Integration of Renewable Energy with Smart Grid Application into the Nigeria's Power Network: Issues, Challenges and Opportunities

Bankole Adebanji, Ayotunde Ojo, Taiwo Fasina, Samson Adeleye, and Julius Abere

Abstract — **Availability of diverse renewable energy sources (RES) in Nigeria makes their large penetration into the electricity supply mix reasonable. The increasing energy demand, and limited fossil fuel resources (with their negative environmental impacts) support the need for energy from RES. The conventional system of centralized power generation can no longer meet up with the growing demand for electrical energy. Hence, the need for a robust decentralized energy system incorporated with computer and automated systems, for information analysis and response to network operations. Smart Grid Technology (SGT) can be used to address some of the issues and challenges inherent in the traditional grid system for efficient and reliable power supply. This work reviewed the current electricity supply status in Nigeria and the existing policies. The existing network was studied and compared with such in some countries. It identified most of the major problems and challenges in the electricity sector and proposed the integration of RES with SGT into the network. Major policy recommendations were made. Some of the barriers that may likely affect the integration of RES with SGT were also discussed. The outcomes are useful for government and renewable energy developers in formulating effective policies for the smooth integration of renewable energy with SGT into the electricity supply mix.**

Keywords — **Electricity supply mix, Network operations, Renewable Energy Sources (RES), Peak load, Smart Grid Technology (SGT).**

I. Introduction

One of the basic requirements for technological and industrial growth for any nation is unrestricted access to modern-day energy services [1]. Electricity serves as the bedrock for the economic growth and development of any nation. It improves the quality of life and the standard of living of its citizens [2].

Electricity supply in the country is generated basically from unsustainable sources, such as large hydro, fossil fuel, and gas thermal stations. Asides from the large hydropower generation, the other sources are major causes of environmental degradation and pollution [3], [4]. Some of the major problems of the power sector in the country are inadequate power generation, outdated long transmission lines, poor communication facilities, electricity theft, outdated metering system, poor maintenance culture, and lack of renewable energy to support peak load [5].

Renewable energy sources (RES) is sustainable and environment-benign with comparatively low maintenance cost [6]. It ensures energy security, climate change mitigation, energy accessibility, and socio-economic development. The country is blessed with abundant RES, such as solar, hydro, biomass, and other resources which can be utilized for effective power generation to close the wide power supply-demand gap. Integration of RES into the grid will indeed increase grid resilience, reduce transmission/distribution losses, lower the cost of generation, and fewer generation requirements for new brand utility capacity [6].

Grid integration, especially in meeting flexibility requirements, serves as an encouragement to investors and operators that more RES penetration can be effectively and reliably managed [7], [8]. However, the stochastic /variability and uncontrollable nature of RES posed a serious challenge for integration into electric power systems [7], [9]. The variable RES like solar and wind are more variable than the conventional sources, hence the need for power system planning and operations [8]. Some of the technical challenges are voltage regulation, harmonic distortions, power quality, protection, and grid system stability depending on whether it is small or large scale integration [7].

Smart technology is an intelligent system capable of closely matching supply with demand while improving efficiency and reliability. Smart grid technology (SGT) is efficient and more cost-effective than the conventional technology for grid upgrades in accommodating more RES for integration or for any other purposes [10]. Some of its advantages are reduction in peak demand, reduction in transmission congestion costs, increased energy efficiency, and the ability to accommodate more renewable energy [7]. Integration of SGT will attract so many benefits to the utilities, consumers, and the communities at large [11]. SGT implementation will make the electricity supply system to be more reliable, efficient, and stable. It is a better way in solving the problem of inefficiency since it is self-healing and frequent power outages will be reduced. The cost-benefit analysis of SGT showed that utilities will make very high

Submitted on March 22, 2022.
Published on May 12, 2022.
Bankole Adebanji, Ekiti State University, Nigeria.
(e-mail: bankole.adebanji@eksu.edu.ng)
A. Ojo, Ekiti State University, Nigeria.
(e-mail: ayotunde.ojo@eksu.edu.ng)
T. Fasina, Ekiti State University, Nigeria.
(e-mail: Emmanuel.fasina@eksu.edu.ng)
S. Adeleye, Ekiti State University, Nigeria.
(e-mail: adedayo.adeleye@eksu.edu.ng)
J. Abere, Ekiti State University, Nigeria.
(e-mail: julius.abere@eksu.edu.ng)

financial savings on smart grid investment. There will be tremendous improvements in the robustness, reliability, and security of the grid. Also, there will be easy detection of Also, there will be easy detection of electricity theft and vandalization of electrical infrastructure will be reduced through effective monitoring.

Consumers will have the opportunity to be involved in the production and control of their own small-scale electricity. Consumers will have the option to determine how and when to use their electricity supply with the introduction of updated information through metered electricity usage. Reduced power outages due to an efficient, reliable, and secured grid will also be of benefit to the consumers. Integration of renewable energy with SGT into the national grid will transform the existing grid into a more efficient and reliable system which will enable the community to enjoy better services. It will indeed solve the problems of intermittent power generation, more RES permits easy operation of so many power producers. The environmental impacts due to fossil fuel generation will be reduced through optimization of flow from generating stations and removal of inefficient resources. Integration of RES with SGT will reduce environmental effects. Even with so many benefits of SGT, less attention has been drawn to the application of SGT to the grid infrastructure in the country. This work intends to consider the usage of SGT on the national grid in order to attract generation and distribution utility investors.

II. Nigeria's Electricity Supply Status: An Overview

Power supply in Nigeria is insufficient, unreliable, and ineffective. Almost half of about 200 million people are yet to be connected to the grid with most of them living in rural areas [9]. The power sector has been unbundled into generation, transmission, and distribution sectors. The reform brought about a series of 18 successor companies: 6 generation companies (Gencos), a national Transmission company (TCN), and 11 distribution companies (Discos). The Gencos are charged with a generation of electricity. Some of the generation companies are partly owned by independent power producers (IPP) and the Federal government. The total installed generation capacity is 13,234 MW. The generation mix is 85% gas and 15% hydro. The available capacity fluctuates between 3000 MW and 6,000 MW due to lack of maintenance, lack of gas, and low head of the hydro and transmission constraints [1]. Most of the generating stations are quite old with some of them operating far below installed capacities. As the population increases the supply-demand gap continues to become wider due to insufficient generation. It is indeed very obvious that the generation is absolutely insufficient to satisfy the over 200 million teeming population [12], [5].

The Transmission Company of Nigeria (TCN) is solely owned by the Federal government. It is primarily charged with the management of the transmission sector. This is made up of two divisions, namely: system operator and market operator. The existing transmitting system is inadequate, weak and majorly radial. The transmission system consists of about 5,523.8 km of 330 kV lines, 6801.49 km of 132 kV lines, 6098 MVA transformer capacity at 330/132 kV, and 8090 MVA transformer capacity at 132/33 kV [13]. The wheeling capacity of TCN is 5500 MW, with a distribution capacity of about 6 GW [14]. The transmission line perpetually come up with high power loss due to too long transmission system, thereby reducing the actual power delivered at the distribution/consumer end.

The distribution sector consists of eleven distribution companies (Discos) spread across all the six geographical zones of the country. Most regions in Nigeria have very poor distribution and marketing networks. Power interruptions and outages occur at the distribution levels without prior notice. The Discos are responsible for electricity distribution to consumers [15]. The distribution system is faced with a very poor voltage profile due to power loss caused by high transmission losses and overloaded transformers. Some of the major problems at the distribution level are overloaded transformers, sub-standard distribution networks, billing discrepancies, electricity thefts, poor customer relations, poor maintenance, vandalization, and the absence of automated control to prevent failure [14], [15].

A. *The Traditional Grid Network*

The traditional grid, as shown in Fig. 1, is a centralized power generation radial network with unidirectional power flow which made it absolutely impossible to accommodate decentralized generators. The traditional grid (which can be adjudged to be reliably fair in some nations and may not be so in others) is experiencing some challenges globally.

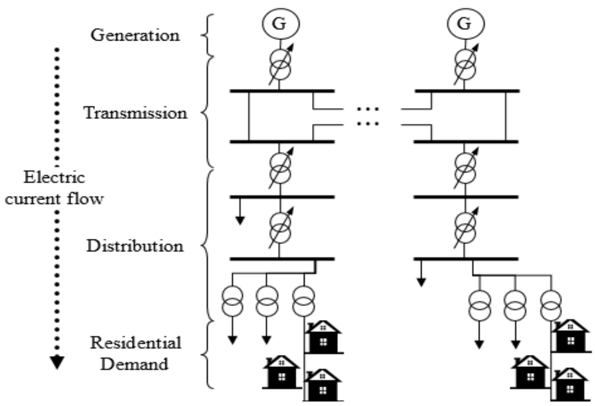

Fig. 1. Traditional grid network [16], [17].

B. *The Future Grid.*

The envisioned future grid (Fig. 2) for Nigeria's power system is a comprehensive review of the current technology on the existing network and the integration of an environment-friendly option like RES. Smart Grid (SG) can be seen as a technology changing the traditional method of meeting electric power demand to a sophisticated environment-friendly and reliable power grid [19]. The future grid is expected to be a paradigm shift from centralized power generations to a decentralized generation. It allows for easy application of SG in terms of reliability, efficiency, cost reduction, and other parameters. The future grid is expected to be a multi-directional change, characterized by SG including RES, multi-directional power flow, and real-time data-based operation. It is expected to be transitive, interactive, and accessible.

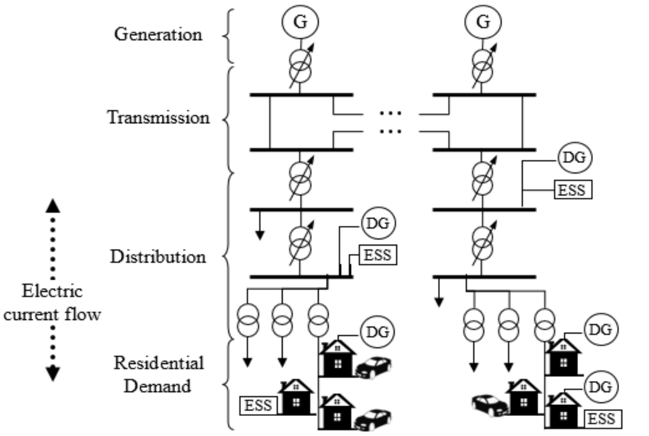

Fig. 2. Future grid network [16], [17].

III. Renewable Energy Development in Nigeria Vis-À-Vis Global Trends

Energy demand in the world today is speedily growing out of the limits of installable generation capacity, which simply means that there should a concrete plan for future energy demands. Energy solutions should be supported by utilizing renewable energy sources [20]. Capacity installations and investments in renewable energy tend to increase and spread to all corners of the world. Distributed renewable energy systems are known to provide households in developing and emerging countries with access to electricity and clean cooking services [22]. From the renewable 2021 global status report, It could be noted that the renewable power capacity in Nigeria in Giga watts is less than 2 (Fig. 3), and about 0.01 renewable power capacity per person if the hydropower is not included (Fig. 4). Comparing the power capacity of Nigeria to other top developed countries shows that the power capacity is relatively small, but the trends indicate an increase in the power capacity annually as shown in Fig. 5.

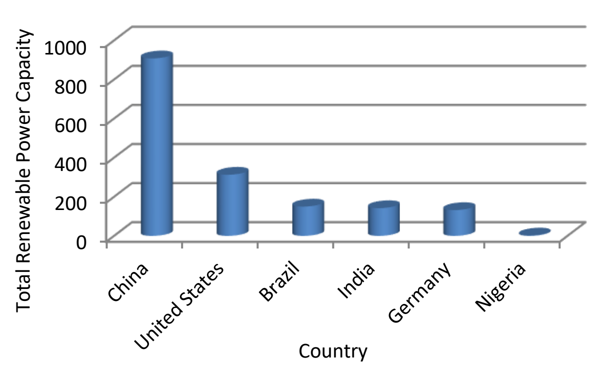

Fig. 3. Renewable power capacity of the top five countries and Nigeria.

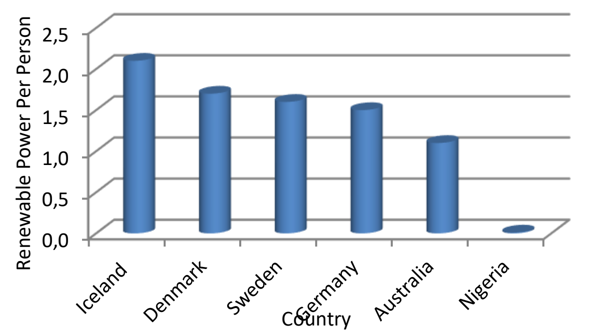

Fig. 4. Renewable power capacity per person of the top five countries and Nigeria.

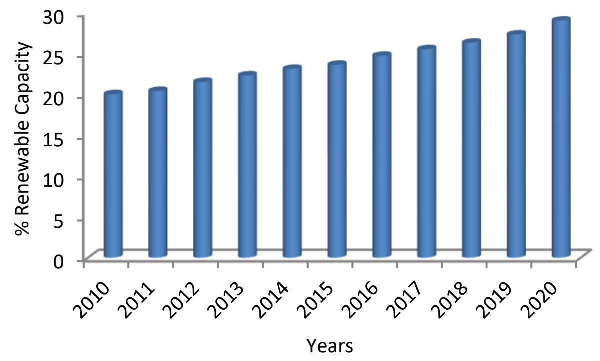

Fig. 5. Trends in percentage renewable electricity from 2010 to 2020.

A. Renewable Energy Growth: Barriers, Issues, and Challenges

There are numerous factors that impede the adoption and development of renewable energy technologies. Politics and governance, technical, social-cultural, financial, and economic, market-related, geographical, and ecological factors are among the most common [22]. All of these factors work together to limit the development and use of renewable energy sources. Adoption of renewable energy technologies (RET) may be hampered by a lack of policies and regulations that encourage the development of these technologies. Because of the nature of its structures, the renewable energy market requires clear policies and legal procedures to encourage investors. Furthermore, regulatory measures such as standards and codes facilitate the wide acceptance of RET by lowering technological and regulatory risks [21].

Inadequate technology and a lack of infrastructure to support the technologies are technical barriers to renewable energy development. People are hesitant to RET adoption because of a lack of trained personnel to train others, demonstrate, maintain, and operate renewable energy structures. In areas with low educational levels, there is a high level of fear of failure [25] Because most renewable energy technologies are imported, they are more expensive in some countries than commonly used non-renewable technologies, such as coal-fired production. Other challenges include socio-cultural barriers and a lack of knowledge and awareness of renewable energy technologies and systems in rural communities [23]. These factors have retarded the rate of development, circulation, and utilization of renewable energy infrastructure and technological know-how. As a result, communities must raise more awareness of RET while also paying close attention to their socio-cultural practices [24]. Initial capital, transaction costs, and the availability of incentives/subsidies are all important factors in determining the rate of adoption of RET. Conventional energy sources, when compared with the initial capital cost of renewable energy is relatively on the high side, thereby raising the renewable energy generation cost [25].

B. Overcoming Renewable Energy's Barriers.

In order to attract foreign investors and to encourage local participation in RET development. There is a need to address some of these problems through gradual implementation of the following recommendations:

i. Legislative support should be made about the price and capital investment in the forms of relief (feed-in-tariff) in cash and kind so that the acquisition price can be brought down as is practiced in Spain and Sweden [28].
ii. Fiscal support can address the financial barriers. These include tax exemptions on imported RET equipment, and tax holidays on power generation through RETs as it's being practiced in some developed countries like Denmark, Sweden, Germany, and Netherlands [26].
iii. There should be more applications of RET for local adoption; for instance, in the use of solar cookers, heaters, water pumps, street light, etc. Local ownership and involvement should be encouraged.
iv. The creation of a renewable legal and regulatory framework is essential. The government can set up national targets as was done in the case of New Zealand, Austria, Denmark [39].
v. Research and Development supports for RETs should be institutionalized. Technological and environmental concerns should be integrated into the national/state/local (government) energy development plans.

Policy formulation should be in form of collaboration between power service providers and all other stakeholders including consumers at the local level in order to remove barriers hindering RES integration. Policy should focus on more ways of reducing deforestation and encouraging small hydropower and other RES. Investment in energy by citizens will surely enhance long-term economic benefits [27], [28].

IV. Smart Grid Technology (SGT) Concept

The global shift towards Smart Grid Technology (SGT) and associated applications are a result of continued improvement in its technology. This has been triggered by the zeal to reduce the use of fossil fuels due to its detrimental effects. This has been iterated in several international policies and treaties including the Paris Agreement of 2015, Kyoto Protocol of 1997, and the United Nations Framework Convention on Climate Change (UNFCCC) of 1992. In addition to the concerns over exhaustion of conventional energy sources, improvements in efficiency, and reduction in the cost of utilities amongst others are being explored. This is very glaring in the areas of research and development (R&D), and the deployment of the attributed technologies to the field. SGT serves as an alternative platform to be explored with great potential yet to be fully developed.

A. Comparative Study of Smart Grid Technology (SGT) Application of some Selected Developed Countries

Smart grid technology opens up avenues for other meter and metering technologies to thrive, as it serves as a baseline for others. Its deployment is vital in the implementation of other ultramodern energy-efficient technologies. The deployment of SGT ushered in many associated technologies such as Smart meter (SM), and Automated Meter Reading, and Vehicle grid (V2G) and Plug-in hybrid electric vehicle technology (PHEV).

B. Smart Meter (SM) and Automated Meter Reading

The smart meter (SM) is equipped with the ability to measure the consumption of electric energy including the voltage, current, and power factor. The obtained data can be read/displayed both onsite and/or remotely. As shown in Table I, European countries such as Sweden have deployed 100% of their smart meter capacity. Sweden is a matured energy market with well-informed customers concerned about the environment [29]. A move to improve and deploy 2nd generation of smart meters on the entirety of their smart grid has been reported in the literature [29]. The USA and China respectively are on 75% and 69% smart grid installation capacity, respectively, even with their technological capacities [30], [31]. The gradual implementation can be ascribed to the willingness of the people to change, lack of popularization, and gradual change in policy to attract incentives and benefits.

C. Vehicle to Grid (V2G) and Plug-in Hybrid Electric Vehicle Technology (PHEV)

This technology integrates electric and hybrid electric vehicles into the smart grid system. The power generated in the V2G through electric-drive vehicles is targeted at particular energy (electric) market. This serves as an alternative to the known conventional energy sources. Also, it promotes energy mix with renewable energy sources and balances the electricity demand in the power system. Although there is no clear-cut analyzed data to differentiate the per capita market share of the V2G and PHEV systems for distinctive countries, the generalized data show prospects due to rapid research advancement and product deployment into the market [32]. Literature has it that, Europe has the biggest share of 45%, followed by Asia-Pacific and North

TABLE I: Comparison of Smart Grid Technologies in Selected Countries

Technology development	Sweden	USA	China	Nigeria
Type of grid	Smart grid	Traditional and Smart grid combination	Traditional and Smart grid combination	Traditional grid
Smart meters deployment	100%	75%	69%	0%
Automated meter reading - Communication Unit - Data receiving and Processing Unit - Billing System	Deployed - Electricity - Water - Gas	Deployed - Electricity - Water - Gas	Deployed - Electricity - Water - Gas	N/A
Vehicle to Grid (V2G)	Deployed R&D continued	Deployed R&D continued	Deployed R&D continued	N/A
Motivation	- Renewable energy, - improved services and - energy efficiency	- Renewable energy, - Enabling infrastructure, and - improved energy efficiency	- Renewable energy, - development of the power grid state - energy efficiency	- Ineffective traditional grid

Sources: [29]-[32].

America having a total share of about 50 percent [40]. Asides from the R&D facets of the sampled countries, there are interconnection policies and other financial incentives to promote renewables and connect them to the electric grid, though the degree and type of support vary [32].

D. Smart Grid with Renewable Energy Integration into Nigeria's Power Network

RES integration into the grid is a way of developing efficient ways of meeting national electrical power demand. Good integration maximizes the cost, ensures effective variable integration of renewable energy into the power system while maintaining system stability and reliability. Some of the factors that may affect its implementation are low generating capacity, power maintenance of existing infrastructure, and vandalism of transmission distribution equipment.

The main constraints on the smart grid computational development are as stated below [38]:

i. Complex operation and control of power system.
ii. Lack of user-friendly computational tools.
iii. High penetration of renewable energy sources (RES).
iv. Power system models depend highly on intelligent operation and control.
v. Predictions of loading price, demand, and other related services without provision of economic goals.

Despite so many benefits of the smart grid on power system operations, there are some challenges or barriers in smart grid implementation. Some of the challenges can be classified as technical, social, and economic challenges [33].

E. Technical Challenges

Some of the challenges or barriers posed in the integration of several devices with the grid network are lack of enough grid infrastructure, storage, unidirectional network, power flow, stability concerns, and poor data privacy. The current grid network is not adequate enough to accommodate the integration of RES and other distributed generation which may indeed pose other challenges in design, operation, and maintenance [33]. The variability or stochastic nature of some RES like solar, wind, etc. which may be incorporated in smart grid technology may demand storage technologies. The most common storage devices, battery, has a relatively short life span of 4-5 years. Some other storage facilities like pumped storage, flywheels, hydrogen storage, and thermal storage have one setback or the other.

The current network is based on unidirectional power flow, whereas the smart grid is based on bidirectional power flow, allowing for multi-stakeholder interactions. Some communication technologies used in smart grid deployment have their own limitations. Furthermore, smart grid communication protocols are not well defined. Optical fiber is safe and fast, but it is prohibitively expensive. Although RES has several advantages over conventional and nuclear energy sources, high RES and MGS penetration would raise stability concerns. Smart grids are expected to include DG (RES) and micro-grids on a large scale (MGS). The DG is what causes bidirectional power flow. The integration of SGT into the grid increases the vulnerability of electricity infrastructure to malicious attacks from software hackers as it transitions from analog to digital communication. It is preferable to discover such flaws before a security breach occurs.

F. Social Constraints

When there is insufficient awareness among stakeholders, new technology may face setbacks. To improve the effectiveness of any project's implementation, it is necessary to involve investors and users from the program's inception. The benefits of these technologies must be properly educated to the stakeholders. Other challenges, in addition to a lack of awareness, include a lack of relevant operational guidelines, a lack of privacy, and a fear of arbitrary price increases [37]. Although there are numerous opportunities for investment in smart grid and renewable energy in Nigeria, the current level of insecurity is a major deterrent to foreign investment.

G. Economic Challenge.

The high capital costs associated with smart grid application in Nigeria may be a major determinant of its acceptance, particularly at the local level. To overcome this obstacle, access to low-interest or interest-free loans should be made available.

H. Registrations and other Miscellaneous Challenges

Aside from the technical and socioeconomic challenges, stakeholders must be aware of the legal and regulatory frameworks that govern new technology. New technologies, such as smart grid integration, should be accompanied by regulations and policies that encourage stakeholders to take an active role. The policy should take into account equal cost/risk sharing among stakeholders, incentives for smart grid promotion, and well-defined roadmaps and standards [34]-[36]. Other challenges in this section include power theft, a lack of a dedicated and specialized workforce, ineffective coordination, and so on.

Many of the opportunities presented by smart grid development can be classified as local, national, or global. Integrated communications, advanced control methods, sensing and measurement technologies, and advanced components are examples of local opportunities. Integrated communications-enabled open architecture and interaction while sensing and measurement technologies enabled accurate and faster response. Opportunities for regional and national levels include features such as resist-attack and self-healing, provision of higher quality power that will save money lost on outages, motivating consumers to actively participate in good operations, and accommodating all generated energy storage options. Global energy challenges, both policy and technical in nature, would necessitate efficient analyses in order for smart grid technology to function.

V. CONCLUSION

The current energy policies and regulations need to be reviewed urgently in order to provide incentives for capital investments and motivation for SGT integration on the national grid. This paper identified most of the major problems and challenges in the electricity sector and proposed a solution for integrating RES with SGT into the network. Some of the potential barriers to integrating RES with SGT were discussed. The existing traditional centralized power grid is incapable of meeting the world's ever-increasing demand for electrical energy. As a result, a decentralized multi-directional power flow smart grid technology is required (SGT). Before a project is fully implemented, stakeholders at different levels should make substantial research funds available for prototypes and demonstrations of smart grid projects. The findings will be extremely beneficial to governments at all levels and renewable energy developers in developing effective policies for the smooth integration of renewable energy with SGT into the grid.

REFERENCES

[1] Adebanji B., Adepoju G.A., Olulope P.K., Fasina E.T. and Adetan O. Feasibility and optimal design of a hybrid power system for rural electrification for a small village in Nigeria. *International Journal of Electrical and Computer Engineering*, 2020;10:6214-6224.

[2] Adepoju G.A. and Adebanji B. Feasibility and optimal design of small hydropower-solar-photovoltaic-diesel-generator hybrid power system for Itapaji – Ekiti state, Nigeria. *Science Domain International, Journal of Scientific Research and* Reports, 2017;11(2):1-10.

[3] Adebanji B., Adepoju G.A., Ojo J.O. and Olulope P. K. Optimal sizing of an independent hybrid small hydro-photovoltaic–battery-diesel generator hybrid power system for a distant village. *International Journal of Scientific and Technology Research*, 2017;6(8):208-213.

[4] Ojo A.A., Awogbemi O. and Ojo O.A. An overview of the exploitation of renewable energy resources in Nigeria, South Africa and the United Kingdom. *International Journal of Renewable Energy Research*, June 2020;10(2):843-860.

[5] Fasina T., Adebanji B., Abe A. and Ismail I. Impact of distributed generation on Nigerian power network. *International Journal of Electrical Engineering and Computer Science, IJEECS*, March 2021; 9(4):3041-3050.

[6] Alshahrari A., Omer S., Su Y., Mohammed E., and Alotaibi S. The technical challenges facing the integration of small-scale and large scale PV system into the Grid: a critical review. *Electronics*, 2019; 8: 1-28.

[7] Awodiji O.O. and Folly K.A. Impacts of wind farm integration on electricity production. *South African Universities Power Engineering Conference, SAUPEC*, 2017 Stellenbosch University, January 30-February 1, 2017.

[8] Barau A.S., Abubakar A.H., and Kiyowa A.I. Not there yet: mapping inhibitors to solar energy utilization by households in African Informal Urban Neighbourhoods. *Journal of Sustainability*, 2020;12:2-14.

[9] Adebanji B., Atoki O., Fasina T., Abe A., and Adetan O. Comparative study of off-grid and grid-connected hybrid power system: issues, future prospects and policy framework. *Indonesian Journal of Electrical Engineering and Computer Science (IJEECS*), 2021;22(2):144-151.

[10] Ekpenyong E.E. and Anyasi F.I. Integration of solar electricity into national grid: case study of Nigeria. The need for energy review. *International Research Journal of Engineering and Technology*, 2018;5(3):1285-1290.

[11] Dada O.J. Towards understanding the benefits and challenges of smart/Micro-grid for electricity supply system in Nigeria. *Renewable and sustainable Energy Reviews, Else view*, 2014;38:1003-1014.

[12] Atoki O.D., Adebanji B., Adegbemile A., Fasina E.T. and Akindele O.D. Sustainable energy growth in Nigeria: The role of grid-connected hybrid power system. *International Journal of Scientific and Technology Research*, 2020;9(9):274-281.

[13] Okafor F.N. Improving electric power sector performance: the role of nigeria electricity regulatory commission. *Nigerian Academy of Engineering 2017 Public Lecture* held on March 29, 2017 at University of Lagos, Akoka, and Lagos, Nigeria.

[14] Sambo A.S. Energy crisis in Nigeria: engineers' protective steps towards energy self sufficiency. *Lecture as the first in the series of the distinguished lectures in honor of Engr. Dr. E.J. S. Uujamban* at the university of Benin, Benin City, 6 April, 2018;1-27.

[15] Abaniki V.K., Ikheloa S.O., Okodele F. Overview of the Nigerian power sector. *American Journal of Engineering Research*,2018; 7:253-263.

[16] Papadopoulos P, Jenkins N, Cipcigan LM and Grau I. Distribution networks with electric vehicles. *44th International Universities Power Engineering Conference, (UPEC)*, September 2009;1-4.

[17] Fasina E.T., Hassan A.S., Cipcigan L.M. Impact of localised energy resources on electric power distribution systems. *International Universities Power Engineering Conference, (UPEC 2015)*, Stoke on Trent, United Kingdom 2015;456-461.

[18] Fasina E.T., Oliyide R.O., and Cipcigan L.M. Localised energy systems in Nigerian power networks. *IEEE 15th International Conference on Industrial Informatics INDI' 2017* July 2017. Emden, Germany

[19] Salkuli S.R. Challenges, issues and opportunities for the development of smart grid. *International Journal of Electrical and Computer Engineering, IJECE*, April, 2019;10(2):2279-1186.

[20] Dogan B., Driha O.M., Lorente D.B., and Shahzad U. The mitigating effects of economic complexity and renewable energy on carbon emissions in developed countries. *Sustainable Development*, 2021;29(1):1-12; https://doi.org/10.1002/sd.2125.

[21] Erdogan S., Okumus I., and Guzel A.E. Revisiting the environmental Kuznets curve hypothesis in OECD countries: The role of renewable, non-renewable energy, and oil prices. *Environmental Science and Pollution Research*, 2020;27(19):23655-23663.
Khan A.G., Hossain M.A., and Chen S. Do financial development, trade openness, economic development, and energy consumption affect carbon emissions for an emerging country? *Environmental Science and Pollution Research*. 2021; 28(19):1-11.https://doi.org/10.1007/s11356-021-13339.

[22] Li J., Zhang X., Ali S., and Khan Z. Eco-innovation and energy productivity: new determinants of renewable energy consumption. *Journal of Environmental Management*, 2020; 50-59 111028. https://doi.org/10.1016/j.jenvman.2020.111028.

[23] Fagbohun O.O. and Adebanji B. Integrated renewable energy sources for decentralized systems in developing countries. *IOSR International Journal of Electrical and Electronic Engineering (IOSR-JEE)*, 2014;9(5):26-35.

[24] Ansari M.F., Kharb R.K., Luthra S., Shimmi S.L., Chatterji S. Analysis of barriers to implement solar power installations in India using interpretive structural modeling technique. Renew. *Sustain. Energy Rev*. 2016;27:163-174.

[25] Emodi E.D., Ebele N.E. Policies promoting renewable energy development and implications for Nigeria. *British Journal of environment and Climate Change*, 2016; 6:1-18.

[26] Braun G.D. State policies for collaborate local renewable integration, *Electricity journal*, 2020;33:1-9.

[27] Oyedepo S.O., Babalola O. P., Nwaiya S. C., and Kilanko O. Towards a sustainable electricity supply in Nigeria: The role of decentralized renewable energy sector. *European Journal of Sustainable development research*, 2018:1-31.

[28] Alvarez O., Ghanbari A., Markendahl J. A comparative study of Smart Grid development in developed and developing countries.In: *7th Annu. C. Conf*., Copenhagen, 2014.

[29] Cooper A. and Shuster M. *Electric Company Smart Meter Deployments: Foundation for a Smart Grid*, Washington, D.C., 2021. https://www.edisonfoundation.net//media/Files/IEI/publications/IEI_Smart_Meter_Report_April_2021.ashx#:~:text=As of year- end 2019,expected by year-end 2021.

[30] Nhede N. *More than 570 million smart electricity meters to be deployed in Asia, Smart Energy Int*. https://www.smart-energy.com/industry-sectors/smart-meters/smart-electricity-meters-rollout-in-china-india-japan-and-south-korea/ (accessed August 29, 2021).

[31] Koenigs C., Suri M., Kreiter A., Elling C., Eagles J., Peterson T., Stephens J., Wilson E. A Smarter Grid for renewable energy: different states of action. *Challenges*. 2013:4:217-233. doi:10.3390/challe4020217.

[32] Kappagantu R. and Daniel S.A. Challenges and issues of smart grid implementation: a case of Indian scenario. *Journal of Electrical system and Information Technology*, Feb.2018;5:453-467.

[33] Dauda A.F., Japheth D.S., Edwin M. and Mandu A.E. Smart grid (SG) technology and implementation challenges in Nigeria electricity power grid systems. *International Journal of Engineering Technology and Research*, April, 2017;4:71-79.

[34] Dileep G. A survey on Smart grid technologies and applications. *Renewable energy*, August, 2020;2589- 2625.

[35] Reddy S.S. Optimization of Railroad Electrical Systems with the Integrated Smart Grid. *International Journal of Applied Engineering Research*, April, 2017;12(6):1027-1030.

[36] Vendoti S., Mralidhan M. and Kiranmayi R. Modeling and Optimization of an off -grid hybrid renewable energy system for electrification in a rural area. *Energy Reports*, 2020:6:594-604.

[37] Jung C.M., Ray P., and Salkili S.R. Asset Management and maintenance: a smart grid perspective. *IJECE*, October, 2019;9(5):3391-3398.
[38] Oyedepo S.O. Towards achieving energy for sustainable development in Nigeria. *Renewable Energy Reviews*, 2014;34:255-272.
[39] More A. *Vehicle-to-Grid (V2G) Market Size In 2021* : Top Countries Dataw-ExpressWire.(2021). https://www.rfdtv.com/story/44533092/vehicle-to-grid-v2g-market-size-in-2021-top-countries-data-with-730-cagr-global-industry-brief-analysis-by-top-key-companies-and-growth-insights-to (accessed August 29, 2021).