of time. Currently, there is no redundancy in the network and the power flow can only be transported through a unidirectional path for the load centres to be served. Another setback is that the internationally acceptable transmission line losses should be in the range of 2-6% but in Nigeria's transmission system, the losses are an average of 7.4%. This is quite huge! Certainly, this justifies the number of recorded system collapses that have been recorded in the last ten years (See Table 1).

The government, as the sole custodian of the transmission company of Nigeria, has made a number of decisions to improve the transmission carrying capacity of Nigeria's electricity supply value chain. In March 2012, with the help of the Bureau of Public Enterprises (BPE), the government secured the technical assistance of Manitoba Hydro International (MHI) for the management of the transmission infrastructure. This was for three years (in the first instance). This is estimated to cost US$23m. Within this period, the MHI is expected to stabilize the national grid as it reduces the line losses below the current alarming value. After the completion of the first three years, there was an extension of the contract for an extra year, which terminated in July 2016. At the expiry of this date, MHI returned the TCN to Nigerian government. However, before the exit of MHI, the BPE brought forth two suggestions. Firstly, it recommended that the TCN should be placed on concession to a private investor which will be responsible for the operation and investment in the network in such a way that there would be a schedule for the investment recovery pattern for the private entity. An alternative proposal was that the TCN should hand over to a private investor that could complete the ongoing projects (at the point of entry). After which the private entity would operate, maintain and transfer.

Furthermore, the latter proposition advised that future system expansion projects should be batched on a build, operate, maintain and transfer basis. This may finally lead to regionalizing the transmission service provider arm of the TCN. None of these proposals was adopted by the government. Invariably, the government sourced experts from within the country. This indicated that the government took over from the MHI. Due to this new development, the initial fund promised by the World Bank for the purpose of revamping the transmission infrastructure was not released.

On July 2019, the government signed another agreement with Siemens Energy AG. The roadmap to ensuring the gradual ramping up of the transmission capacity was developed. Within two years (i.e., by 2021 after the agreement was signed), the transmission was expected to have been elevated to 7,000MW.

Year	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Partial Collapse	20	6	08	02	04	04	06	06	01	04	01	02	02	02
Complete Collapse	22	13	16	22	09	06	22	15	12	07	03	02	05	01
No of system collapse	42	19	24	24	13	10	28	21	13	11	04	04	07	03*

Table 1: Annual statistics of system collapse

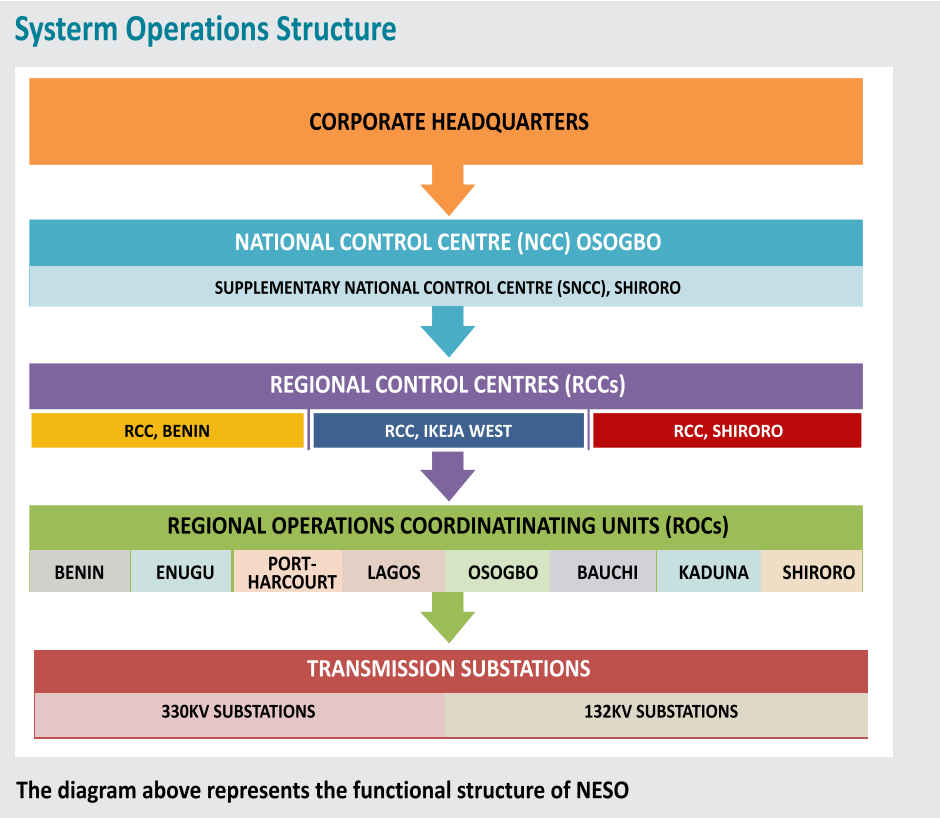

Fig. 1: Structure of operation of the system in Nigeria electricity industry (NESO, 2023)

While in another two years after, i.e., 2023, the second phase was expected to bootstrap the capacity to 11,000MW. The government's target by 2025 was 25,000MW. In early August 2023, the two phases should have been completed, but Siemens has not completed any! The reason for the delay was connected with the disruption of the supply chain by COVID-19. Siemens is now asking for a review of completion to last till 2030. This also means there would be rescoping of the projects due to the current economic situation.

3.0 CHALLENGES

Nigeria loses US$29Billion yearly as a result of inadequate electricity supply. The World Bank report once declared that Nigeria has the largest population of electricity poverty index ("Nigeria to improve electricity access", 2021). The energy poverty is due to electricity demanded but not supplied (EDNS). The challenges are:

i. **Lack of Automated Control and Monitoring System:** The modern grid is expected to be operated with a very dynamic real-time monitoring and control facility that should be equipped with prognostic features to detect grid disruption before its occurrence. However, the grid facilities that are in operation in Nigeria's electricity supply industry (NESI) are devoid of this effective engineering tool. In view of the absence of the supervisory control and data acquisition (SCADA) facility in the national grid, there is a lack of timely protection coordination against system collapse (See Table 1). This makes the number of cascaded interruptions very prominent instead of localizing the fault with the help of supervisory control and data acquisition (SCADA) system. The available interaction of the various layers of the system operation in the national grid is as shown in Fig. 1. This can hardly help in avoiding the unproductive experience that the national network is going through.

ii. **Fragile Transmission Line:** The installed capacity of the generation companies (GenCos) is estimated at an average of 12000MW. While the available capacity theoretically reaches about 8000MW. However, the total grid wheeling capacity is a little above 4000MW . The remainder of the generation by the GenCos is "stranded" thus the extra power generated is rejected by the transmission system operators. This idle capacity has adverse financial implications on the

"While in another two years after, i.e., 2023, the second phase was expected to bootstrap the capacity to 11,000MW. The government's target by 2025 was 25,000MW. In early August 2023, the two phases should have been completed, but..."

electricity supply chain. This is well explained graphically in Fig. 2 (Oluseyi, et al, 2018). Some of the causes of fragility are due to zero spinning reserves and lack of SCADA facility which are major tools for qualifying a grid as being robust, reliable and resilient, among others.

iii. **Grid Attacks:** Another major threat to grid security is the intentional attack by vandals. For example, on 23rd May 2023 in the nation's southwest region, the Papalanto - Abeokuta 132kV line collapsed due to vandal attack on Tower 56 to Tower 65 ("Vandals apprehension",2023). Also, there are unintentional attacks on the grid infrastructure such as those caused by fire outbreak or rainstorms. Lastly, natural disaster attacks may also be experienced. Transmission towers are affected by erosion, rainstorms, floods and other natural occurrences.

iv. **Poor Town-to-gown collaboration:** Though the government established the national power training institute (NAPTIN), this kind of training facility does not have the capacity for a strong and painstaking research culture. For undergraduate and graduate students of power engineering, there are hardly any enough demonstration facilities in the dry/ simulation laboratories in any public university/ polytechnics.

It would have been a lot more productive if the TCN can collaborate with universities by instituting a centre of excellence for power system research in some Universities in Nigeria. This will lead to the installation of state-of-the-art training facilities for power system simulation for undergraduate and graduate students.

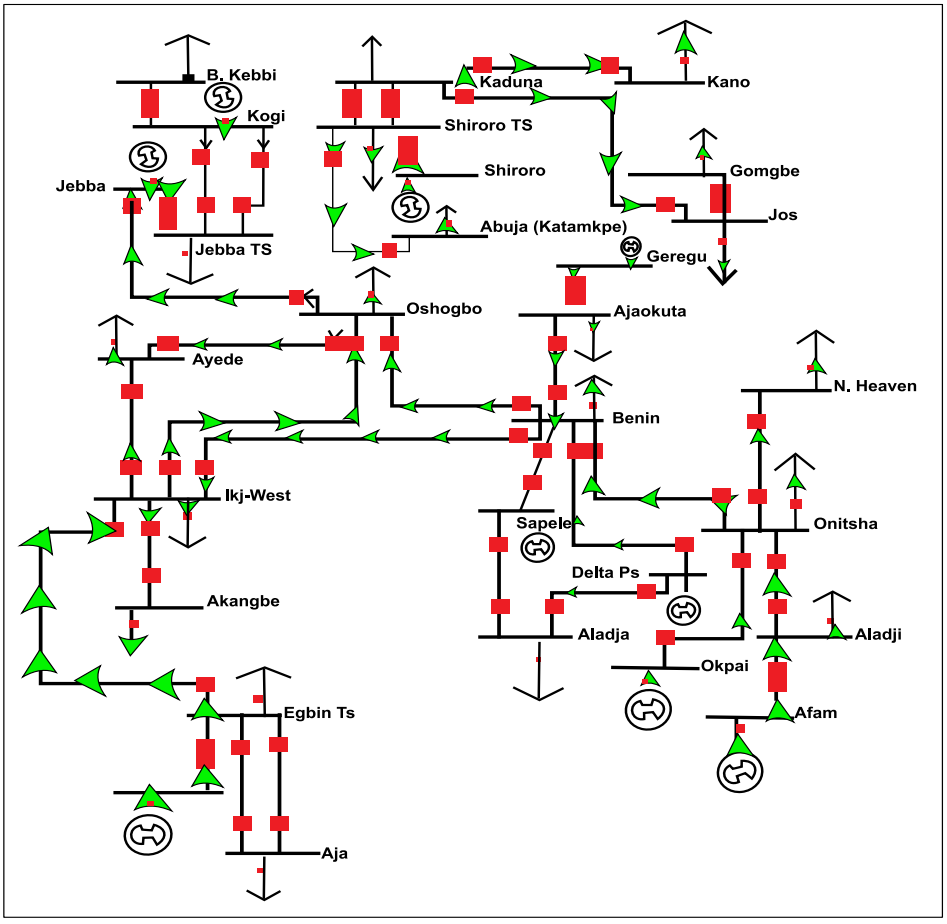

Fig. 2: Powerworld simulation of Nigeria-31 bus transmission network (Oluseyi, et al, 2018)

3.0 SOLUTIONS

There are several solutions but some of them that are critical to the Nigeria's current state of electricity conditions shall be evaluated herein.

i. **Decentralization of the National Grid:** As a peculiar nation with a huge landscape coupled with several failed attempts by the government at the center to execute any enduring contract with the last two international power producer giants (i.e. Manitoba Hydro International and Siemens), it will look more brilliant to propose that the TCN should be decentralized into six companies so that each zone would manage the transmission facilities within their respective regions. There may be better working relation with the GENCOs and the DISCOs within such locations. This would bring multisectoral collaboration within the power supply value chain.

ii. **Provision of Ancillary Power Service:** The grid was stable without collapse for 421 days till September 13, 2023 (TCN, 2023). The instability witnessed in the system can be viewed as normal because the power system usually relies on the spinning reserve. This is not available. This is further exacerbated by the fact that the

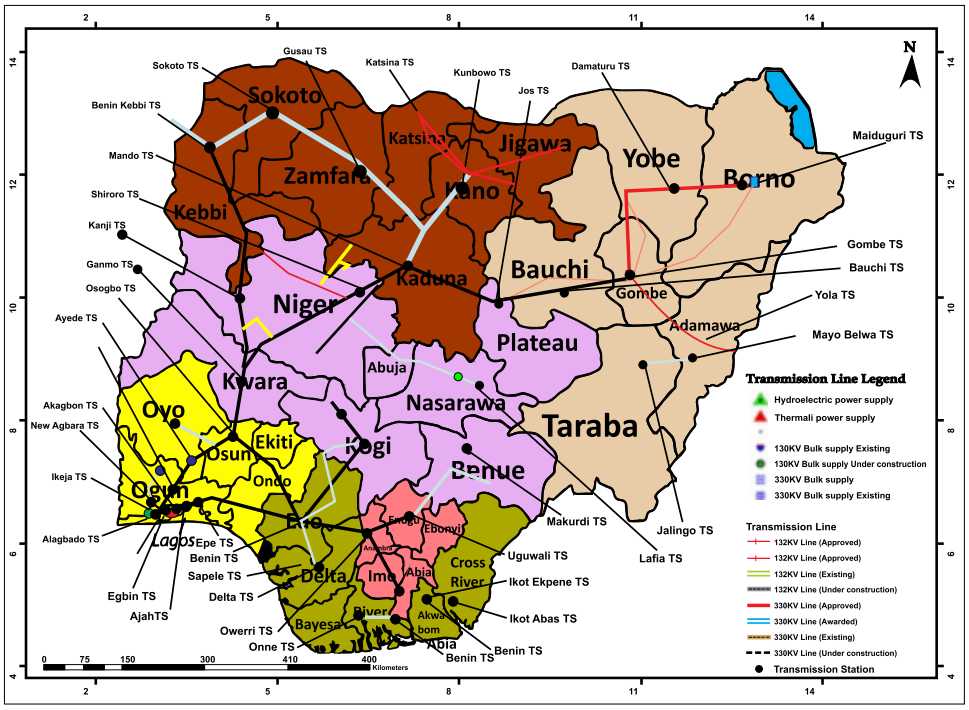

Fig. 3: Map of Nigeria showing the interconnection of the power transmission components

Nigeria power system operates on a very high frequency; this is most of the time at above 51Hertz. This is a vesting ground for system collapse. Ancillary service is not available within Nigeria's electricity industry to serve in the event of grid collapse. Even, the Grid CodeVersion 02 section 15(1-3) clearly mandated that 10% of the total available generation should be set aside as a spinning reserve. So Nigeria's grid requires about 600MW for spinning reserve. Since there is no incentivization for this ancillary service, it is non-existent in the power system of Nigeria. It is high time the NERC took a decision on the provision of this ancillary service ("Nigeria electricity grid", 2022).

iii. **Closing of the Transmission Radial Circuits:** Technically, Nigeria's grid is said to be a radial system. There should be a concerted effort to develop it further by transmission expansion program (TEP) to close the grid in such a way that a failure in one section of the country will not cause the entire location to have a blackout. Rather, the system can be fed from another transmission path. Based on Fig. 3, the ongoing projects and planned future projects would put paid to this.

iv. **Upgrading of Transmission Equipment:** Nigeria's grid needs to be strengthened in a number of ways. One crucial aspect of such an exercise is to provide upgrade for the old transmission equipment.

v. **Encouragement of Aggressive Transmission Expansion Projects:** As stated earlier, there is definite need to upgrade the existing transmission system to form a closed circuit configuration. Thus, there is a need for the construction of additional lines to relieve the existing overload lines (both 330kV and 132kV lines). In line with this, there is an ongoing program tagged 'Transmission Rehabilitation and Expansion Program'. This is an ongoing intervention that is yet to be concluded. It is in its 1st phase called 'Nigeria Expansion Program Phase 1' (NTEP1). It is sponsored by the African Development Bank (ADB). The ongoing projects in this program are double circuit quad transmission lines along 138km Alaoji - Onitsha corridor as well as 12 km Delta - Benin line and 204 km Kaduna - Kano and 2 units of 132/33kV (2X60MVA) substation at Rigasa and Jaji. Other substations include 2x150MVA substations in Zaria and Millenium City. Also, in February 2022, Japan International Cooperation Agency is known to have committed US$240M to the transmission expansion in Ogun and Lagos States. The Central Bank of Nigeria is also participating in some development of a strong transmission system. Other expansion programs involve the Nigeria Electricity Transmission Access Project (NETAP), which procured 6 units of 150 to 187.5 MVA 330/132/33kV transformers for installation in the Yola, Mayo Belwa, Bauchi and Maiduguri transmission substations. Another set of five substations (namely, Azare, Wudil, Dan Agundi, Kumbotso and Hadejia) were equipped with transformers with varying capacities of 300MVA and 100MVA for 330/132/33kV transmission substations. Beyond transmission expansion, another facility provided for boosting the voltage profile of the grid is the provision of the Gombe transmission substation with static VAR compensation for power quality improvement. The interconnection and expansion of power system in Nigeria in relation to the geographical locations for the existing, under-construction and proposed transmission lines and substations are shown in Fig. 3.

vi. **Mitigation of Grid Protection Failure:** Currently, the failure or maloperation of the

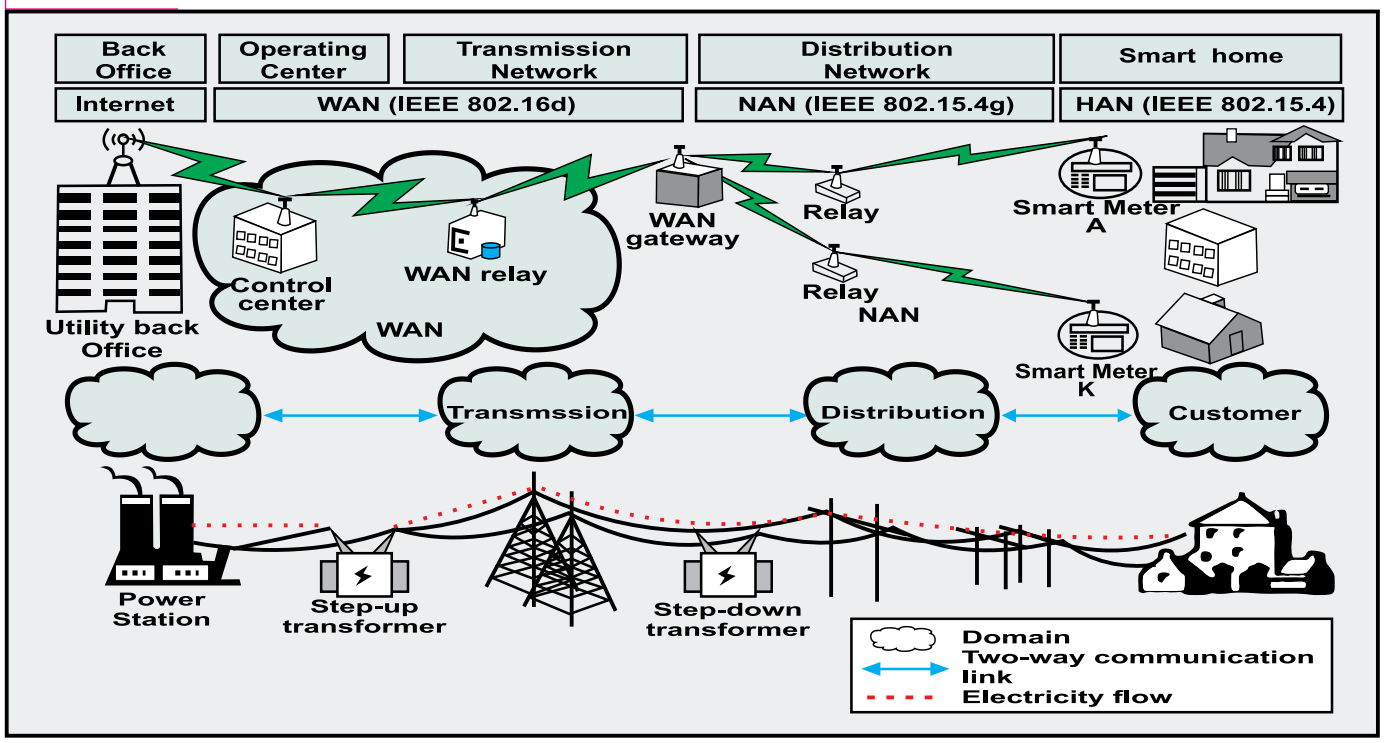

Fig. 4: Deployment of smart grid systems in electricity operation (Hussain & Gao, 2018)

protection scheme is the source of about 60% of system shutdowns. Nigeria's power system landscape has about 740 transmission-distribution interfaces that are not protected at the injection substations. Thus, to overcome the tripping of crucial transmission line due to spurious protection maloperation, there is a need for formidable and well coordinated grid protection scheme.

vii. **Provision of Modern Automation System:** The deployment of efficient and state-of-the-art energy management system will improve the system reliability. There are other ancillary facilities such as the supervisory control and data acquisition (SCADA) and other modern telecommunication devices that should be installed on the lines to provide advanced prognostic measures that would save the grid from incessant collapse. These facilities are equipped to digitally monitor the grid in real-time so as to make it easy for line operators to trace and repair without service disruption of the grid operation. In some climes, robots are becoming entrenched in this service. See Fig. 4.

viii. **Deployment of Energy Efficient and Demand Response Facilities:** Energy efficiency is achieved by the use of electrical appliances that consume less energy while demand response is an intervention from the grid operators to induce the electricity consumers pattern of energy consumption. The interaction between the energy efficiency and demand response has great potentials to assist the grid in doing away with unnecesssary overloading of the system. This will thus reduce the power system cost of operation, boost service reliability and encourage decarbonization of the energy value chain. There would be a need to deploy the smart grid to improve the demand response. The implication is that the consumers can shift their electrical load consumption from the periods of high demand to the periods with low demand (Oluseyi, Akinbulire & Awosope, 2006; Oluseyi, Akinbulire & Awosope, 2007). There are many demand response solutions in relation to electricity supply efficiency that can be adopted by utility companies. They include: Price-based Demand and Incentive-based Demand Response.

"Nigeria's power system landscape has about 740 transmission-distribution interfaces that are not protected at the injection substations."

"It is heart-warming to note that the Electricity Act 2023 allows the state governments and individuals to enter into electricity production industry with the aim of industrialization."

ix. **Fastracking the Implementation of the Energy Transition Policy:** Energy transition has been gaining traction in the whole of Africa. As a matter of fact, Africa (including Nigeria) has enough renewable energy resources to provide adequate and uninterrupted electricity for national needs. Thus, Nigerian government has been focusing attention on developing green energy projects. This has led to the development of plans for energy mix. As a matter of emphasis, in a Resilient Cities Network Report on the Lagos Urban Power Profile, it is believed that by Year 2036, Lagos will provide reliable electricity to every resident in the state ("Lagos Urban Power Profile", 2023). In energy transition, a school of thought has appealed for the deployment of natural gas as the transition fuel before the full operation and utilization of renewable energy technologies. This will not only relieve the grid electricity system, it will also protect the environment against noxious gas discharge that is ubiquitous with the fossil-based electricity generators.

4.0 CONCLUSION

It has been established that the current system operation of the electricity grid in Nigeria has a number of weaknesses that may not necessarily be intentional. The solutions recommended in this treatise to the government at the centre can be used to achieve adequate provision of electricity for enhanced economic and industrial growth of the country. It is heart-warming to note that the Electricity Act 2023 allows the state governments and individuals to enter into electricity production industry with the aim of industrialization.

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EXECUTION OF SOLAR ELECTRICITY PROJECTS

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1.0 INTRODUCTION

For thousands of years, humans have harnessed solar energy. The earliest record of solar energy use was in the 7th century B.C., when fires were started by focusing sunlight on an area using magnifying glasses. Scientific experimentation with solar energy to generate heat for steam engines began in the 18th century and the first successful development of a solar panel was by Bell Labs in 1964. However, solar energy only became truly popular in the 1970s [1], [15]. In this modern era, solar energy is touted as one of the replacements for conventional technologies based on fossil fuels given the challenges of environmental pollution and security. Hence, the global electricity generation from solar systems, which is on the increase, requires proper understanding of the design, installation, utilisation and maintenance to sustain qualitative systems, protect the environment, lives and properties from any misuse. Fig. 1 shows solar electricity circuit features while Fig. 2 shows a diagrammatic arrangement of the earth's solar system.

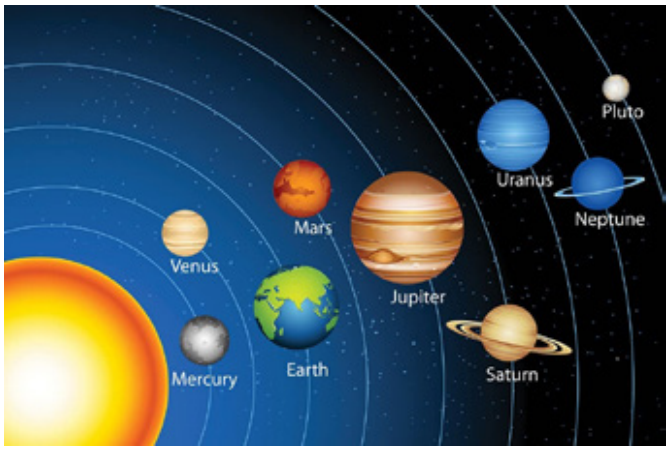

Fig. 2: The earth's solar system (Source: Depositphotos.com)

2.0 GLOBAL SOLAR ENERGY GENERATION PER CONTINENT

Global solar energy generation continues its increase with Asia in the lead, North America, Europe, South America, Africa and Oceania in that order, all geared towards the United Nations (UN) policies on renewables [2].

i. UN Policies on Renewable Energy:

The UN has a target of 45% reduction in greenhouse gases by 2030. 2050 has also been set as its goal for net-zero emissions [3]. To attain these lofty goals, the UN is in top gear to support and encourage the full implementation of carbon emissions reduction and mitigations for climate change control via the utilisation of renewable energy technologies and methods, including the application of solar and wind energy via government policies throughout the globe.

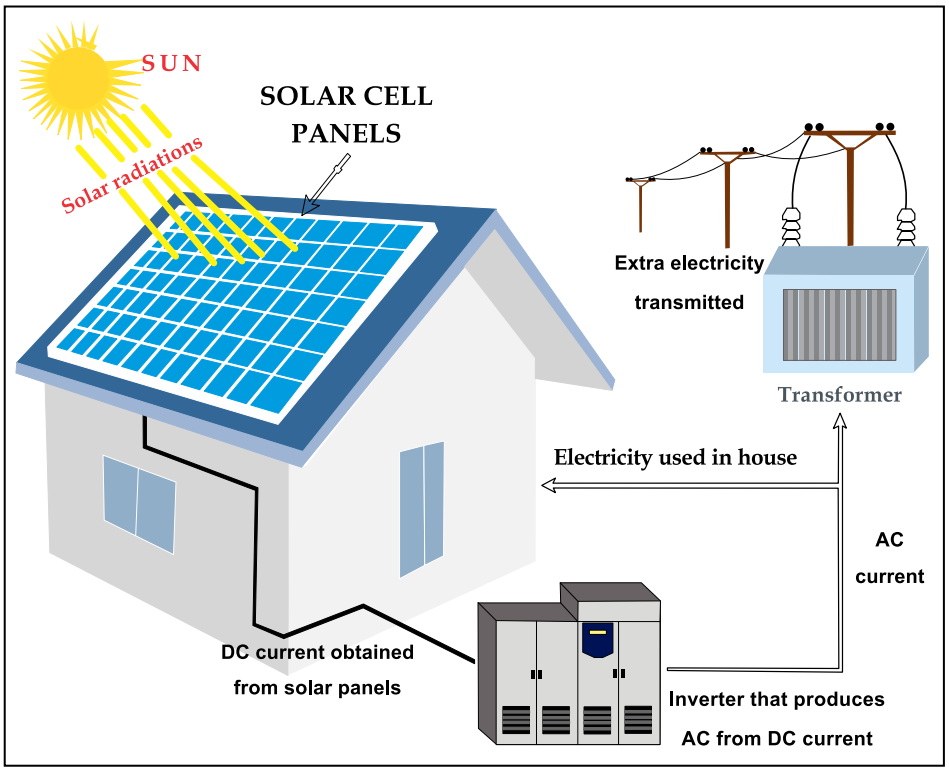

Fig. 1: Solar energy capture and conversion to electricity (Source: Learning Chemistry)

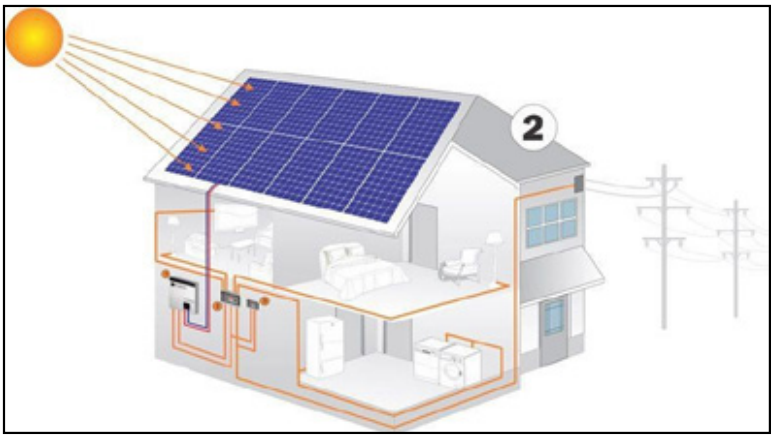

Fig. 3: Grid-tie system (Source: sintech.co.za) Key:

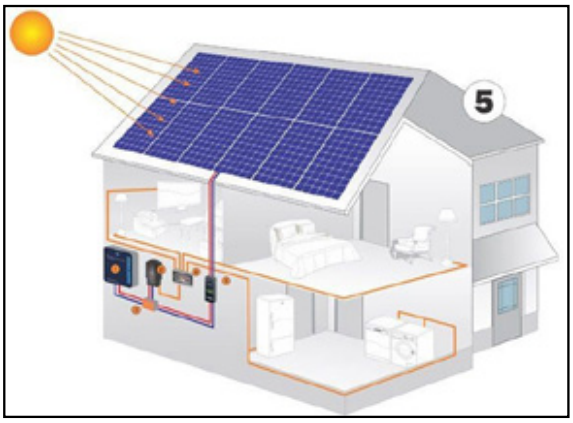

Fig. 4: Off-grid system (Source: sintech.co.za)

ii. Government Policies on Solar System:
As solar systems are a part of the general policies on renewables, specific policies tailored towards solar systems are being formulated and implemented by various governments. Such policies of governments on solar systems include mandatory solar installations on new buildings, rebates for installing solar systems and feed-in tariffs mandating utility companies to purchase excess energy generated by individuals or groups from their solar systems and to resupply such person(s) when required after sundown [4].

3.0 TYPES OF SOLAR SYSTEM

The types of solar systems available in the market include: [6]:

i. Grid-tied systems: These systems are connected to the electricity grid and allow homeowners to sell energy back to the grid. In such cases, excess solar power produced in the day time may be sent or sold to the grid and at night time, that power may be received from the grid [7]. See Fig. 3.

1. Batteries in Battery Cabinet.
2. Inverter/Charger
3. DB Board
4. Solar Charge Controller

"Such policies of governments on solar systems include mandatory solar installations on new buildings, rebates for installing solar systems..."

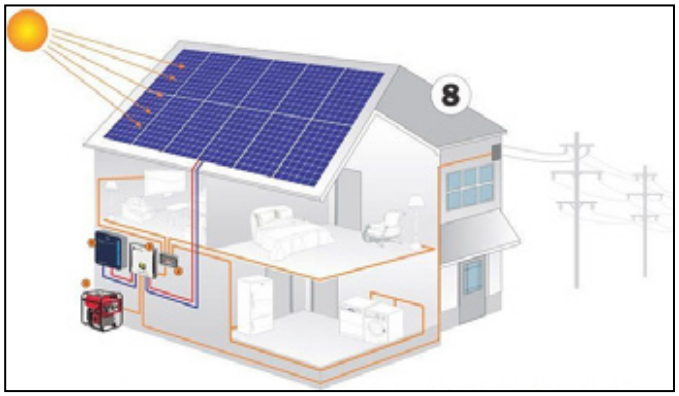

Fig. 5: Hybrid system (Source: sintech.co.za) Key:

5. Grid-Tie Inverter
6. kW/h Input / Output Meters

ii. Off-grid systems: These systems are the opposite of grid-tie solar systems. They are standalone (not grid-tied), relying on battery storage to supply electric power at periods of low or no sunlight [8]. See Fig. 4.

Key:

a. Battery
b. Inverter/Charger
c. Combiner Box
d. DB Board
e. Solar Charge Controller

iii. Hybrid systems: These systems are a combination of grid-tied and off-grid components, allowing for the use of both grid electricity and solar energy when required [9]. See Fig. 5.

a. Backup Generator
b. Battery
c. Inverter/Charger
d. DB Board

iv. Concentrated solar power systems: systems are thermal systems which concentrates sunlight onto a small area using mirrors or lenses, thereby generating heat that is used to power turbines for electricity generation [10]. See Fig. 6.

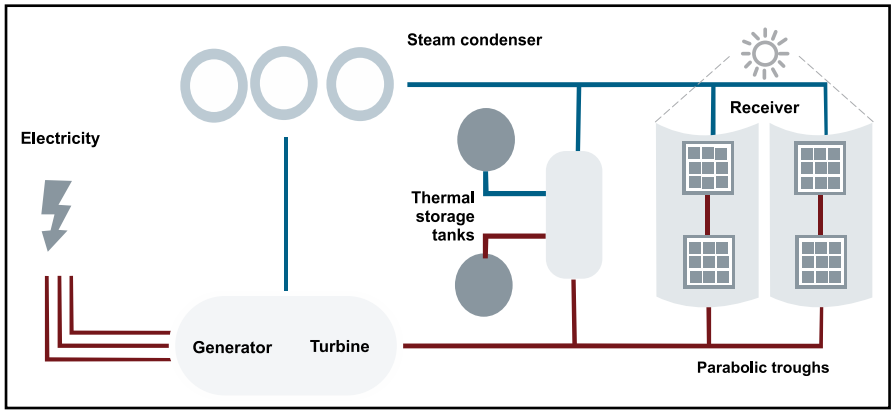

Fig. 6: Parabolic Trough technology (Source: Siemens-energy.com)

4.0 COMPONENTS OF A SOLAR ELECTRICITY SYSTEM

Typically, a solar system consists of solar panels, an inverter, a charge controller (a.k.a charge regulator), a battery bank (if battery backup is required) and a monitoring and/or control system [6], [11]. See Fig. 7. The solar system works as follows: sunlight is captured by solar panels which convert it to Direct Current (DC) electricity and passes the electricity to a charge controller. The quantity of electricity supplied is controlled by the solar charge controller which prevents the overcharging of batteries by regulating the voltage and current going to the battery unit.

The electricity (still DC) is then sent to the inverter/ UPS (Uninterruptible Power Supply) to be converted into alternating current (AC) electricity that can be used in the home. At the same time, the battery bank stores excess energy for use during periods of low sunlight or as a backup during power outages or poor weather conditions. The monitoring and/or control system tracks energy production and consumption, and is used to control the solar system by starting up, shutting down, programming it to e.g., deliver certain amounts of electricity within a specified time period within a day, or just about anything an equipment manufacturer may decide the system should do.

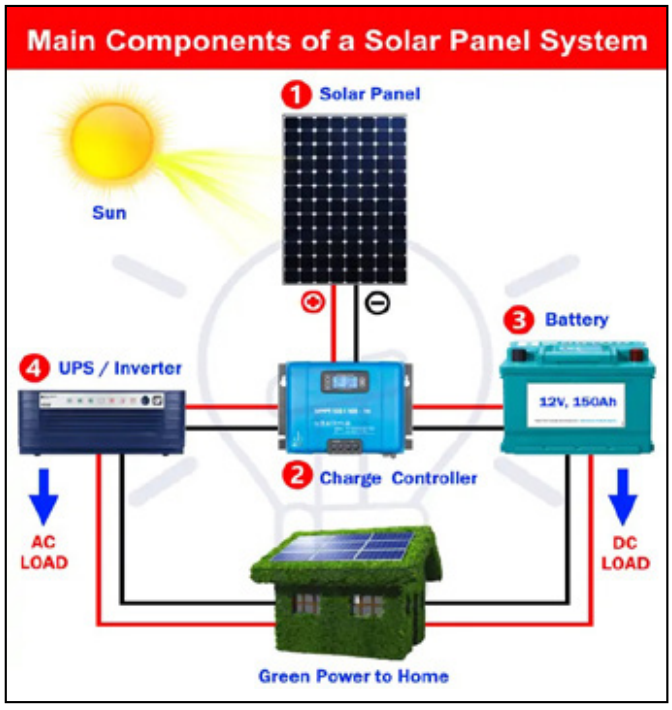

Fig. 7: Main components of a panel electricity system

Importantly, solar systems differ by voltage specification. That is, a solar system may be 12V, 24V, 36V, 96V, 120V, 180V, 240V, 360V, 400V, etc, depending on the design which is usually based on the number of batteries connected in parallel, series, or series and parallel for optimal performance.

5.0 SIZING OF A SOLAR ELECTRICITY SYSTEM

The major determining factor for sizing a solar system is the energy need. Other factors that play important roles in sizing solar systems are the average sunlight per day, the property size (i.e., the site), and the arrangement of the solar system components. It is recommended to use the services of an expert installer who would determine and advise on the optimal solar system size [12].

6.0 COSTING OF A SOLAR SYSTEM

Costing a solar system is done only after all technical aspects have been satisfied. The cost of a solar system depends on regulatory charges (if applicable), the size of the system with respect to the number and type of components to be used, and professional fees for its installation. It has been noted that as economies of scale improves due to advance in technology, solar systems will become more and more affordable. Also, government incentive like rebates and/or tax credits help improve affordability [13].

"...cost of a solar system depends on...size of the system with respect to the number and type of components to be used..."

6.1 QUOTATION

S	DESCRIPTION	QTY	UNIT(N)	TOTAL(N)
1	5KVA 48V inverter	1		
2	48v 100a charge controller MPPT	1		
3	12v 200/220ah inverter battery (Wet Cell/Tubular)	8		
4	Battery rack	2		
5	Flex pipes 25mm2	10		
6	300W PV Module	16		
7	DC surge protector	1		
8	AC surge protector	1		
9	Breaker casing	1		
	DC breaker	1		
10	Cabling DC 16mm2	80		
11	Cabling AC 10mm2	60		
12	Screws, nuts, nails, flat, angle grip & holder	1		
13	Flash band	1		
14	Solar panel rack (aluminum profile)	8		
15	Trunking 50 x 50	3		
16	Electrical fasteners (lugs, plugs, tapes, clips etc)	1		
17	Cabling AC 35mm2 Battery cable	6		
18	Changeover switch	1		
19	logistics	1		
20	Ladder (2 days)	2		
	Cost to provide items 1-20			
	Professional charges and Accessories for Installation	lot		
	Total			
	7.5% V.A.T			
	Grand Total			**0.00**

Table 1: *Typical costing sheet for a 5Kva solar system (Source: CEC-SC Ltd [17])*

7.0 INSTALLATION PROCEDURE FOR SOLAR SYSTEM

The procedure for installing solar systems depends on the type and size of system involved. Generally, it involves, site assessment, system design, equipment selection, installation. Testing and commissioning. Usually, an expert installer would carryout site assessment to determine the optimal location solar panels, considering factors like roof orientation and accessibility, possible shading of sunlight, and available space to install the solar panels and associated equipment. Then, the solar system will be designed based on those factors, the energy need, and budget. When the client approves of the design, equipment will be purchased and installation carried out.

A more detailed procedure has been enumerated below [14]:

7.1 A TYPICAL INSTALLATION PROCEDURE FOR A 5KVA SOLAR SYSTEM

i. Site Assessment: This is the first step. The site is assessed to determine the location for the solar system. This evaluation will consider the type of property (bungalow, duplex, skyscraper, etc.), roof orientation, any shadingand available space for solar panel installation.

ii. Design and Equipment Selection: Following the completion of site assessment, the solar system would be designed based on the energy needs i.e., energy consumption, peak loads, and backup power requirements. The equipment selection will then be done based on the design.

iii. Permits and Approvals: To work within regulatory requirements, all necessary permits must be obtained before the commencement of solar installation.

iv. Installation: After meeting all regulatory requirements, the installation would proceed as follows:

   a. Rig-up scaffolding or ladder to access building/property roofs or prepare the ground depending on what type of solar mounting is required, whether rooftop, ground, or water mount.
   b. Mounting the solar panels: - The solar panels are mounted onto the roof, ground, or water mounting structure/racks using the appropriate mounting method.
   c. Wiring: - Install electrical wiring to connect the solar panels, charge controller, inverter, and battery bank.
   d. Charge controller and inverter Installation: - Install the charge controller and inverter in a safe and clean environment, easily accessible for maintenance.
   e. Battery Bank Installation: - Install battery bank (if required), in a safe and secured position.
   f. Testing: - On completion of the installation, test the system for proper functionality of each component, and of the whole system.

   It should be noted that, besides solar panels, the inverter, charge controllerand batteries should be treated as indoor equipment such that they are not exposed to weather

conditions like rain, heat, dust and sand storm.

v. System Commissioning: After installation and testing, the system should be commissioned. This involves connecting the system to the electrical grid or backup generator and verifying that all components are working together properly. See. Fig. 8.

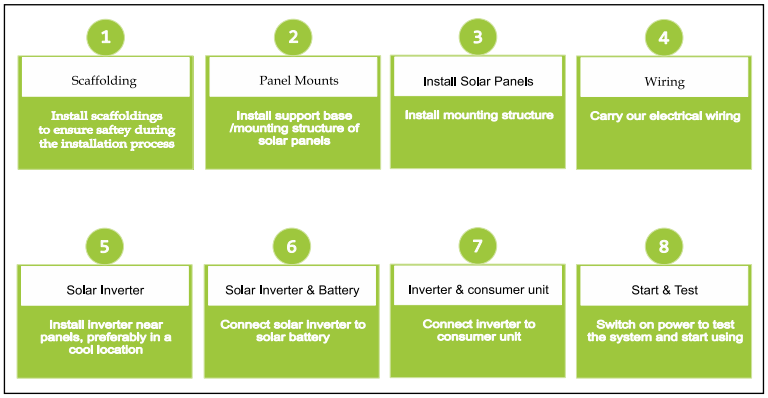

Fig. 8: *Wiring the solar panels, charge controller, inverter, battery, consumer unit, commission* (Source: Greenmatch.co.uk [14])

vi. Maintenance: Regular maintenance is essential to keep the system functioning at optimal levels. This includes cleaning the solar panels, inspecting wiring and connections, and monitoring the battery bank and inverter for signs of wear or damage.

It should be noted that the above procedure is a general guide and specific installation procedure may vary depending on the unique requirements of each property. It is recommended to hire a professional installer to ensure safe and effective installation of a solar electricity system.

8.0 ENERGY CONVERSION IN SOLAR SYSTEMS

Using a solar system is relatively simple. The sun shines on the solar panels and they convert the sunlight to direct current (DC) electricity. This DC electricity then flows through the charge controller to the inverter and the inverter converts it to alternating current (AC) electricity which is compatible with the electrical power for most home's electrical systems (appliances). It has the characteristics as electricity from the grid supply [14].

9.0 ISSUES WITH SOLAR SYSTEMS

It is not all rosy with solar systems. Just as you have with other power systems, solar systems have their issues. For example, seemingly simple issues like shading may cause a solar system to be ineffective and inefficient. Other issues like poor installation and equipment failure can render a solar system useless. Leaking roofs, improper wiring may result in damages to life and property. The solar system may fail from production error, weather phenomenon like lightning, rain storm, wind storm, poor installation, and other unknowns [14].

10.0 HOW TO MAINTAIN SOLAR SYSTEMS

Regular maintenance is required to ensure solar systems function optimally. Tasks like solar panel cleaning, wiring and connection inspections, monitoring of inverters and battery banks for wear or damage, monitoring energy production and consumption would help identify and therefore solve issues [14].

11.0 ADVANTAGES OF A SOLAR SYSTEM

Some of the advantages of solar systems are [14]:

i. **Reduced energy bills:** Utilisation of solar energy reduces reliance on the grid and so saves on grid energy bills.

ii. **Environmental benefits:** As a renewable energy source of electricity and heating, solar energy is clean and does not produce harmful greenhouse gases.

iii. **Increased home value:** Homes with solar systems tend to be valued higher than those without them.

iv. **Energy independence:** With solar systems, energy dependence on the grid is reduced or totally avoided depending on the type of solar system installed.

12.0 DISADVANTAGES OF A SOLAR ELECTRICITY SYSTEM

Some of the disadvantages with solar systems, include [14]:

i. **High initial capital:** The upfront cost of installing a solar system is usually higher than with other electricity generating systems for the same amount of power produced per unit time, although such costs may be offset by long-term savings.

ii. **Weather dependence:** Since solar energy production is weather dependent, its reliability may be hindered by cloud cover, shade from obstacles like trees, other structures, and periods of darkness.

iii. **Maintenance:** Although the maintenance of smaller Solar systems require minimal

"In all, the solar system is gaining popularity for its clean, renewable energy, easier to install and use..."

maintenance, that of big solar systems require regular maintenance to ensure optimal performance, which may impact the overall systems cost.

13.0 OTHER METHODS FOR ELECTRICITY GENERATION

Like solar systems, other methods for electricity generation exists. Some of them are, nuclear power, hydroelectric power, coal power, thermal (natural gas) power, wind power, wave power, and biogas power. Each system when compared with solar system has its pros and cons depending which determines the choice of the user [1], [6].

13.1 COMPARISON BETWEEN SOLAR SYSTEM AND OTHER METHODS OF ELECTRICITY GENERATION

i. **Fossil Fuels:** In comparison to solar energy, fossil fuels (petroleum products, coal, natural gas) which are cheaper and widely used in electricity generation, are dirtier, emitting greenhouse gasses and contributing to climate change. Due to their toxicity when inhaled, they impact negatively on the health and overall wellbeing of plants, animals, and humans.

ii. **Hydroelectric Power:** Hydroelectric power is one of the renewable energies besides, solar, wind, and wave energies. Although it does not generate harmful gases, it may harm the environment due to its method of electricity generation requiring capturing the energy generated by falling water to turn turbines to generate electricity. The requirement to dam water bodies to allow for controlled falling water alters ecosystems, impacting the environment (marine life) which does not occur with solar systems.

iii. **Wind Power:** Wind power is another renewable energy source of generating electricity. Here, wind turbines capture the energy of the wind, converting the kinetic energy from the rotation of the turbines to electricity. And although wind power is clean energy, the noises and rotation of the wind turbine propellers can be noisy and impact vision, respectively. Whereas, with solar panels, there are no noises or visual impacts. Like solar energy, wind power is clean and renewable. However, wind turbines can be noisy and may have visual impacts.

iv. **Nuclear Power:** When atoms are split in a nuclear reactor, they produce heat which is used to turn turbines for electricity generation. This generation of electricity from nuclear reaction is itself relatively clean but, the significance of the risks associated with nuclear accidents and nuclear waste disposal are dire. Unlike nuclear power, solar systems are not associated with such risks making them safer and easier to use.

In all, the solar system is gaining popularity for its clean, renewable energy, easier to install and use processes and for its relatively low environmental impact [17], [18].

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Actolog Renewables Presents:

INTEGRATED RENEWABLE ENERGY SOLUTION (IRES)

OVERVIEW

The epileptic supply from the Nigerian power grid, rising cost of diesel, the global awakening to the environmental hazards caused by fossil fuels and the need for cleaner and more sustainable alternative sources of power have necessitated the demand for renewable energy in Nigeria.

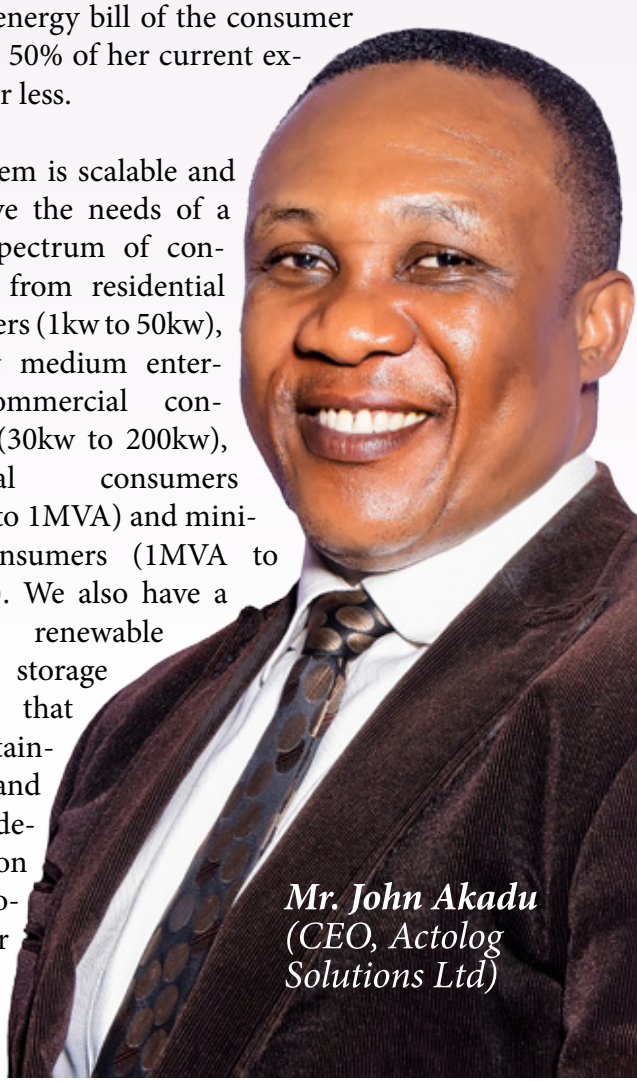
The current challenge in the renewable energy market is the design and implementation of a renewable energy solution that is well adapted to the unique needs of the Nigerian energy consumer. The Nigerian renewable energy solution must, therefore, be cost-effective yet reliable and must be designed in such a way that it can be integrated into the existing Electricity distribution companies (DISCOS)/ Generator installations while delivering value to the user in terms of maximum availability and measurable reduction in their energy bill.

With over two decades of experience in the provision of uninterruptible power supply to critical loads in Nigeria and the West African sub-region, Actolog Solutions Limited (through her subsidiary – Active Renewables), in conjunction with her foreign partners, is offering 'Integrated Renewable Energy Solutions (IRES)' to her clients to ensure affordable, reliable, uninterruptible power in Nigeria.

By utilizing solar power, lithium ion batteries, public utility power and back-up generators, our solution does not only provide uninterruptible power supply but also cuts the huge power cost expended on diesel generators used by many power consumers in augmenting erratic public power supply.

The system is well integrated and automated to prioritize the use of solar power (basically free) and to either eliminate the use of diesel generators or reduce their usage to about 5% or less, thereby reducing the energy bill of the consumer to about 50% of her current expenses or less.

The system is scalable and can serve the needs of a broad spectrum of consumers, from residential consumers (1kw to 50kw), small & medium enterprises/commercial consumers (30kw to 200kw), industrial consumers (100kw to 1MVA) and mini-grid consumers (1MVA to 10MVA). We also have a mobile, renewable energy storage system that is containerized and can be deployed on a temporary or permanent basis.



Mr. John Akadu (CEO, Actolog Solutions Ltd)

Renewable Energy Powered Home

We have done a cost-benefit analysis to show the consumers how much money they could save on their power bill if they deployed our system compared to the conventional DISCO/Generator installation.

THE CHALLENGES OF POWER CONSUMERS

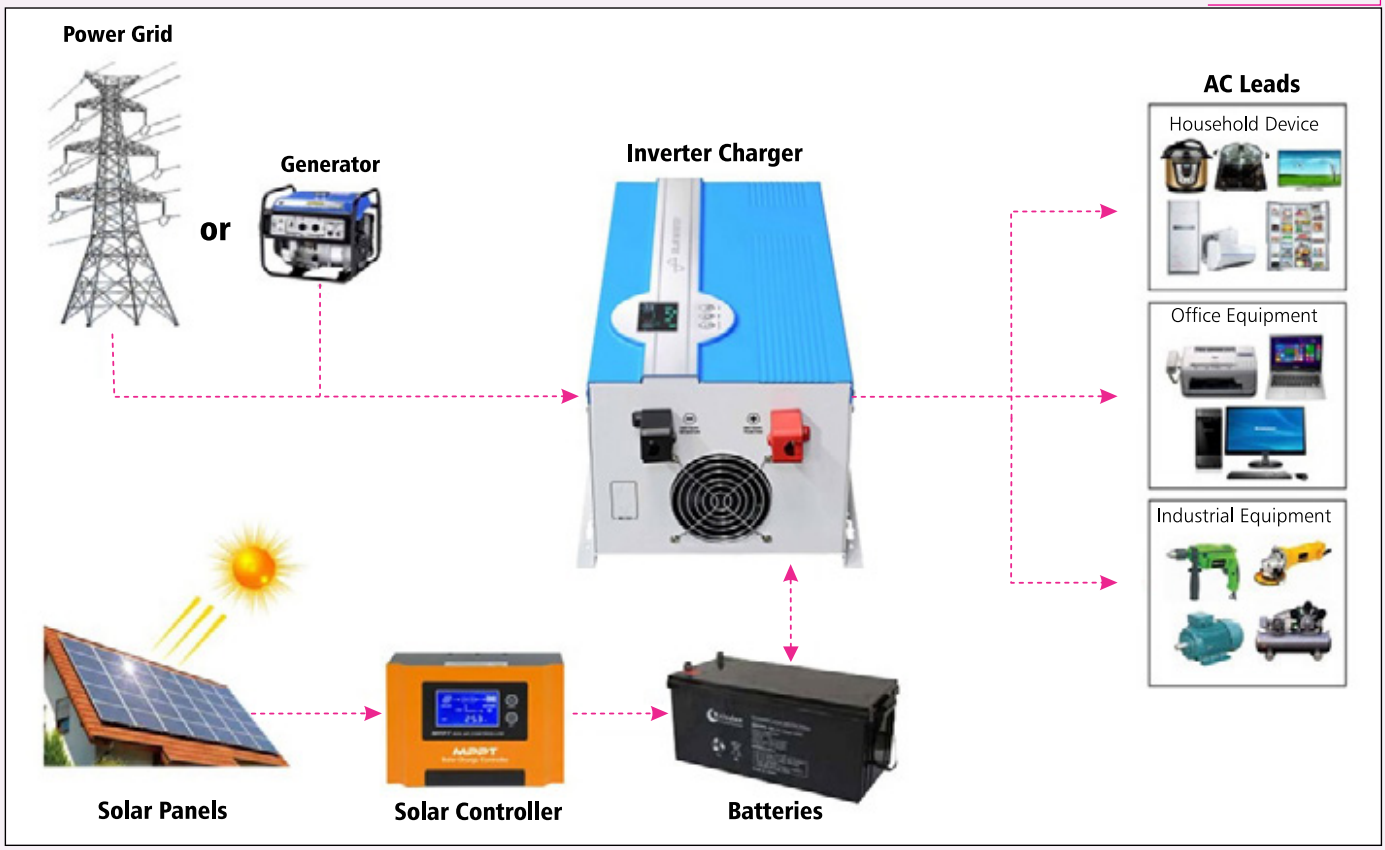
Residential, commercial and industrial consumers of power in Nigeria are currently going through harrowing experience due to the erratic power supply from the national grid, high tariff, high cost of diesel and the attendant challenges of maintaining diesel generators, etc.

In a few cases where the consumers have made efforts to install alternative power systems like inverter/solar power systems, these have largely failed due to poor design/installation, inferior materials and a general lack of professional standard in a largely unregulated industry. These have left most consumers to continue relying on the unreliable diesel generator/DISCO combination. The challenge is exasperated by high cost/poor availability of diesel, poor generator maintenance and diesel theft, leaving most consumers with huge monthly power bills.

THE CURRENT POWER ARCHITECTURE FOR POWER CONSUMERS

The current power architecture for most consumers consists of diesel power generators and public utility power sources with a manual change over switch.
Some consumers have attempted to introduce inverter systems into the mix for small (light) loads, while the heavier loads are left directly on DISCO/ generators.
Other users, such as banks, have introduced inverters for their ATMs connection

DISCO/Generator to inverter to UPS to LOAD connection



A symbolic diagram showing the Integrated Renewable Energy Solution (IRES)

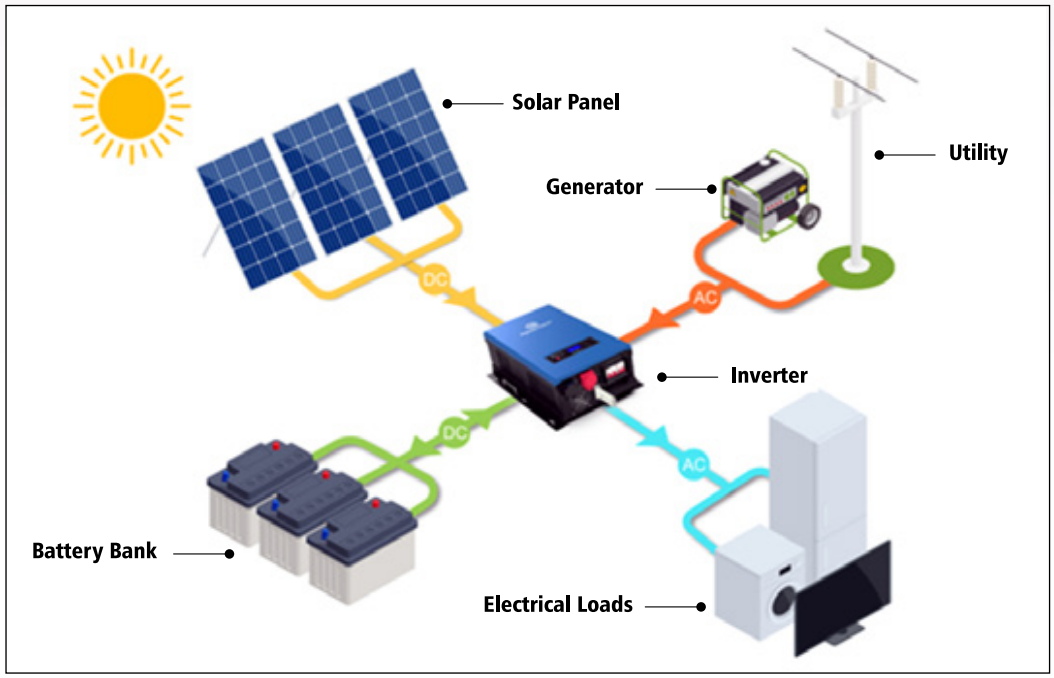
These mostly over-sized, under-sized and often redundant power generation/usage have resulted in over-bloated power bills for the various consumers, with multiple points of failures in the system. The problem has, therefore, remained largely unsolved!

OUR SOLUTION

Our solution provides integrated renewable energy solution (IRES) from four (4) sources, viz:

- High quality Solar power through photovoltaics (PV) panels
- Renewable energy storage (lithium-ion, VRLA, Gel) battery system (See Fig. 4).
- Public utility (grid) power supply
- Power generators

This module can be placed in parallel or cascade arrangement to achieve up to mini-grids of 10MWH



A 500KWH Lithium-ion commercial energy storage system.

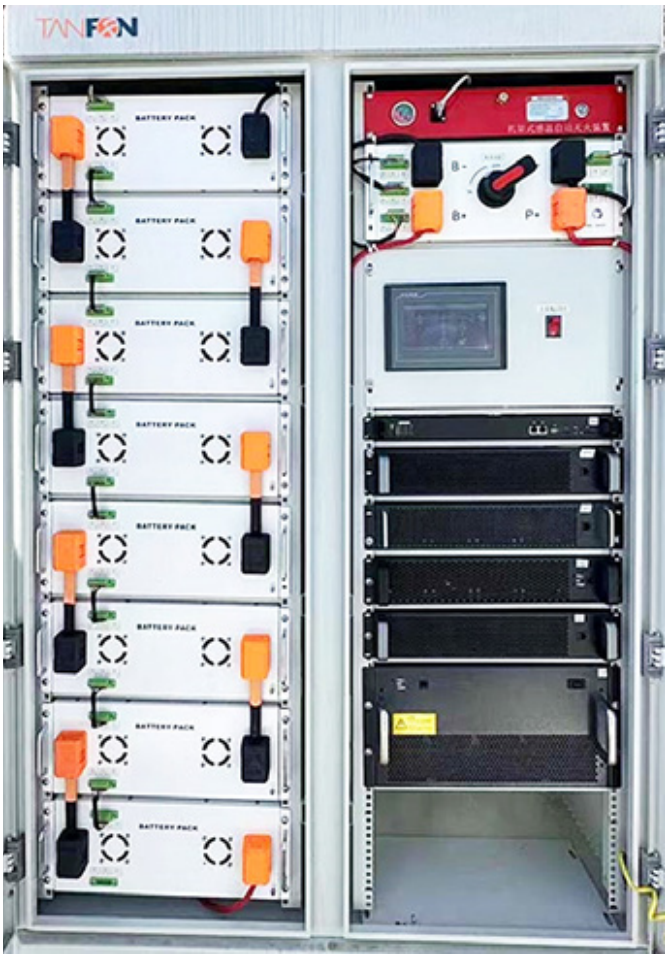
"These mostly over-sized, under-sized and often redundant power generation/ usage have resulted..."

This solution is designed and installed in such a way that the four sources of power are integrated and automated with solar power set as priority 1, then the batteries (priority 2), DISCO (priority 3) and then the diesel generator. See Fig. 2. In a fully automated and perfectly synchronized system, the solar panels will provide full power for the load during the day and in low-lid (cloudy days). During the night, stored energy in the batteries will supply power to the load. In any case where the batteries drain below the set threshold, the public power (DISCO) source will kick in automatically. In very rare cases, when the batteries are drained and there is neither sunlight nor DISCO, the system is designed to start up automatically to power the load and charge the battery bank for re-use.

With this system, it is estimated that about 60% of the power demand of a typical installation will come from solar power, 20% from stored battery power, 15% from DISCO and only 5% or less (if at all needed) would come from diesel generators. In this way, consumers can cut their energy cost by over 50% while enjoying uninterruptible power supply 24 hours/day.

TAILORED SOLUTIONS FOR DIFFERENT CONSUMERS

The comprehensive (360 degrees) power solutions for various consumers fall within the following ranges:



A 500KWH Lithium-ion commercial energy storage system

- Residential power consumers (1kw to 50kw)
- SMEs Commercial power consumers (30kw to 1MW)
- Industrial/Mini-grid power consumers (1MVA to 10MVA)
- All-in-One Solar lighting (for outdoor lightings)

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ACEN ACTIVITIES IN PICTURES

FIDIC TRAINING FOR WORLD BANK

24TH – 26TH APRIL, 2024

L - R: *Mr. Ishtiak Siddique, Lead Procurement Specialist, World Bank, Nigeria Country Office and Engr. Kam-Selem A. Bukar, ACEN President declaring the 3-day Training Workshop open.*

Cross section of participant

Sitting from 2nd left is Mr. Akin Onimole (World Bank Procurement Specialist), Barbara Ziolkowska (World Bank), Engr. Olufunmilayo Kadri (ACEN MD), Mr. Ishtiak Siddique (World Bank Lead Procurement Specialist), Engr. Kam-Selem A. Bukar (ACEN President), Mr. Husni Madi (Facilitator) and other participants at opening of the 3-day training workshop.

2024 SEMINAR & EGM AT KANO

WEDNESDAY 24TH JULY, 2024

ACEN President, Engr. Kam-Selem A. Bukar, FNSE presenting appreciation plaque to the Keynote Speaker, Engr. Nuruddeen A. Rafindadi, FNSE, FAEng, OFR who is flanked to the left by ACEN Past President, Engr. F. Ajibade Oke, FNSE; (R – L) ACEN Vice President, Engr. Kunle Adebajo, FNIStructE and 2024 EGM Planning Committee Chairman, Engr. I. A. Maimaje, FNSE

Left & Top: Cross-section of delegates at the event.

2024 EGM Planning Committee

2ND BUSINESS EVENING 2024 AT PORT HARCOURT

27TH JUNE 2024

(L – R) ACEN Past President, Engr. George C. Okoroma, FNSE, JP presenting appreciation plaque to the Guest Speaker, Engr. Tony O. Nwogbo, FNSE, FNIEEE and the Coordinator, ACEN Zone 6, Engr. (Dr) Edward N. Moore, FNSE

A cross-section of the participants present at the event

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SOME ONGOING CONSTRUCTION SUPERVISION WORKS

Lagos Rail Mass Transit (LRMT) Blue Line Project (Section2)

Lagos Rail Mass Transit (LRMT) Red Line Project

Re-construction of Lagos Ibadan Express Way (LIE)

DESIGN AND EXECUTION OF AN ELECTRICITY SUBSTATION PROJECT

Engr. Olawunmi Abolarin, *MNSE (Chief Engineer/Head, Electrical Services, Samabot & Associates Ltd.)*

Engr. Sam Otenaike, *FNSE (Principal Partner/CEO, Samabot & Associates) Ltd.)*

1.0 INTRODUCTION

In Nigeria, electricity production over the last 40 years has varied from gas-fired, oil fired, hydroelectric power stations to coal-fired stations with hydroelectric power systems and gas fired systems being predominant.

Nigeria is a vast country with a total of 356, 667 sq. miles (923,768 sq. km) of which 351,649 sq. miles (910,771 sq. km or 98.6% of the total area) is land. The country is made up of six geo-political zones subdivided into 36 states and the Federal Capital Territory (FCT).

Furthermore, the vegetation cover, physical features and land terrain in the nation vary from flat open savannah in the north to thick rain forests in the south with numerous rivers, lakes and mountains scattered all over the country. These national physical and political attributes themselves present challenges for the effective provision of power needs to all nooks and crannies of the country.

Adequate power is a necessity to ensure that Nigeria is among the industrialized nations. Therefore, these three critical activities must be effectively carried out with satisfactory results.

i. Adequate power must be generated
ii. Power must be transmitted effectively to all parts of the country
iii. Power must be distributed efficiently to the consumers

Electricity is generated at voltages between 11.5 – 16kV and steppedup by a step-up transformer to 330kV at the power stations. The next phase of getting power to the consumer is transmission. Transmission begins with the transportation of voltage, 330kV along transmission lines (otherwise referred to as conductors) and is stepped down by a transformer to 132kV at the transmission substation. This voltage is further transported along transmission lines to injection substations and stepped down to 33kV.

Distribution of electricity starts at this point. The voltage is stepped down by a distribution transformer to 11kV which in turn is stepped down to 0.4kV for industrial purposes and further converted and distributed at 230V before it gets to our homes or offices. See Fig. 1.

Adequate power supply is an unavoidable prerequisite to any nation's development. Electricity generation, transmission and distribution are capital-intensive activities requiring huge resources of both funds and sound professional capacity.

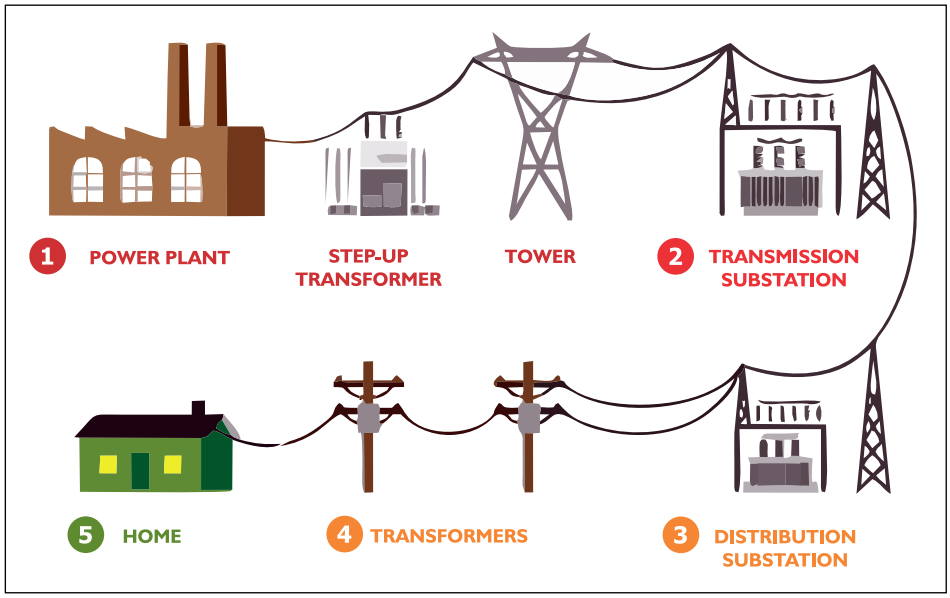

Fig. 1: *Electricity transmission*

2.0 ELECTRIC SUBSTATIONS

An electrical substation is the interface between parts of the power distribution grid and transmission system. The substations are where the voltages are increased to high values by using step-up transformers. After the transmission, they are again stepped down for distribution. In addition to changing the voltages, the substations have a variety of protective devices like circuit breakers and fuses to protect the distribution networks.

"Once these factors have been considered and criteria selected, the design team can begin to develop a detailed design for the substation."

Electric substations are designed in such a way that various distribution circuits can be isolated for repairs and load shedding. Substations are normally outdoors and are enclosed by a wire fence. However, in residential or high-density areas, the substation may be indoors and housed inside a building to restrict the humming noise of the huge transformers. While electric substations take part of the distribution of electricity, they have many other functions as follows:

i. To step up and step down the voltage for transmission and distribution: As power is transmitted at a higher voltage over long distances, the current is lower. This results in lower transmission losses but does not provide the proper current for homes and businesses to use. This calls for stepping up and stepping down the voltage as necessary.
ii. Switching and isolating the circuits for maintenance: Switching is also an important function of substations. Closing down a feeder circuit when the load demands are high needs to be done for the safety of the generating plants. Switching high voltages is a dangerous activity. Special circuit breakers like air circuit breakers and oil circuit breakers for reducing arcs have to be used.
iii. Load shedding: When the power demand is more than the supply, the substations shed the load on distribution circuits to maintain a balance across the electrical network.
iv. Correction of power factors' circuits: The power factor has to be kept at the correct value when reactive loads are there to protect the generating plant and increase efficiency.
v. Substations have bus bars fixed as part of the facilities for splitting the power for distribution. Thick bars of copper to which various distributing circuits are connected by nuts and bolts are known as bus bars.

3.0 SUBSTATION DESIGN AND EXECUTION

3.1 PRELIMINARY CONSIDERATIONS

From the foregoing, it has been established that a sub-station is an assemblage of electrical apparatus for voltage transformation and switching functions and distribution purposes. Hence they can be categorized as:

i. Transmission Substations(330kV/132kV)
ii. Distribution Substations (33kV/11kV/0.415kV)
iii. Switching substations
iv. Any combination of the above

Normally, a power system is designed such that the effect of an outage (caused by the failure of a single component such as the transformer, transmission line or distribution line) will result in minimal interruption of service and affect customers minimally. Failure of a single component often forces a greater than normal load to be carried by other components of the system. Such contingencies must be planned for and incorporated into the design criteria.

When evaluating the switching arrangement for a substation, the engineers need to be aware of the system configuration of which the substation will be part of. System contingency arrangements need to permit the outage of components in a substation for maintenance and unscheduled outages.

Distribution substations can be designed to operate unattended. Indeed, this is becoming the global trend in what is termed'Distribution Automated Systems'. Remote indication, control, metering and methods of communication are often provided so that most parts of the system can be monitored from a central point.

The design of an electricity substation project is a complex process that involves a number of design criteria selections such as:

- The type of substation (air-insulated switchgear (AIS) or gas-insulated switchgear (GIS))
- The voltage level of the substation
- The capacity of the substation
- The location and purpose of the substation
- Sources of supply
- The environmental conditions at the substation site

Once these factors have been considered and criteria selected, the design team can begin to develop a detailed design for the substation.

3.2 APPLICABLE STANDARDS

For a substation design to be acceptable and approved for execution, there are standards and regulations that must be strictly adhered to. Some of these are outlined below:

NESIS 2015	Sections 2.1 through 2.5 "Substation Overview, Civil Works, Electromechanical Works, SCADA, HSE"
CAP 106 LFN 1990	Regulations appertaining to substations and switching stations
ELECTRICITY ACT	Electrical Installation Regulation 1995 Section 3 and 4 (PART VII)
CAP 106 LFN 1990	Transformation and control of energy at high voltage
IEC 61200	Electrical installation guide
IEEE Std. 1127	IEEE Guide for the Design, Construction, and Operation of Electric Power Substation s for Community Acceptance and Environmental Compatibility.
IEC 61660	Short-circuit currents in D.C auxiliary installations in power plants and substations
ANSI Std. C37.30	Standard Definitions and Requirements for High-Voltage A Switches, Insulators, and Bus Supports.
IEC 61968	Application integration at electric utilities - System interfaces for distribution management
IEC 61969	Mechanical structures for electronic equipment - Outdoor

3.3 SUBSTATION DESIGN PLANNING

Two of the most critical factors in the design of a substation are its location and siting Failure to carefully consider these factors can result in excessive investment in the number of substations and associated transmission and distribution facilities. It is becoming increasingly important to perform initial site investigations prior to the procurement of property. Previous uses of a property might render it very costly to use as a substation site. Such previous uses might include its use as a dumping ground where buried materials or toxic wastes have to be removed prior to any grading or installation of foundations.

The following are factors to evaluate when selecting a substation site:

- Location of present and future load center
- Location of existing and future sources of power
- Availability of suitable right-of-way and access to site by overhead or underground transmission and distribution circuits
- Alternative land use considerations
- Location of existing distribution lines
- Nearness to all-weather highway and railroad siding, accessibility to heavy equipment under all weather conditions, and access roads into the site
- Possible objections regarding appearance, noise or electrical effects
- Site maintenance requirements including equipment repair, watering, mowing, landscaping, storage and painting
- Possible objections regarding present and future impact on other private or public facilities
- Soil resistivity
- Drainage and soil conditions
- Cost of earth removal, earth addition and earthmoving
- Atmospheric condition, salt and industrial contamination
- Space for future as well as present use
- Land title limitations, zoning and ordinance restrictions
- General topographical features of site area and avoidance of Floodplains, wetlands and prime or unique farmlands where possible
- Public safety
- Public concern related to site of schools, day-care centers and playgrounds
- Security from theft. vandalism, damage, sabotage
- Total cost including transmission or distribution lines with due consideration of environmental factors
- Threatened and endangered species and their critical habitat
- Cultural resources
- Possible adverse effects on neighboring communications facilities

3.4 DESIGN DOCUMENTS

The engineer's detailed work requires the use of valid requirements and criteria, appropriate guidelines and engineers own expertise in order to provide the construction drawings and associated documents required for the needed substation. The engineer's ability to weld the diverse constraints into an acceptable design is essential.

Having critically evaluated all factors listed in 3.3 above, the design team must also ensure that the present and future load demands for the power end users is captured and forms the basis of the

substation capacity.

Adequate engineering design provides direction for construction, procurement of materials and equipment and future maintenance requirement while taking into account environmental, safety and reliability considerations.

Below are some deliverables expected from the substation design team:

i. A schematic diagram of the required substation equipment, showing the electrical equipment and connections between them
ii. A site plan of the substation showing the equipment layout and their connection
iii. For substations with indoor switch gear panels, the building plan showing all room spaces designed to accommodate proposed equipment with required allowances of space, etc
iv. Detailed cable routes either through floor trenches/ducts,etc
v. Detailed structural designs encapsulating all previous topography studies,etc to ensure the stability of structures for the substation equipment
vi. A detailed layout plan for the substation, which shows the location of all equipment, buildings, and other structures (See Fig. 2).

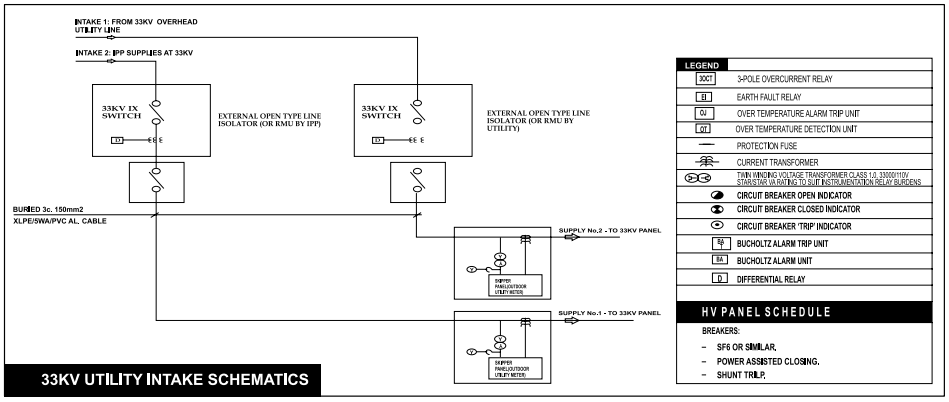

Fig. 2: *A schematic diagram of an electricity substation*

Fig. 3: Some equipment in an electricity substation

3.5 SUBSTATION EQUIPMENT SELECTION

Another key area in the design process of a substation is the major equipment selection.

Most substation equipment are not manufactured in Nigeria although some are assembled here. It is only in recent years that few Nigerian cable manufacturers ventured into the manufacture of medium and high voltage cables manufacturing.

For substations that require indoor switchgear panels, there is usually provision for factory inspection and acceptance tests in the contract. Such equipment include 33kV or 11kV gas insulated switch gear panels, HV switching and distribution automated system equipment, etc. These equipment specifications are tailored to fit the engineers request based on the capacity of the substation and requirements. Typical equipment found in a substation are:

- Power Transformers(Step up/step down)
- Ring Main Unit
- Switch Gear Panels
- Incoming / outgoing overhead or underground cables ➢ Protective Outdoor Circuit Breaker:
- Current Transformer (CT)
- Voltage Transformer (VT)
- Bus System
- Lightning/Surge arresters ➢ Disconnecting Switches
- Auxiliary Systems
- Relay and Metering Devices (See Fig. 3).

3.6 SUBSTATION EXECUTION

The execution aspect of a substation is largely affected by the extent of evaluations and considerations put in by the design engineers. Like any other project, the execution of a substation project requires excellent project management.

The execution of an electricity substation project typically involves the following steps:

i. Startup activities: These include the site handover by client, municipal or government clearances, soil investigation, earth resistance tests, etc.
ii. Site preparation: This includes clearing the site,

"There are diverse challenges encountered in substation project execution which at times may or may not have been anticipated."

grading the land and installing any necessary drainage or erosion control measures road networks.

iii. Procurement of equipment

iv. Civil engineering construction work: This includes foundations for all internal and external equipment and building structures.

v. Equipment installation: This includes installing all the electrical equipment in the substation such as transformers, circuit breakers and switchgears. It also includes installation of fire protection systems.

vi. Cabling: This includes installing all the electrical cables that connect the equipment in the substation.

vii. Testing and commissioning: Once all the equipment and cables have been installed, it is necessary to test the substation to ensure that it is operating properly. This includes testing the electrical and mechanical connections, the protection systems and the control systems.

viii. Health and safety installations: They have to be checked.

ix. Security: Electricity substations are critical infrastructure, so it is important to take steps to secure them from unauthorized access and vandalism.

x. Project close-out: Once the substation has been successfully tested and commissioned, it is ready to be put into service.

4.0 CHALLENGES ENCOUNTERED IN SUBSTATION DESIGN AND EXECUTION IN NIGERIA

4.1 ENUMERATION OF THE CHALLENGES

There are diverse challenges encountered in substation project execution which at times may or may not have been anticipated. The common challenges are:

i. Inadequate or improperly done site surveys leading to wrong assumptions by the design engineer: The consequence of this kind of challenge is additional costs. An example is a switch gear panel room cable trench that continually gets filled with water due to capillarity arising from poor soil investigation. The moisture in turn begins to affect components of the switch gear panel adversely. A proper soil investigation result should have shown this tendency and the problem would have been resolved during foundation works.

ii. Mismatch between equipment design specifications and procured equipment specifications: This is a two way problem as it also indicates that there is communication gap between the design/supervising engineers and the contractors.

iii. Challenges as a result of not following standards and applicable regulations: This happens mostly as a result of lack of understanding on the design engineer's part. A design engineer should not use personal preferences for technical issues.

iv. Construction delays: They may be caused by bad weather, labor shortages, equipment procurement, etc.

v. Obtaining environmental permits and approvals from government agencies: The procedures involved in acquiring some of these documents are time consuming.

In addition to these challenges, there are a number of other factors that can impact the success of a substation execution project such as:

a. A detailed schedule for the project
b. A workable budget for the project
c. A risk management plan

4.2 OVERCOMING THE CHALLENGES

Electricity substation projects can be complex and time-consuming, so it is important to have a good project management plan in place. The following are ways to overcoming these challenges:

i. Employ experienced, competent and certified engineering professionals for the design, supervision and executing stages of the project.

ii. Early planning is important. This involves identification of the project goals and constraints.

iii. There should be effective communication between all stakeholders.

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COMPANY INTRODUCTION

INTERACTIVE ENGINEERING CONSULT LTD. (I.E.C.L) is an indigenous Project Management and Engineering Firm that offers services in the areas of Engineering Project Management, Systems Design, Procurement and Implementation in the construction and oil and gas industries in Nigeria. The company has over the years developed an established project management approach to accommodate and manage unique requirements for any type of engineering projects.

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Engr. Hassan Odediran, FNSE
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* To produce designs on water and sewage treatment plants, trunk mains and reservoirs
* Civil/Structural Engineering
* Water Resources Engineering
* Highway Engineering (Roads and Bridges)
* Pre & Post Contract Services on Electrical, Mechanical and Civil/ Structural
* Production of Front-Line Engineering Design for Complex Systems
* Procurement Services on M & E Equipment
* Feasibility Studies and Procurement Audit Reports
* Functional Design, Project Evaluation, cost estimate and control
* Condition survey expert of all building types in use or abandon
* Power Generation/ Transmission/Distribution design and supervision
* Preparation and Analysis of Tender & Contract Documents
* High Voltage Design of Substations and Transmission
* Facilities Management and Project Monitoring Supervision
* Research and Development
* Assessment of existing

services provision (electrical + mechanical) in ProductionFacilities, Utility Buildings such as in Textiles Industries, Bottling Company, Plastic Factories, Hospitals, Educational Institutions, Residential Blocks, Office Block, Shopping Complex and Airports.

* Enumeration of precautions required for major equipment Performance in Industries and Corporations.
* Technical audit for plants and machineries.
* Oil Industry Service Company Provider under Specialized Category – Major Construction Services and Heavy-Duty Equipment Supply, Installations and Maintenance.

The Firm operates its Headquarters at Plot 268/231, IEC Villa, IEC Crescent, Off American International School, Cadastral Zone B.02, Durumi District, Abuja, with its annex office in Ilorin Kwara State at No. 10 Old Jeba Road, Opposite GSS by Agric Round About, Ilorin, Kwara State and Branch office in Kaduna at 10B, Shehu Ibrahim close off Sani Sami road, Malali-GRA Kaduna, and liaison offices in most of the State Capitals namely, Enugu, Lagos, Oyo, Taraba, Niger, Edo &Kwara, Taraba, Rivers, Bayelsa & Kano.

The Firm is staffed with highly skilled and experienced seasoned professionals in the respective fields of Engineering and Procurement. It is also registered by C O R E N to practice consultancy with Registration No. EF.00206. N S E with Registration No. 310 this has been responsible for our ability to handle a wide range of project.

New International Terminal Building at Akanu Ibiam Airport Enugu

The Firm is also registered with A C E N with Registration No. F146, and our process are designed to comply with international standards such as ISO 9001 and a high-level quality management system is adopted in the company processes from top to bottom.

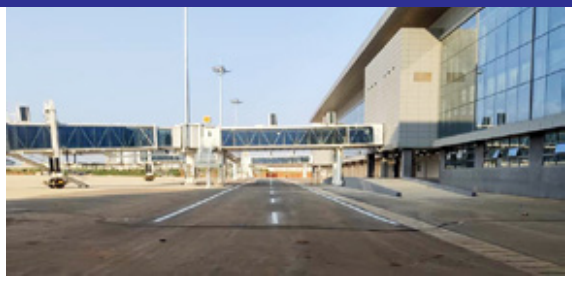
OUR APPROACH TO PROJECTS

We continuously aim to improve the delivery of projects through the incorporation of lessons learned and the application of robust systems and process.

* Maintain core team of resources.
* Structure project team around project and client needs.
* Supplement resources with selected skilled resources.
* Focus on Project, Engineering and Construction Project Management (supported by sound engineering experience and qualifications).
* Capital, Cost Saving and Business Improvement.

The full range of IECL services and expertise are contextualised according to eight integrated Service areas that extend across all phases of the project lifecycle.

A facility in the new international terminal building.



New International Terminal Building at MMIA, Lagos

ADVANCED ENGINEERING DESIGN AND CONSULTING

IECL engineers provide full multi-disciplinary conceptual, basic and detailed engineering design and consulting services. Where appropriate, we use widely accepted industry practices and processes as a foundation, but always differentiate our service by the level of detail and our fresh way of approaching challenges. The result: accurate, quality work and innovatively engineered solutions that are fi t for purpose.

We develop ideas from concept to final detail using advanced analysis software and 3D modelling tools. Our combined knowledge and experience guide us to focus on what is relevant and required.

New International Terminal Building at Makia Kano

Workers on site at Makia, Kano

DETAILED PLANNING / SCHEDULING / TIME MANAGEMENT

The project scope of work and deliverables are allocated to appropriate work packages based on the Work Breakdown Structure. The activities required to complete the scope and deliverables are identified at the relevant level for planning the particular phase of the project.
We develop a project schedule aimed at meeting predetermined milestones through allocation of adequate resources to finalise activities in time. We complete the project execution plan during the set-up and mobilisation phase, ready to guide the project at implementation kickoff.

We spend a lot of effort on front end loading activities, planning in particular, to increase the probability of project success.

ADDED VALUE: DEFINITION OF THE SCHEDULE INPUTS-

* Work package definition
* Procurement package dictionary
* Project milestone target dates
* Engineering deliverables
* Incorporation of fabrication and delivery schedules
* Logistics and transport strategy
* Construction strategy development and packaging
* Commissioning systems identification

SEQUENCING OF INTERACTIONS

* Milestone driven activities
* Identification of mandatory and discretionary dependencies through experience-based input
* Sequencing the engineering input per discipline work package, procurement per commodity, construction per area and commissioning per system to establish the most appropriate and

practical execution scenario
* Predecessor and successor planning to illustrate the relationships of various activities

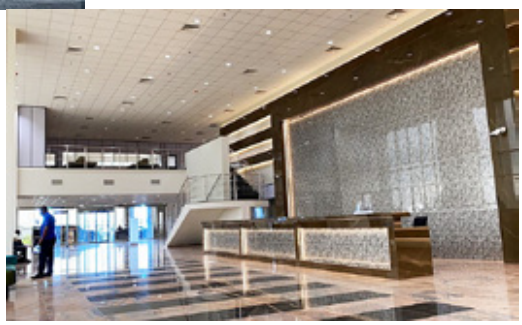
RESOURCE ESTIMATION

Establishing resource requirements and availability
Conduct resource levelling with histograms

DURATION ESTIMATION

Determining production levels by evaluating market indicators to arrive at realistic time frames
Evaluating various scenarios through simulation to determine schedule contingency

Left: *NCDMB HQ Building In Yenagoa Bayelsa State;* ***Top:*** *The Project Team;* ***Bottom:*** *A facility in the building.*



SCHEDULE DEVELOPMENT

Identifying the critical path
Reviewing the cost impact of fast-tracking critical items
Developing the most realistic schedule to match the scope and execution model

SCHEDULE CONTROL

* Incorporating the change management procedure on an ongoing basis to accurately forecast the impact of any changes before they are implemented
* Progress reporting and forecasting of ongoing activities to ensure timely corrective action
* Earned Value Analyses reporting to link capital expenditure and schedule progress
* Forecasting expected final completion dates and likely scenarios through simulation of remaining activities

ACCURATE PROJECT ESTIMATES / BUDGETS / COST MANAGEMENT

Budgeting is a specialised process that provides a quantitative estimate of the likely costs of the project elements. Throughout the study phases we use our experience and the evolving information provided by our engineering processes to develop the budget and estimates for resources and activities. After project approval, estimates are based on final project plans and scope of work. These are further refined when actual tender information is available, and construction commences.

ADDED VALUE: COST ESTIMATING

COST ESTIMATING

* Incorporation of the Work Breakdown Structure into each activity to enable scope definition, reporting and reviews
* Accuracy of quantities through engineering effort and rates obtained from market input captured inappropriately defined procurement packages allocated to a Cost Breakdown Structure
* Flexibility of reporting and analyses by capturing all items in a database
* Review information is extracted from the central repository using pivot tables
* Simple and effective presentation of relevant data enables informed decision making

CASH FLOW

Accurate cash flow, and ultimately financial models, are derived by linking the estimate data to the

Nogaps Odukkpani, Calabar

execution schedule through the use of the WBS-based data capturing process

CONTINGENCIES AND ALLOWANCES

By identifying and capturing the foreign exchange component of each activity, it is possible to analyse sensitivity to exchange rate fluctuations. Allowances to address the uncertainty in base data are derived using statistical analyses software to model expected variations of each cost item
Contingency values are based on the risk profile and likelihood of occurrence predicted for the execution period to arrive at a realistic contingency apportionment

CHANGE CONTROL

* Change control is implemented from the base case budget to accurately identify the effect of any change and manage the outcome on the final project cost

COST CONTROL

* Accurate cost control is achieved through diligent capturing of data at prescribed recurrence periods
* Cost Reporting Commitments, cash flow and forecasting are captured per item on a monthly basis to understand trends and likely outcomes that allows timely intervention and corrective action

EFFECTIVE PROCUREMENT MANAGEMENT

Our procurement and contracts management competencies are first applied at the study phase
to produce procurement / contracting strategies.

Our expertise covers all aspects of the contracting of services and procurement of equipment
/ materials. We produce pertinent documentation for tenders and proposals, as well as
procedures for adjudication processes, contract placement, management and closure.

The contribution we make extends beyond procurement process, strategy and documentation.
We tap into our network of professionals in a variety of technical disciplines, so that clients
are not exposed to the effects of the industry skills shortage.

ADDED VALUE: PLANNING

* Establishing the most effective procurement philosophy according to specific client requirements
* Developing a procurement management plan that accurately describes how the process will be managed

ENQUIRY PROCESS

* Inviting appropriate bidders through a pre-qualification and selection process
* Reviewing the various conditions of contract to optimise potential value for each application
* Ascertaining the most suitable measurement criteria, be it fixed price, re-measurable or perhaps time and material (cost plus) based contracts
* Utilising a Procurement Management Plan to control the outcome of the procurement process

ADJUDICATION

* Using evaluation criteria in a weighted matrix to determine the best suited candidate for each contract, taking into account capacity, capability, experience and technical approach
* Evaluation of lifecycle costing, integration of systems and operability
* Direct and indirect cost evaluation and modelling
* Manage clarification meetings and contract negotiations to the benefit of the client and supplier.

AWARD AND ADMINISTRATION

* Contract management
* Continual involvement during contract administration to ensure accurate delivery of the scope of work

* Coordination of quantity surveys and progress reports
* Risk mitigation through expediting / delivery monitoring and control
* Claims resolution
* Contract closure

CONSISTENT QUALITY CONTROL, RISK MITIGATION AND SAFETY MANAGEMENT

Safety, Risk and Quality Management planning and development of procedures are initiated during the study phases of the project but plans and strategies are only effective when consistently applied through all phases of projects.

ADDED VALUE:

* We do not compromise on safety. In all aspects of our work we consider it a priority and apply tools such as HAZOP / maintainability review during design, or toolbox talks / task observation during construction, to ensure a safe environment for all.
* Risk management is an essential part of proactive project management. We focus on early project risk analysis, development of appropriate actions / mitigation strategies / contingency allocation and progressive updates of the risk register. This empowers the project manager and client to take early corrective action to risks identified for meeting project objectives.
* Our passion for quality shines through in the extent to which we apply quality control throughout the project lifecycle. Quality planning, assurance, monitoring and control are performed to agreed standards, targeted to meet or exceed requirements. This relates to all aspects of the project, including project management, engineering, procurement, construction, commissioning and handover.

POLICY

Interactive Engineering Consult Ltd (I.E.C.L) will always be a completely independent Consulting Firm, uninfluenced by any contractor, supplier or manufacturer's interest.

Project team on site at Nogaps Odukkpani, Calabar

The client's interest will always be of paramount importance to I.E.C.L right from the inception to the execution of any project. All detailed studies to be carried out at preliminary, feasibility location studies, planning and design stages, preparation of tender documents and supervision of construction and installations including assistance in management will always be in the client's interest.

Whenever it is desirable, I.E.C.L co-operates either with well-known Consulting Firms representing a specified know-how or specialized experts in order to give the client the best services.

I.E.C.L will always strive whenever possible to transfer technology to fellow Nigerians on any project executed.

QUALITY POLICY

I.E.C.L will make quality a way of life. Quality is the result of good management and will be achieved by the way we get the right things done. We believe there is always a better way to provide services to our clients and strive for continuous improvement.

In rendering our services, we will optimize resource utilization and commit ourselves fully to the task at hand. We consider meeting client requirements as the minimum performance criteria and aim to surpass expectations.

SAFETY, HEALTH AND ENVIRONMENTAL

IECL is committed to a clean, safe and healthy environment for our employees, contractors,
customers and the communities around us. All employees and contractors forming part of the
IECL service, have a duty to prevent harm to themselves, to others and to the environment.

IECL will comply with all the applicable legislation, regulations and customers' requirements
as minimum benchmark for its Safety, Health and Environment (HSE) Policy. IECL will regularly
review this policy, practices and performance to ensure ongoing improvements.

SCOPE OF SERVICES

Interactive Engineering Consult Ltd. offers a variety of services which
include but not limited to the following:

* Condition Surveys
* Preliminary Designs
* Final Designs
* Bill of Quantities/BEME
* Standard Specifications
* Post Contract Supervision
* Procurement Services
* Oil and Gas Services

ELECTRICAL ENGINEERING SERVICES:

(Design & Supervision)

* **Low Voltage:** Interior and Exterior Lighting, Small Power, Switchboards & Distribution Panels, Protection Systems, Standby Power Plants, Alternative Power Generation
* **Medium Voltage:** 33kV, 11kVTransmission Lines, Substations and Associated Works (Infrastructural provision)
* **Extra Low Voltage:** Fire Detection & Alarm, CCTV/ Surveillance System, Audio/Visual Systems, Public Address/Background Music, Voice Evacuation System, Satellite/Terrestrial TV & Radio, Data/Voice/Video Systems, Phone System Design, Network Equipment Design, Internet Services Analysis & Planning, Building Management System (BMS)
* **Power improvements/Backups:** HT & LT Generators, Power House Designs, Cabling Systems
* **Renewable Energy:** Solar Power systems

Press conference with team at Nogaps Odukkpani, Calabar

MECHANICAL ENGINEERING SERVICES

* **Water Supply:** Water Reticulation & Storage, Borehole, Water wells, Network Design, Water Treatment Plants, Boiler Plants and Hot Water Distribution
* **Drainages:** Waste, Foul & Rainwater Drainage System, Central Sewage System, Localized Sewage Treatment Plant, Network Design
* **Air-Conditioning & Ventilation:** Unit & Central Air-Conditioning & Ventilation System
* **Fire Fighting:** Fire Hydrant Network, Wet & Dry Risers, Fire Extinguishers & Suppressants, Fire Pro System
* **Vertical Transport:** Passenger & Goods Lifts, Elevators, Scenic Lifts, Dumb waiter, auto walks.
* **Horizontal Transport:** Travellators

CIVIL /STRUCTURAL ENGINEERING SERVICE

* Civil/Structural design and supervision
* Highway design and supervision
* Dams design
* Bridge Design and supervision
* Geotechnical and Geophysical analysis for buildings, Dams and Bridges Foundation.

PROCUREMENT SERVICES:

* Procurement Audits
* Field inspections and projects evaluation.
* Preparation and evaluation/analysis of Tender
* Preparation of Contract Documents
* Monitoring and Evaluation

POLICY ON MINI-GRIDS, RURAL ELECTRICITY ACCESS AND IMPLEMENTATION IN NIGERIA

Dr. Ibukun D. Fajuke, *Deng (Power Energy Machine & Drive Research Group Dept. of Electrical & Electronic Eng., Faculty of Tech., University of Ibadan)*

1.0 INTRODUCTION

Access to electricity is a critical factor in economic development, social progress and improved living standards. It is envisaged that the electricity supply-demand gap will continue to grow exponentially unless it is met by some other means of power generation. Statistically, an increase of 2.3 % of electricity consumption each year has been reported. This report indicates that there is a high demand of electrical energy consumption across the globe. Hence, the conventional energy generation sources are insufficient to close the energy gap.

In a report by the United Nations in 2018, renewable energy mini-grids are considered as a key solution to expanding electricity access in a timely, sustainable and cost-effective manner in both urban and rural areas. Nonetheless, an enabling policy and regulatory framework are necessary requirements to address investment risks, scale-up deployment and ensure long-term and reliable operation. In response to these challenges, several countries have introduced measures to promote renewable energy mini-grids, including setting targets and designing dedicated policies and regulations for the sector. Often regarded as the giant of Africa, Nigeria is one of such countries trying to develop policies and regulations that promote the use of renewable energy mini-grids.

2.0 ENERGY RESOURCES AND DEPLETION TREND

The country is located in western part of Africa, bordered by Atlantic Ocean to the south, Benin Republic to the west, Cameroon to the east and Niger to the north. The nation has a land mass area of approximately 924,000 km2 with a growing population estimated to be more than 200 million people. Nigeria is richly blessed with reasonably high qualities of various energy resources including crude oil, natural gas and coal. Nevertheless, it is projected that most of these resources will be depleted at the end of the 21st century as shown in Fig. 1. The country is also blessed with renewable energy sources like biomass, hydropower, solar, wind, among others.

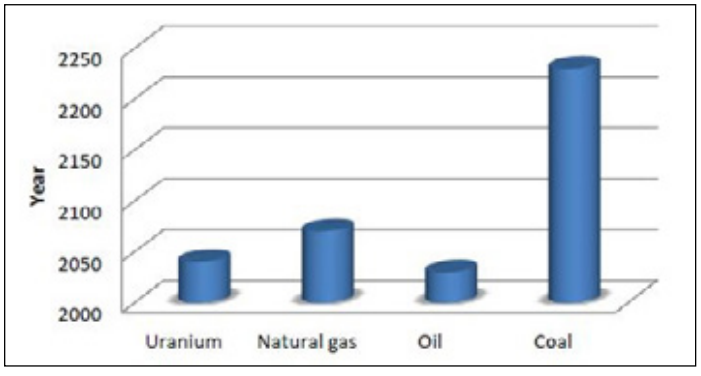


Fig. 1: *Projected depletion of conventional energy resources*

A reasonable percentage of the Nigerian population are rural dwellers with minimal or zero access to electricity. The impact of energy shortage led to the increased use of diesel generators. These diesel generators are used to supply the electricity needed in such areas where the grid extension is uneconomical. However, several factors affect the smooth operation of these diesel generators. Some of these include the emission of carbon gasses, high cost of fuel and maintenance, limited access to good roads during raining season, which hinder the smooth delivery of the necessary fuel and other materials needed for the running of the generators in rural areas.

"Statistically, an increase of 2.3 % of electricity consumption each year has been reported. This report indicates that there is a high demand of electrical energy consumption across the globe."

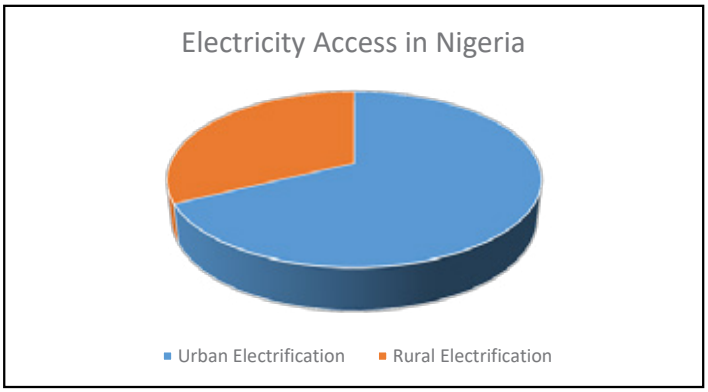


Fig. 2: Electricity access in Nigeria

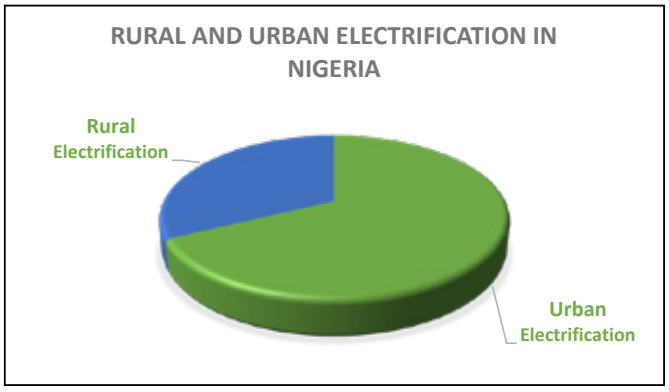


Fig. 3: Variance of electricity access in rural and urban areas in Nigeria

3.0 ACCESS TO ELECTRICITY

In Nigeria, access to electricity is available to approximately 60% of the population as illustrated in Fig. 2, with variances between 41% in rural regions and 86% in urban areas as depicted in Fig. 3. The national electricity demand significantly outstrips supply, exemplified by the fact that, in 2015, only 6 gigawatts (GW) out of the total installed generation capacity of 10.4 GW were accessible. Concurrently, the demand was estimated to be as high as 31 GW. Given this context, where expanding the traditional grid to reach rural areas is often economically challenging, off-grid solutions, such as stand-alone systems and mini-grids, assume a crucial role in advancing electricity access.

4.0 MINI-GRIDS AND THEIR RELEVANCE

The lack of electricity in many rural areas hampers economic activities, limits educational opportunities and affects healthcare delivery. As such, these areas represent a potential market for renewable mini-grids and the government has implemented a policy framework to encourage their adoption. Implementation of mini-grids in off-grid rural communities is expected to provide highly reliable and cost-effective electricity solutions.Mini-grids are small-scale, localized electricity distribution systems that can generate, store and distribute electricity to a limited number of consumers, typically within a community or a specific area. The block diagram of a typical mini-grid system is depicted in Fig. 4. These systems are designed to provide reliable and affordable electricity access, especially in regions where traditional centralized grid infrastructure is lacking or unreliable. Mini-grids can use various energy sources, including renewable energy like solar, wind and hydropower, as well as fossil fuels or a combination of sources. In an integrated approach to electrification, stand-alone systems

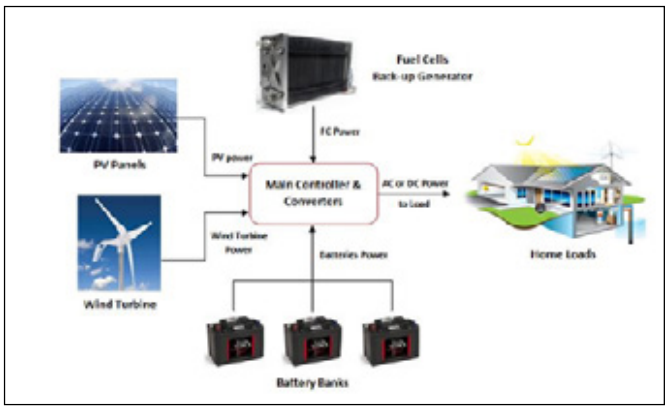


Fig. 4: A typical mini-grid supplying a residential home.

could help realise the immediate economic, social and climate-related benefits of basic electricity access as well as drive demand for larger mini-grids or grid extension. Renewable mini-grids use various technologies to harness electricity from solar, hydro, biogas, biomass, wind and/or hybrid sources (with the latter able to involve storage or diesel plants). Their capacities are in the range of about 1 kilowatt (kW) to about 10 megawatts (MW). A mini-grid may be interconnected to the main grid or autonomous. Autonomous or isolated mini-grids are particularly relevant for rural areas and may later be interconnected to a larger grid, whenever one becomes available.

The number of renewable mini-grids have grown steadily over the past decade. Small-hydro mini-grids are the most widely deployed and responsible for connecting majority of the end-users to mini-grids. This is attributed to the numerous benefits such as reduced costs and improved technology. Solar photovoltaic (PV) has recently experienced rapid growth, from 11 MW of capacity in 2008 to 378 MW in 2017 and 3 GW in 2023 as shown in Fig. 5. The number of people connected to PV mini-grids reached 2.1 million in 2016 and it is projected to reach 500 million at the end of 2030. The entire

continent of Africa has witnessed a six-fold increase in the number of people connected to solar electricity in 2023. The trend is set to continue, given the growing competitiveness of renewable energy mini-grid solutions and national efforts to scale up deployment.

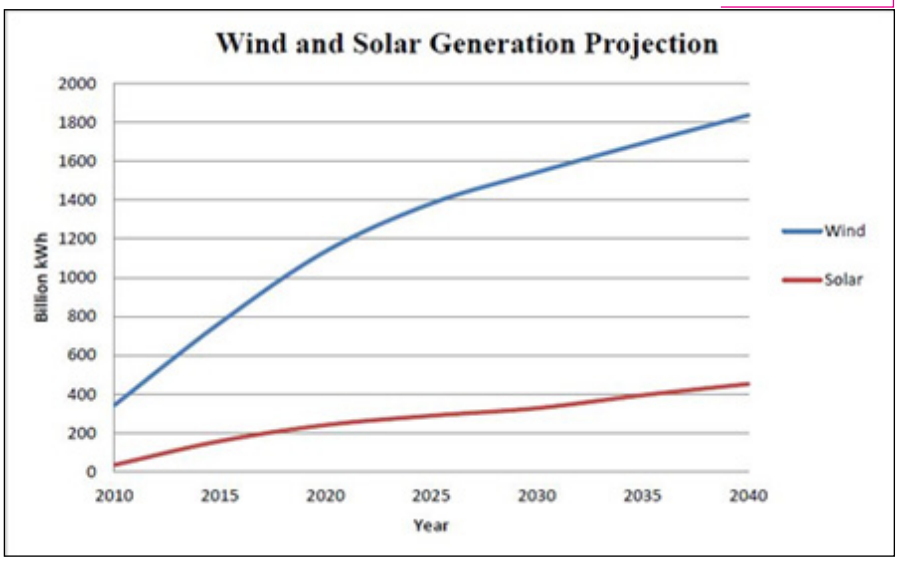


Fig. 5: *Solar and wind power generation projection*

In response to the surging electricity demand in both rural and urban communities, Nigeria has recognized mini-grids as a pivotal solution to provide electricity to rural areas. Successful mini-grid projects in Nigeria such as the Kigbe Community mini-grid and the Gbamu mini-grid projects shown in Figs. 6 and 7 are two notable examples that have transformed the lives of the people they serve and thus demonstrate the impact that these systems can have on rural communities. The government further identified a substantial number of mini-grid sites, approximately ten thousand, with a cumulative capacity of 3,000 MW, which were slated for potential development by 2023. The growing competitiveness of mini-grid solutions, combined with the increasing demand for electricity services in rural regions, serves as the primary impetus behind the continuous proliferation of mini-grids.

Various strategies for implementing renewable energy mini-grids encompass a wide range of models, such as community-owned micro-hydro

Fig. 6: *Kigbe Community mini-grid project*

Fig. 7: *Gbamu mini-grid project*

"The government's unwavering commitment to supporting an expedited expansion is evident in the ongoing efforts to introduce dedicated policies and regulations."

systems, privately operated solar PV direct current (DC) mini-grids and public-private partnerships (PPPs). To expedite the deployment of these mini-grids, it becomes essential to unite the forces of both the public and private sectors. This collaboration hinges on the notion that public financing should be coupled with private investment, all the while ensuring that essential services reach the most disadvantaged and underserved rural communities in an equitable manner.

However, several overarching factors have a significant impact on the enduring viability and socio-economic benefits of mini-grid systems. To begin with, the integration of gender considerations is vital in shaping the design of policies and programs, capacity-building efforts, technology applications and delivery and financing models. Secondly, the adoption of a multi-stakeholder partnership approach is crucial to guarantee the inclusivity and adaptability of electricity access programs, ensuring that diverse perspectives and interests are taken into account.The government's unwavering commitment to supporting an expedited expansion is evident in the ongoing efforts to introduce dedicated policies and regulations.

5.0 POLICY AND REGULATORY FRAMEWORK

Policy and regulatory framework for renewable mini-grids in Nigeria is categorized under three basic measures that define technical standards for main-grid compatibility and priority sites for mini-grids. These include the primary, secondary and tertiary measures. These measures are necessary to scale up deployment and guarantee sustainable growth that maximizes the socio-economic benefits of electricity access in rural communities. Primary measures are inherently tied to the national energy framework and are the responsibility of public institutions tasked with overseeing energy affairs, such as Ministry of Power. These encompass policies and regulations pertaining to the electricity sector, rural electrification plans, regulatory frameworks, quality standards and direct financial support allocated for mini-grid projects.

One noteworthy example of the primary policy put in place in Nigeria is the Nigerian Electricity Regulatory Commission Mini-Grid Regulation, 2016, which underscores the government's proactive stance in facilitating the mini-grid sector's growth. Also, the Electric Power Sector Reform Act that liberalised the power sector is a key building block needed to create a favorable environment for rural electrification through privately operated mini-grids. The Act recommended the creation of the Nigerian Energy Regulation Commission (NERC) as an independent regulating body and the creation of the Rural Electrification Agency(REA) to co-ordinate electrification in rural areas and administer the Rural Electrification Fund to provide financial assistance. Others include the Nigeria Electrification Project (NEP), National Renewable Energy and Energy Efficiency Policy (NREEEP), Mini-Grid Development Action Plan to mention but a few.

On the other hand, secondary measures are not exclusive to the energy sector but wield a substantial influence on the feasibility of mini-grid development. The environmental and social impact (ESIA) assessment scheme created by the Nigerian government is a good example of a secondary measure. The scheme is mandatory to assess the environmental and social impact of any development project in Nigeria with mini-grids included. Furthermore, the Nigerian government has created several taxation and fiscal incentive schemes to stimulate private sector investment. One of such projects is granting tax holidays for up to five years to companies that manufacture solar panels, batteries, solar home systems, light emitting diodes and other components that support solar energy production. Another financing program is the Micro, Small and Medium Size Enterprise Development Fund of the Central Bank of Nigeria. The program was established with the aim of channeling low-interest credit.

Tertiary measures contribute to the central enabling environment for mini-grids, fostering the efficient implementation of both primary and secondary measures. This entails creating conditions that

promote innovation, support research and for development and facilitation of private sector participation in the mini-grid ecosystem. Within the Nigeria Electrification Project, there is a specific component devoted to technical assistance and capacity building, with the primary objective of enhancing the ecosystem for renewable mini-grids. This component concentrates on fortifying the implementation capacities of various institutions charged with mini-grid development, including the Rural Electrification Agency (REA), the Nigerian Electricity Regulatory Commission (NERC) and other relevant stakeholders. The aim is to bolster the expertise and capabilities needed to facilitate the successful advancement of renewable mini-grid projects in Nigeria.

"With continued commitment and innovative solutions, Nigeria can accelerate its journey towards universal rural electrification..."

While the policy framework is in place, there are numerous challenges associated with the implementation of mini-grids in Nigeria. Financing remains a significant hurdle, as does navigating the complex regulatory landscape. Technological limitations and community engagement issues also affect project success. Another major challenge is the administrative processes scheduling, especially those related to regulatory requirements such as 'Environmental and Social Impact Assessments'.
Nevertheless, the future prospects for mini-grids in Nigeria look promising. To ensure their long-term sustainability, it is essential to address the challenges faced during implementation. Recommendations include streamlining administrative regulations, expanding financing options and promoting innovative technologies. Furthermore, communicating grid expansion plans in a timely manner, streamlining the process ofissuing permit and setting up a dedicated financing facility to complement the result-based grants could also potentially address some of the key existing challenges. Local governments could support developers by raising local awareness of electrification projects. It is also important to expand the scope of fiscal incentives (e.g., tax and duty exemptions) to cover additional key assets of mini-grids, apart from the generation components.

6.0 CONCLUSION

Nigeria's efforts in mini-grid implementation can be compared to successful models in other countries, such as India and Kenya. These comparisons reveal valuable insights that can guide future policy decisions and project implementations. The policy on mini-grids, rural electricity access and implementation in Nigeria is a critical step towards addressing the energy deficit in rural areas. While challenges exist, successful case studies and lessons from global best practices show that mini-grids have the potential to make a significant impact on the socio-economic growth of the country. With continued commitment and innovative solutions, Nigeria can accelerate its journey towards universal rural electrification, bringing about improved living standards and economic growth.

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FIXONTIME electric

Installation of 11 KV NOJA Power OSM Recloser for 11KV Feeder Protection

Installation of 33KV 4way RMU at Maroko Injection Substation, EKEDP VI District

The construction of Dual 33KV Underground Cable, 33KV Bays and Installation of Swutchgears for the Blue Line Rail Project

Installation of 11KV Lucy Ring Main Unit and Termination of Cable Using REPL Cable Accessories.

Supply of 11KV and 33KV Cable Accessories Comprising Cable Termination and Straight Shrough Kits

Installation of 33KV NOJA Power OSM Recloser for Transformer Protection at James Hope University, Lekki, Lagos State.

Installation of 33KV 2.5MVA Transformer and 33KV NOJA Power OSM Recloser for protection At Springfield Agro Limited

Installation OF 2nos 11KV NOJA Power OSM Recloser for Automatic Synchronization of 2nos 5MVA transformer at FRIESLANDCAMPINA

The Construction of Dual 33KV Underground Cable, 33KV Bays and Installation of Switchgears for the Blue Line Rail Project

6, Charity Road, (1st Floor), Oko-Oba, Lagos, Nigeria

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"THE CONSULTING ENGINEER" PERSONALITY

ENGR. ADEWALE ADERETI

MANAGING DIRECTOR, FIXONTIME ELECTRIC LIMITED

Wale Adereti presently serves as the Managing Director of Fixontime (Electric) Limited in Nigeria. The company was established in 2017 and boasts of over eight years of extensive experience. Engr. Adereti has a strong track record of project management, team leadership and consultancy across Nigeria, West Africa, East Africa, Europe and the United Arab Emirates.

As the managing director of an electrical power engineering, construction, maintenance and procurement company with educaional background in electrical engineering and extensive experience in large-scale power projects and infrastructure development, his role at FixonTime (Electric) Limited entails not only overseeing day-to-day operations and management, but also making key decisions, developing corporate strategies and handling technical aspects of the business.

Engr. Adereti is not just a business leader but a consummate, strategic and forward-thinking individual. His extensive knowledge of the energy sector and his collaboration with consultants during the privatisation of DISCOs to devise technical and commercial loss strategies are testament to his strategic leadership expertise. His forward-thinking acumen has played a pivotal role in advancing the industry and making significant contributions to enhancing electricity reliability and bolstering distribution network stability.

Wale Adereti's career began at Shell Concepts, a MEP design and consulting firm in Nigeria, where he served as a trainee and graduate engineer. He then moved to Warri on a contract in south-south Nigeria, where he supervised about 32 Electrical subcontractors on various projects at the University of Petroleum and Petroleum Training Institute. His leadership skills were further honed at Voltamp Equipment Nigeria Limited, where he served in different positions and later as Technical Manager, leading the engineering and electrical construction team.

Engr. Adewale Adereti

Wale Adereti's profound grasp of power systems stems from his diploma in electrical technology acquired at the Federal Polytechnic Ede, Nigeria. He later proceeded to Olabisi Onabanjo University, where he obtained his first degree as part of the pioneering class of Electrical/Electronics Engineering graduates.

Engr. Adewale Adereti is a prince from Ile-Ife. He is happily married, and when he is not working, he enjoys researching, playing computer games and travelling. In addition to his work in the power industry, he has other business interests in food, agriculture and water solutions. These are considered his unusual hobbies and areas he would be known for if he had not pursued his current career path. He also runs a solo mentorship program for young engineers and actively supports the advancement of the engineering profession in Nigeria.

A WORD FOR YOUNG ENGINEERS

THE JOURNEY OF A GREAT ENGINEER STARTS WITH A STEP

BY ENGR. ADEWALE ADERETI

Engr. Adewale Adereti

A great number of Engineers are quite successful. However, ten years after graduation, many Engineers are also still struggling. The tough business environment and dwindling economy in Nigeria have demotivated a lot of young engineers. This situation notwithstanding, the motive of this topic, is to reposition the young engineers to know there is light at the end of the tunnel.

i. **You are built to last:** To begin with, you are empowered to be rugged naturally based on your training. Engineering is tough, so the products and practitioners are expected to be rugged. So let your inner man tell you that can be everything you want to be.
ii. **Clarity of purpose:** Knowing where you are going shortens your journey and reduces your wilderness experience. Most people dabbled into engineering by accident. Evaluate your present situation; think of where you want to be, where you want to work or what goals you want to smash. Find out the competences you need for that job or for that goal and acquire them. The journey may be long and rough but if you have clarity of purpose that will inspire you to keep at it till you succeed.
iii. **Get Mentorship:** Whether directly or indirectly, follow successful people near or far; ask to be mentored; study their life; ask questions and mirror your life after the good things you see in them. You can do it through books; attend seminars; engage and exploit opportunities to grow. Get interested genuinely in the profession.
iv. **For the job seekers:** Get out of your comfort; network and do not be afraid to tell people you need a job. If you can, build skill and volunteer; seek to contribute; be desperate to make yourself useful. Approach organizations where you wish to work, whose visions align with yours. You can trade your talents. You are ticking the box of preparation for opportunities. Get a journal and list the companies where you intend to work or serve as an intern. Also send unsolicited applications.
v. Do not despise the days of little beginnings: Not all will start from oil and gas or multinationals; there are opportunities in small organizations also. A positive mindset would be to imagine you need the training more than the money. The skills might be all you need to get to the next phase.
vi. **For those already working:** There are several people who are feeling cheated because they are underpaid. This does not mean you should give less than you are capable of; stay positive. Develop a progressive strategy till the right time comes for an exit that was soundly planned.
vii. **Look out for more opportunities:** This can be in the same organizations, outside or within your social circle. Never think you have made it already. In your company, look for something extra to do. You can offer to manage the company's social media, apply some skills like paying attention to details and volunteer to do quality assurance checks for your company. Acquire customer service skills. In short, do not just do what they ask you to do only; offer to serve even if you are not rewarded.
viii. **For engineering professionals on the way up:** For engineers, develop yourself all round because there is still more room for growth; explore higher positions. Take courses; go for MBA. Be aware also that there are some positions you get by relationships, loyalty and not only by 'certificateship', so build relationships. Learn to network. NSE meetings, ACEN conferences and seminars, COREN Assembly are gatherings to achieve that.

Finally, give out to others and find someone you can mentor too. Like a well, you are meant to feed others, not just yourselves.

MicCom CABLES & WIRES: Making Remarkable Contribution to Nigeria's Economy through Cutting-Edge Technology

Mrs. Olubukola Adubi *(CEO, MicCom Cables & Wires Ltd.)*

Mrs. Olubukola Adubi is the Chief Executive Officer of MicCom Cables and Wires Limited. With over 20 years of industry experience, Adubi has vast international work experience and is well grounded in the entire value chain of the cable and wire industry. As her profile rose in the business world, so has her status, emerging as President of the Cable Manufacturers Association of Nigeria (CAMAN). She is a seasoned administrator, a respected professional of immense influence, an entrepreneur of note and a visionary business executive with the Midas touch. She is a registered professional Pharmacist in both United Kingdom, UK and Nigeria.

Prior to her role as MicCom's CEO, Bukola Adubi honed her crafts in various high-impact roles cutting across Pharmaceutical, Finance and Manufacturing.

Known and reputed for her impeccable leadership skills and dedication, she has always been at the forefront of innovation and efficiency, setting new standards in MicCom Cables and Wires Limited. She established herself as a strategic leader and an asset worthy of emulation.

Being the catalyst and driving force in MicCom's phenomenal growth and success, Adubi has a proven track record of successfully leading cross-functional teams and delivering complex projects on time and within budget. Her strong leadership skills and ability to build effective relationships with customers, stakeholders and team members have been the key to her success and that of the company.

In this exclusive interview, she explained that MicCom Cables and Wires is one of the leading indigenous Nigerian cable and wire manufacturers that stands as a beacon of professionalism and astuteness.

She expressed her delight at the growth of MicCom and the significance of the company's business operations spanning over four decades in Nigeria. She further said, since 1978, with its humble beginnings, MicCom has set out to become one of the leading cable manufacturers in Nigeria, built for itself a reputation backed by commitment to best-in-class service, industry-leading inventory and manufacturing the finest cables and wires.

The company has developed strong technical capabilities and produces several different types of cables and wires for various electrical applications and has obtained quality systems certifications including ISO 9001, ISO 14001 and OHSAS 18001. This is the first and only of such feat in the industry in Nigeria. According to her, MicCom absorbed and introduced the advanced management concept of international standards, equipped with first-class production and testing equipment.

Over the past four decades, since its establishment, the company has experienced leaping development, enjoying high popularity in the domestic and foreign markets. MicCom's longetivity reflects its deep-rooted dedication to the development of critical infrastructure in Nigeria's business landscape, thereby, playing a pivotal role in the nation's progress.

Over these four decades, the company has contributed substantially to the transformation of Nigeria's cable and wire landscape. Through its diverse portfolio of projects, MicCom has facilitated economic growth, enhanced the quality of life for countless citizens and provided employment opportunities, thereby promoting socio-economic development of Nigeria.

Speaking further, Adubi stated that MicCom has evolved into an international player, guided by a legacy of excellence and a commitment to innovation. This has been the compass, steering the company through change, uncertainties and disruptions, she enthused.

It is on this score, the company under her leadership, recognizes the importance of giving back to society. Among the CSR's initiative executed by the management include: building road within the host community. The company also built more than 500 boreholes in several communities in Osun State. Apart from this, the company set up a Cancer Care Foundation to immortalize Adubi's late mother, a co-founder of MicCom, Engr Comfort Olufunke Ponnle, who unfortunately died of cancer in 2012.

In recognition of Adubi's meritorious service to the industry and Nigeria, this mother of two received many awards, recognition and accolades. But Adubi, not one to rest on her oars or accolades, is determined to expand her scope of impacts, level of productivity and leading organisational growth.

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HYDRO-ELECTRIC POWER GENERATION

ABSTRACT

This paper discusses brief history of hydropower dams and hydro power generation, various equipment/devices/ option and processes involved in generating electricity inhydroelectric power plant. It includes citations and description of various features of a hydroelectric power generation plant.

Engr. Aminu Musa
(Principal Manager, Mechanical, Shiroro Hydroelectric Power Plant)

1.0 INTRODUCTION

Hydro power engineering refers to the technology involved in converting pressure and kinetic energy of water into more easily used electrical energy. The prime mover is a water wheel or hydraulic turbine which transforms the energy to useful purpose. For a hydroelectric power plant to provide power on demand either to meet a fluctuating load or to provide peak power, water must be stored in one or more reservoirs. Unless a natural lake can be tapped, providing storage usually requires the construction of a dam and creation of a new lake. Rivers and lakes serve as sources of water for hydroelectric power generation. Gravity causes water to flow downwards. This downward motion of water contains kinetic energy that can be converted into mechanical energy and then from mechanical energy into electrical energy.

The amount of electrical energy that can be generated from a water source depends primarily on two variables: the distance the water has to fall and how much water is flowing. Hydroelectric power stations are, therefore, situated where they can take advantage of the greatest fall of a large quantity of water at the bottom of a deep and steep sided valley or gorge or near the base of a dam.

2.0 OVERVIEW OF HYDROPOWER DAM

The world is becoming increasingly supplied with electric power. For the foreseeable future, hydro-power will continue to be the dominant option for electric power production. The world is keen in reducing high energy pollution and so supports investments in renewable energy to improve on risk associated with carbon emission. Hydro-power generation as a major option of renewable energy source provides bulk supply of energy that is pollution free.

Technology development and consideration have evolved since the introduction of the two well-known types of turbines: the Francis or reaction type of turbine and the Pelton or Impulse type of turbine. These two early types of turbines were developed to considerable sophistication and helped to make the electric generators practically successful. According to R. K. Rajput et'l 2008 in his book, "Power Plant Engineering", the first hydroelectric power plant was started in America in 1882. Subsequent development continued rapidly due to its significance. The first hydroelectric power development of 4.5MW capacity in India was commissioned in 1902 in Mysore. A project of 50MW capacity was then commissioned also in Maharashtra which was eventually upgraded to 500MW in 1947.

Worldwide, an installed capacity of 777 GW supplied 2998 TWh of hydroelectricity in 2006. This was approximately 20% of the world's electricity and accounted for about 88% of electricity from renewable sources.

3.0 HYDROPOWER DAMS

Hydroelectric power plants are constructed mostly in remote areas. Small and major hydroelectric power plants have essential elements common to both. For power generation in hydropower dams, these essential elements play major roles and constitute pre-requisite condition to generate and transmit power. The essential elements are:

* Catchment area
* Reservoir
* Dam
* Spillway
* Penstocks/Conduits
* Surge tanks

"...first hydroelectric power...of 4.5MW capacity in India was commissioned in 1902 in Mysore."

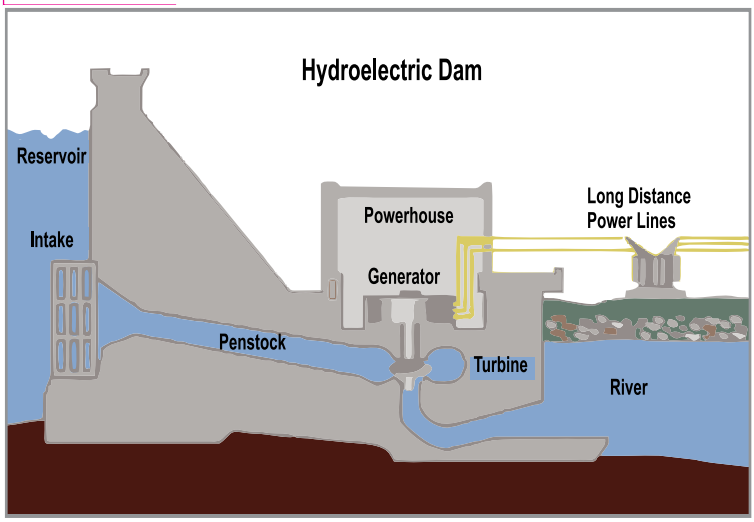

Fig. 1: Cross section of hydroelectric power plant

* Draft tubes
* Powerhouse (turbine, generators, and control equipment)
* Switch Yard for power evacuation (*See Fig. 1*)

3.1 CATCHMENT AREA

This is the whole area behind the main dam draining into a stream or river across which the dam was constructed. The main characteristics of the catchment area includes its size, surface orientation, shape topography and its geology.

3.2 RESERVOIR

In view of the wide variation in rainfall intensity during the year, there is always a necessity to store water for power generation. The storage is constructed in such a way that water is available for power generation throughout the year and in sufficient quantity even during worst dry periods. The whole mass area where the stored water covers is called reservoir. The reservoir is a primary and most important requirement for any hydroelectric plant. The reservoir is employed to store water which is further utilized to generate power by running the hydraulic turbines. The two main types of reservoirs are (i) the natural reservoir which is a lake situated in a high mountain and (ii) the artificial reservoir which is built by erecting a dam across the river.

3.3 DAM

A dam is a barrier or barricade that raises water for storage to create a hydraulic head. A reservoir dam stores water by raising its level as water flows in. Dams may be concrete or earth filled construction. They must be designed to satisfy the requirement of stability against water pressure and must be able to pass the maximum flood with safety. Most dams' designs are trapezoidal in shape for higher stability. However depending on the topology of area, designs like arch shape, slab and buttress type may beconstructed.

3.4 SPILLWAY

When incoming water enters a reservoir, the level of water rises in the dam. The rise in water level accumulates excess water which endangers the stability of the dam structure. To relieve excess water in the reservoir, a structure is provided in the dam body or in the periphery of the basin. This safeguarding structure is called spillway. Spillway gates are safety structures installed in dams to maintain normal dam operations by discharging excess water from the reservoir. The manner of water discharged is controlled by releasing excess inflow to the reservoir. In most types, water spills and flows over the body of the spillway whereas in other types, water spills over the cress and then flows through the body of the spillway.

3.5 PENSTOCKS/CONDUITS

The penstock is the conduit pipe that conveys water from the reservoir to the turbines. It aids the conversion of potential energy to kinetic energy in the system. Movement of water is regulated by intake gate structure. The conversion takes place once the intake gate or sluice gate is opened. Water flows in by gravity to the turbines through the penstock.
Selection of types of spillways and penstock are generally based on the type of dam and quantity of flood water to be discharged. For large dams, spillway gates and intake gates for penstock are installed and controlled by hydraulic control systems. These are applied on high head dams where large volumes of water are normally discharged.

3.6 SURGE TANKS

Surge tanks are structures through which penstocks are primed. The tanks are designed to eliminate air in penstocks and replace with water from reservoirs. Most surge tanks are constructed in reservoirs to take best advantage of the dam head. In large dams, the surge tanks house the pumps, motors and hydraulic systems meant for smooth operation of the intake gates.

3.7 DRAFT TUBE

The draft tube is the passage that carries the water discharged from the turbine runner to the tailrace.

The draft tube is lined with reinforced concrete walls. The main purpose of the draft tube is to recover as much as possible of the energy still remaining in the water as it flows through the turbine. The remaining energy of the water is present in the form of kinetic energy and the draft tube converts this energy into another form and is designed and shaped to reduce the velocity of the water.

"A hydro-power plant is an assembly of systems or subsystems to generate electricity."

3.8 POWERHOUSE

The powerhouse is the housing structure that the turbines, generators and all electro-mechanical equipment are installed. The powerhouse prevents rainwater and dust from the electronic equipment for a safe operation. Due to the nature of generating equipment, an air-cooling system is installed to provide cooling to excitation, protection and control systems. In most hydropower plants, the generator step-up transformers are mounted outside the powerhouse.

3.9 SWITCH YARD

Power generated is transmitted to switch yard at high voltage level from where it is transmitted to substations over long distances before stepping down the voltage for consumption. The switch yard is equipped with various electrical equipment such as transformers, reactors, isolators, current/voltage transformers, circuit breakers, etc. for proper transmission.

4.0 POWER GENERATION

A hydro-power plant is an assembly of systems or subsystems to generate electricity. It is designed and constructed to be useful economically and be environmentally friendly to society. The main set of equipment for generating power isthe prime mover (turbine)and generator. When the two are coupled together, they produce electricity with the help of water. The type of prime mover determines the type of power plant. To achieve or aid power generation in a simple, safe and controllable pattern, a technically designed hydro-turbine machinewith a governor system is used.

4.1 HYDROPOWER TURBINE

A turbine is a rotating device from which work is extracted from the action of a working fluid. The working fluid for a hydro-turbine is water. There are different types of hydro-turbines and most of their applications vary from design, reservoir capacity and head level of the dam. Hydro-turbines are classified according to the following:

- Head and quantity of water available
- Name of originator
- Action of water on moving blades
- Direction of flow of water in the runner
- Disposition of turbine shaft
- Specific speed of the turbine

Hydro-turbines are divided into Impulse and reaction turbine. Reaction turbines are subdivided into (1) Francis Turbine and (2) Kaplan & Propeller Turbine.

Francis turbines may be designed for a wide range of heads and flows. This, along with their high efficiency, has made them the most widely used turbine in the world. Their heads are in the range of 20 meters to 700 meters and their output power varies from just a few kilowatts up to one gigawatt. Large Francis turbines are individually designed for each site to operate at the highest possible efficiency, typically over 90%. The prime mover (turbine) is responsible for producing the mechanical power. The turbine unit comprises speed rings, wicket gates, turbine bearing, runner, turbine venting system and draft tube to mention but a few.

i. **Electro-Hydraulic Governor:** Most hydroelectric generating units are now controlled by electronic governor with hydraulic actuator. The electronic governor regulates the speed of the turbine, prevents the unit from hunting and provides a stabilizing effect. The governor controls the speed of the generator prior to synchronizing. When the machine is in synchronism with other generators in the system, the governor's action controls the machine loading. The regulation of the turbine speed is accomplished by changing the flow of water to the turbine. This regulation is essential so that the generator can produce power at constant frequency toensure a stable system. Power is generated, transmitted and distributed at a frequency of 50Hz. The frequency is the slowest electrical wave speed possible to provide continuous electrical supply to electrical equipment. The electro-hydraulic governor

consists of two parts- the electronic controller and the hydraulic actuator. In modern electronic governors, the interface between the controller and the hydraulic actuator is the electro-hydraulic transducer which sits on top of the main distribution valve in the actuator. The speed control system comprises the followings:

a. ***Governor Oil Pump:*** The oil pumps are usually of the gear type driven by electrical motors. They usually come up and load automatically. There are two oil pumps on every unit and the operating principle is as follows: One pump is selected to operate on priority basis while the other is on standby. When the pressure drops, the one on priority starts and builds up the pressure. The standby pumpcomes in when the one on priority fails. Uninterrupted availability of these pumps is essential to the operation of the generator.

b. ***Governor Pressure Tank (Accumulator):*** This is a pressure tank that stores air and oil at a high pressure. Understanding the operating principle of the pressure tank is necessary because the air/oil ratio must always be balanced. A pressure gauge is always provided on the side of the tank so the oil in the tank is monitored. It should be noted that:

→ High oil in the pressure tank with normal pressure means that there is insufficient air in the tank.

→ Low oil in the pressure tank with normal pressure means that there is too much air in the tank. It should be noted that if the oil level reduces in the tank to a certain level, the turbine could trip and drop the intake gate immediately as the oil may be insufficient to close the gate fully.

Introducing air into the tank is by the automatic air supply valve which is being triggered by one of the pressure switches. This exercise could also be done manually if the solenoid valve is defective.

Loss of oil in the accumulator tank rapidly could be caused by so many reasons such as:

- Defective check valve
- Leakage of oil from servomotor
- Leakage at the actuator cabinet

The simplest way to know this is by observing if the governor oil pump isrunning very often.

c. ***Pilot Valve and Relay Valve:*** The pilot valve and relay valve are used to control the flow of oil to the servomotor. The relay valve operates inside the pilot valve at a pressure lower than the operating pressure. This ensures a smooth operation of the guide vane distribution valve.The pilot valve is physically mounted on top. The pilot valve is very small and light and it is designed to be moved by movement of the governor head i.e., transducer. It is not designed to move or handle the large quantities of oil that may be required to move the gate but to actuate the pressure oil to the relay valve. The relay valve and the guide vane distribution valve are coupled internally inside the actuator cabinet.

d. ***Servomotor:*** This is the large hydraulic operating cylinder that opens or closes the guide vanes. The servomotors are located at the turbine pit area and are two in number connected to the shift ring. The guide vane distribution valve admits oil pressure to one end of the cylinder and opens at other end. The piping connection are made diagonally, this means the piston in the cylinder unit in turn moves the gate.

e. ***Shut Down Devices:*** In the event of failure of the electronic governor due to fault, a shutdown device is provided to cause the closure of wicket gates. These shut down devices are located at the actuator cabinet, which operate automatically without notice. In some cases, if the operator observes any serious abnormality, a manual shut down device is also provided at the same location.To save the generator from over speeding, mechanical over speed pendulum is mounted at the top of the slip ring chamber (coupled to the generator shaft) which actuates the intake gate to drop in the event of over speed.

"...if the operator observes any serious abnormality, a manual shut down device is also provided..."

f. ***Return Motion Cable:*** The restoring cable is used for mechanical feedback to the governor system and for determining the wicket gates positionfor instrumentation and control.

"Hydroelectric power plant has a life span in the range of 50 – 100years. It should be noted that old technology is being replaced with new one or improved upon. The type of technology applied several years ago is being phased out..."

4.2 HYDROPOWER GENERATORS

The main function of the generator is to transform the mechanical energy from the turbine into electrical energy. The generator is built up of numerical joint systems, roughly divided into rotary (rotor) and static parts (stator). The momentum in the rotor is supplied by the turbine. A magnetic flux is created by the excitation system. The stator is an electrical coil wrapped around an iron core. The number of poles in a stator of a generator determines the speed of the generator. Basically, the lesser the number of poles, the higher the speed of the generator.

When the rotor is rotating within a stator, an alternating current/voltage is produced in the rotor by the rotating magnetic flux (due to excitation voltage).This will in turn produce an alternating current/voltage in the stator winding through mutual induction.

In the conversion process, there are losses mainly in the form of heat. This heat must becooled by ventilation or cooling systems such as radiators (for cooling the stator windings) or heat exchangers (for cooling the generator and turbine bearings). The chain of energy losses begins from gravitational potential energy (water way losses) to kinetic energy in moving water (turbine losses) tomechanical energy (turbine - generator losses) and electrical energy to end users (transmission losses)

Generators have control and protection systems. They are designed and installed to work either vertically or horizontally. In both ways, the process of generating power is the same and they all require the control and protection systems. The control equipment performs various control functions for smooth running of the generator.

In order to prevent costly damage and unnecessary downtime due to faults, protection system is providedto, timely and effectively, protect the generators. Different types of instruments and sensors (e.g., temperature sensors, pressure and level gauges) are used for control while protective relays (in conjunction with CTs and VTs) are used for protection systems.

Faults on generator are always associated with stress. The stresses acting on a generator are complex. The stresses can be classified into mechanical, electromagnetic, thermal and environmental/ surrounding, etc.Mechanical stresses are both static and dynamical and limited to components in physical contact.Electromagneticstresses from electrical and magnetic fields can affect components at a distance without any physical contact.Thermal stresses create movements and tension.Environnemental stresses are frommoisture, oil, etc.

It is important to discover warning signs to be able to plan and organise a cost-effective action to mitigate these stresseswithin the production limits. With no faults sensed by protective devices, electricity generation is a continuous process.

5.0 CONCLUSION

Hydroelectric power generation has been an important aspect in engineering practice over a century. Harnessing its potentials and quality/ design of equipment or type of dam involved in modern technology are ever increasing to meet up with demands. Hydroelectric power plant has a life span in the range of 50 – 100years. It should be noted that old technology is being replaced with new one or improved upon. The type of technology applied several years ago is being phased out in recent times due to sophistication in design.

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TIT-BITS ON ELECTRICITY

1.0 INTRODUCTION

In this presentation, the discourse covers four areas, namely "Reminiscences on Electricity Lesson", "Discovery of Electricity" and "Maturity of Electricity into Super Projects".

Engr. Enefiok Ubom, *FNSChE*

2.0 REMINISCENCES ON ELECTRICITY LESSON

The curricula of Physics and Electrical Engineering provide opportunities for lessons on 'Electricity'. Electricity is a wide subject and there is a bit we can share about the exciting days in a Physics class in high school when 'Electricity' was taught. We are treating this under the title 'Reminiscences on Electricity Lesson'.

Modern knowledge of the electronic structure of the atom of elements and the application of the law of conservation of energy paved the way towards understanding the phenomena of electricity and electric current as provided by the following definitions:

i. **Electricity** is a form of energy resulting from the existence of charged particles (such as electrons or protons), either statically as an accumulation of charge or dynamically as a current.

ii. **Electric current:** Electric current is defined as the rate of flow of electrons in a conductor. The SI Unit of electric current is the Ampere.

Understanding electric current paved the way to knowing more about electricity in the context of terms such as ohm, volt, resistance, watt, kilowatt and kilowatt hour.

iii. **Ohm:** Electric current flows in circuits. Circuits are made up of wires and wires are not perfect conductors. Most home electrical wiring is made of copper or aluminum and both of them have a certain amount of natural resistance or friction, which slows down the flow of electricity. When electricity passes through electrical devices and appliances, they also apply their own resistance. Resistance is measured in ohms, which is named after the German physicist and mathematician, Georg Simon Ohm.

iv. **Voltage, Current and Resistance:** The¬ three most basic units in electricity are voltage (V), current (I) and resistance (R). Voltage is measured in volts, current is measured in amperes (amps) and resistance is measured in ohms.

Of all these different units of electricity, wattage is probably the most familiar. Wattage is the amount of power an electric device consumes. Nowadays, most light bulbs which are in use are those with no incandescent filament and are called 'Energy Bulbs'. They are quite bright even at wattage as low as 5 or 10 or 18. They consume less electric power than the old incandescent bulbs. To calculate wattage, you simply multiply voltage by amperage, expressed as V x A = W. Wattage is measured in units called watts and named after James Watt, the Scottish engineer who popularized the steam engine.

v. **Kilowatt and Kilowatt-hour:** The basic unit of electricity is the kilowatt-hour (kWh). In simple terms, 1 kWh is the amount of energy used by a 1kW (1000 watts) electric appliance for 1 hour. This also means 100-watt light bulbs used for 1 hour.

2.0 DISCOVERY OF ELECTRICITY

One may ask the question: How did 'Electricity' start? Electricity was never invented, it is a form of energy which has always existed throughout the universe. It was discovered. The term 'electricity' was coined by William Gilbert, an English Physicist & Physician & Natural Philosopher in 1600 to describe static electricity. There were also two other men, Benjamin Franklin and Michael Faraday who were at the forefront of research in electricity and implementation.

i. **William Gilbert:** After years of experiments, he concluded that a compass needle points north–south and dips downward because the earth acts as a bar magnet. He was the first to use the terms electric attraction, electric force and magnetic pole. He is often considered the father of electrical studies.
SOURCE: https://byjus.com/question-answer/who-invented-electricity/

ii. **Benjamin Franklin:** He coined new terms namely, "positive", "negative", "charge", "conductor" and "battery". He proved that lightning was electrical in nature with his famous experiment in 1752 with a kite and a key. Franklin's experiment demonstrated the connection between lightning

Fig. 1: *Mambilla hydropower project site at Dong River near Mambilla Plateau (Image courtesy: Ebere Jude Ekemezie)*

and electricity. After his successful demonstration, Franklin continued his work with electricity, going on to perfect his lightning rod invention. In 1753, he received the prestigious Copley Medal from the Royal Society in recognition of his "curious experiments and observations on electricity.

iii. **Michael Faraday:** He was the first to produce an electric current from a magnetic field, invented the first electric motor and dynamo, demonstrated the relation between electricity and chemical bonding, discovered the effect of magnetism on light and discovered and named diamagnetism, the peculiar behaviour of certain substances. In 1831, using his "induction ring", Faraday made one of his greatest discoveries - electromagnetic induction: the "induction" or generation of electricity in a wire by means of the electromagnetic effect of a current in another wire. The induction ring was the first electric transformer.

3.0 MATURITY OF ELECTRICITY INTO SUPER PROJECTS

William Gilbert, Benjamin Franklin, Michael Faraday and others not specifically stated in this presentation carried out early studies about electricity and these studies were quite significant in bringing about clear understanding of electrical phenomenon and electricity. Leaning on the understanding gained over the years, electrical engineers of today can execute super projects. Such a project in Nigeria is cited here:

3.1 MAMBILLA HYDRO-ELECTRIC POWER PROJECT

Mambilla hydropower project is a 3.05GW (3.05 million watts) hydro-electric facility being developed on the Dongo River near Baruf in Kakara Village of Taraba State, Nigeria. The project is being undertaken by Nigeria's Federal Ministry of Power.

Mambilla hydroelectric facility will comprise four dams and two underground powerhouses having 12 turbine generator units in total.

The four dams to be constructed on the Dongo River for the Mambilla hydropower project include Nya (formerly known as Gembu), Sumsum, Nghu and Api Weir dams.

Nya and Sumsum will be 100m and 35m-tall roller compacted concrete (RCC) dams with crest length of 515m and 460m, respectively.

Nghu will be a 95m-high rockfill dam with a crest length of 650m, while Api Weir will be a small regulatory dam to raise the water level of the river.

Expected to commence operation in 2030, Mambilla will be Nigeria's biggest power plant, producing approximately 4.7 billion kWh of electricity per year. Within the boundaries of Nigeria, this is a super project fitting the description of Nigeria's biggest power plant. See Fig. 1.

The engineering, procurement and construction (EPC) contract for the Mambilla Hydropower project was awarded to a joint venture between China Gezhouba Group (CGGC), Sinohydro and CGCOC (formerly CGC Overseas Construction), in November 2017. Chinese Export Import (Exim) Bank is funding 85% of the estimated $5.8bn project cost, while the remaining 15% funding will come from the Federal Government of Nigeria.

The power generated by the facility will be transmitted to the national grid by four 500kV DC transmission lines connecting Makrudi and one 330kV DC transmission line connecting Jalingo. Nigerians are waiting eagerly for the timely completion of this project considering the current huge power generation, transmission and distribution gaps in the country.

SOURCE: https://www.nsenergybusiness.com/projects/mambilla-hydropower-project-nigeria/

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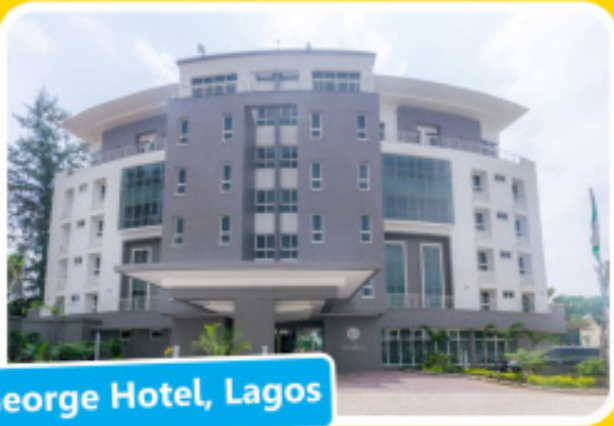

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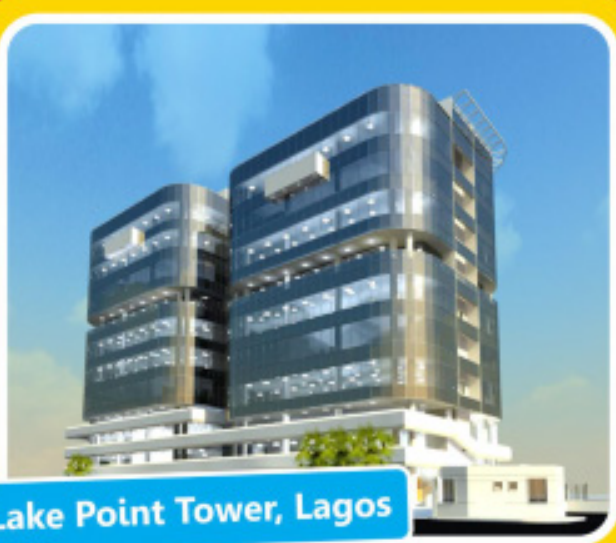

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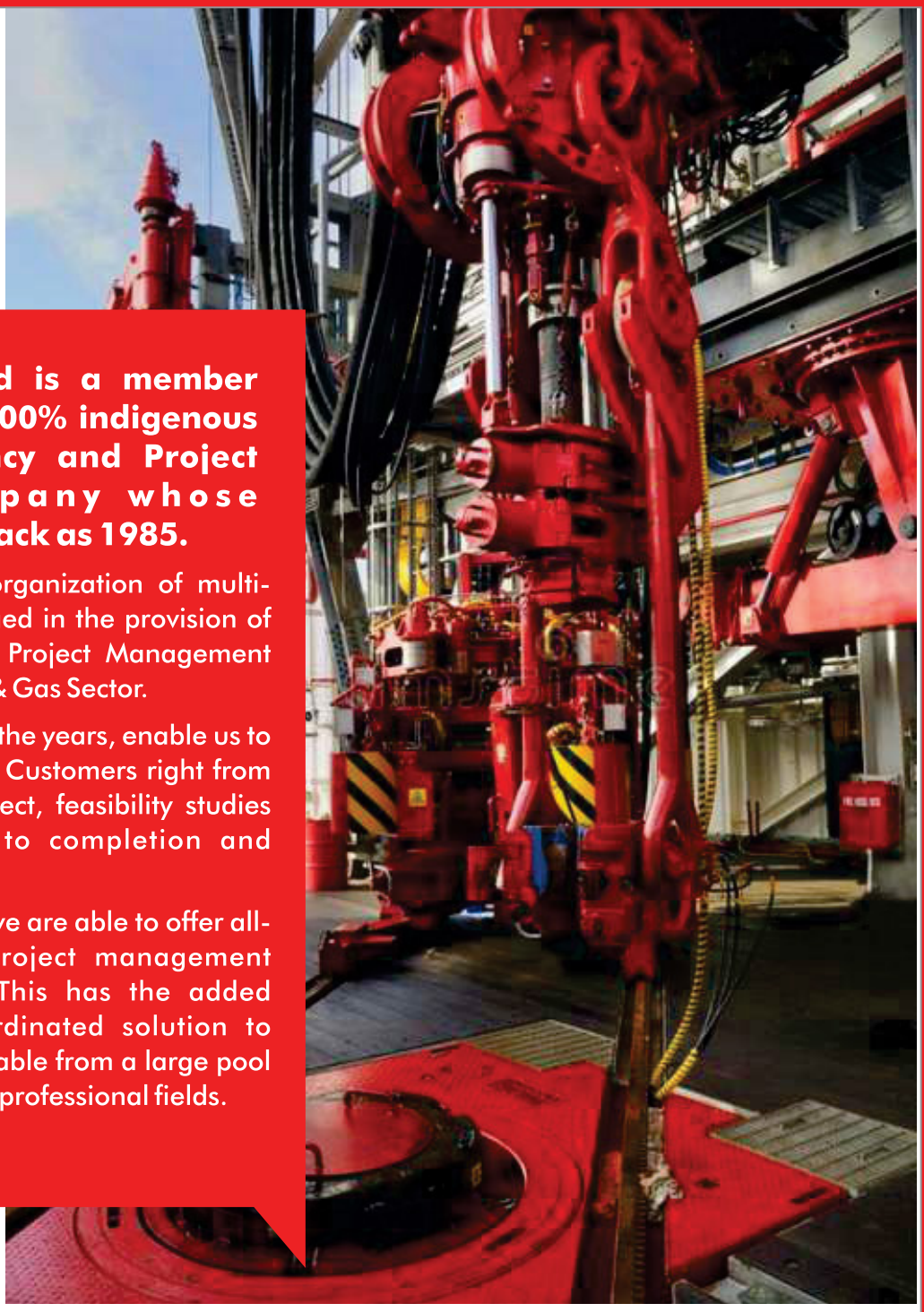

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