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Energy Growth and Sustainability Through Smart Grid Approach: a Case Study of the Nigeria Electric Grid

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Abstract – *Over the last few years, energy growth and sustainability in Nigeria have suffered many difficulties resulting to inadequacy in the country's power supply. Numerous solutions proffered by industry experts and energy reforms by the Nigerian government have brought little or no improvement in the energy sector including the unbundling of the nation's major power company (Power Holding Company of Nigeria, PHCN). The nation's poor power supply resulting from outdated and unmaintained transmission and distribution facilities, inadequate power generation coupled with decrepit metering system used by consumers have immeasurably affected the nation's economic development. This paper aims at introducing smart grids and distributed generation approaches as the potential and viable solutions to solve Nigeria's poor power generation, transmission, and distribution issues. The smart grid technology transforms the nation's traditional grid technology in order to achieve improved efficiency and reliability by incorporating new communication technologies, which have been lacking in the Nigerian power system. In this paper, the Nigerian energy sector is also examined and the benefits of smart grids to the sector are presented. The current situation of Nigeria in terms of smart grid implementation is also assessed and discussed while its challenges and recommendations are documented. However, it is concluded that in modernizing the current grid and considering the potentials of smart grid, numerous benefits can be achieved and the power supplied to consumers will be significantly improved.*

Keywords*: Smart Grid, Energy, Sustainability, Nigeria, Renewable Energy Sources*

Nomenclature

GDP	Gross Domestic Product
NESI	Nigeria Energy Supply Industry
ANM	Active Network Management
RES	Renewable Energy Sources
DG	Distributed Generation
NERC	National Electricity Regulation Commission
AMI	Advance Metering Infrastructure
ECIA	Environmental Control & Inspection Agency
FGN	Federal Government of Nigeria
PHCN	Power Holding Company of Nigeria
EV	Electric Vehicles
V2G	Vehicle-to-Grid
DER	Distributed Energy Resources
NNPC	Nigeria National Petroleum Cooperation

I. Introduction

The development, the progress, and the economic growth of every country around the world are largely dependent on the energy sector. As much as it helps to alleviate poverty, it also assists in enormous job creation and massive industrialization. Energy is considered as a key driver of all the sections of a country's economy since the growth in an economy is a function of how much energy is available from sources that are cost-effective, environmentally friendly, and accessible.

A country's standard of living can be squarely linked to the per capita of its energy consumption. The per capita energy consumed is the actual measure of the per capita GDP of the country in addition to the measure of its prosperity [1]. Erratic energy supply is still a critical and key issue for most countries in this modern day especially in Africa. It is estimated that about 600 million people in sub-Saharan Africa are still without access to electricity, and this figure contributes to more than two thirds of the global total with five countries contributing to about half of that number. These countries are Tanzania, Ethiopia, DR Congo, Uganda, and Nigeria [2].

Nigeria is a country with a population of over 200 million people, and abundantly endowed and gifted with many energy resources including coal, oil, natural gas, wind, solar, biomass and so on. Despite the natural endowment, the country still suffers from severe power crisis and energy challenges. According to the World Energy Council, Nigeria is ranked 106th in the global energy trilemma index and it is estimated that about 40 million of the country's population do not have access to electricity. An earlier investigation into this dilemma reveals that the energy space in Nigeria is plagued with poor energy conversion and conservation coupled with ineffective utilization and management and this has resulted to the under development of the sector [3]. The

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energy issues in Nigeria have been lingering for more than two decades and it is seen to be a major and contributing factor to the rise in poverty levels thereby grounding most industrial and commercial activities. It has been reported by the Council for Renewable Energy in Nigeria that about US$ 985 million (376 billion naira) is lost yearly due to the constant power outages [4].

Outside this colossal economic income loss, there have also been an increased in carbon emissions emanating from "generators" which serves an alternative source of power supply resulting to severe health hazards, deteriorating living conditions and high cost of living. In a broad sense, Nigeria is highly dependent on fossil fuel for energy generation, which is not enough to meet the needs of the country. However, there is a strong need to diversify into various renewable energy resources in order to harness more energy and create an energy future for the country. This means that the government will have to play a very huge role in ensuring that renewable energy is available for the masses. The reform activities that might aid the energy sector also need to be discussed by the government and appropriate stakeholders while necessary recommendations should be made taking clues from countries that have achieved a successful energy transition.

II. Literature Review

In the recent past, there have been several indigenous researches focused on the availability of renewable energy and its sustainability and how the energy output of the country can be increased. In [5], the authors have explored the potentials of sustainable sources of power supply via solar energy. It has been analyzed that every year, there is an average daily solar energy of about 5.25 kWh/m^2/day, with 3.5 kWh/m^2/day around the coastal areas of Nigeria and 7 kWh/m^2/day around the Northern part of the country. With an estimated 6.5 hours of sunshine over the country, there is an average of 1,934.5 kWh/m^2/year solar energy intensity giving rise to an average of 6,372,613 PJ/year of solar energy descending on the energy land mass of the country. This figure is 120,000 times more than the total annual average of electrical energy generated by the country power company, the Power Holding Company of Nigeria (PHCN). In [6], the authors have conducted a statistical analysis on the potentials of wind energy sources in the Northern part of Nigeria. Using Weibull distribution, a 10-year data has been obtained from Maiduguri in Borno State. A cost benefit analysis has been also carried out and it has been seen that there is much wind energy to be harvested for the production of electricity especially in the core northern states, the mountainous part of the central and eastern states and the offshore parts of the country, where wind is abundant all through the year.

While the authors in [7] have explored the wind energy potential by measuring wind speeds in Nigeria from Port Harcourt (2.32 m/s) to Sokoto (3.89 m/s) for blade design, the authors in [8] have tried to access the factors that might affect the choices of setting up a wind power system in various parts of Nigeria. Ebhota et al., in [9], have outlined the sectors that consume the most energy in Nigeria. The authors have gone further in order to investigate the national energy demand and consumption dynamics of the country. The population of the country is also interconnected to most sectors in the country and it has been concluded that the power supply relies heavily on the handling of power generation, efficient power transmission, and distribution, domestic power equipment manufacturing infrastructure, population growth management, and power infrastructural development coupled with enabling policies for power sector investments. [10] has provided an overview of the Nigeria power sector and the challenges it faces. It has also analyzed the current electrification rates in the different geopolitical zones of the country and has proposed an off-grid solar PV in the Northern part of Nigeria in order to boost the electricity access in the country. The work has also gone further to establish the relative successes of rural electrification programs in countries like Kenya, Chile and Peru while drawing the lessons learnt from these countries to make recommendations regarding rural electrification through off-grid development. While trying to appraise the unresolved issues lingering around the power sector in Nigeria, the authors in [11] have evaluated the issues hindering the positive delivery of stable power supply and smooth operation of the energy sector. Their study has explored secondary data sources and system theory as the supporting framework. The work has revealed that capital investment, technical losses, enabling environment, politicization of the power and energy sector, high debt profile, and the national grid system are amongst the challenges preventing the actualization of the reformed objectives. However, the work has recommended a holistic liberalization of the sector, metering of customers and comprehensive economic management are viable solutions in order to reduce the poverty level of citizens relating to the power sector.

The pathway available for Nigeria to meet its 2030 electricity access has been critically examined and identified in [12]. With the aid of the published data and stakeholder's interviews, the authors have built three potential scenarios for electrification and growth in demand, generation, and transmission capacity. The demand assumption has also incorporated existing knowledge on pathways for electrification with the aid of grid extension and solar home systems. The results from this work have revealed that, in the most ambitious Green Transition scenario, Nigeria meets its electricity access goals but renewable energy goals are not fully achieved and back up generation will continue to play a substantial role to keep up with the growing demand.

The authors in [13] have studied and examined the problems ravaging the electricity sector and the energy potential of green energy resources in Nigeria. The study has revealed that the major source of electricity generation in the country, which is natural gas, and the method of transmission that is currently in use have been serious contributors to the myriad of challenges the country is facing. The studies have also gone further in order to reveal that a total of 1182.375 GWh of energy can be achieved from green energy sources in Nigeria per day. This amount of energy can be obtained through decentralized off-grid energy solutions. However, the authors have recommended that the Nigerian government should be more pragmatic in diversifying the country's electricity supply mix by creating policies that favours other energy solutions and majorly investing in off-grid green electricity solutions. Based on secondary data sources, [14] has presented a descriptive and analytic clarification of issues associated to power sharing which is seen as a vital impediment to the poor electricity generation, transmission and distribution in Nigeria. The paper has also evaluated the implications of autonomous handling of power by the Federal Government of Nigeria (FGN). It has been observed that only FGN owns the exclusive rights to electricity transmission in Nigeria and this singular policy negates sustainable electric power supply in the country. However, the authors have recommended that the devolution of powers would significantly boost the energy sector and other sectors of the country's economy. The growth and the challenges involved in the gas power plant sector of Nigeria have been identified in [15]. The work has analyzed the gas production and consumption rate data and the volume of export and demand during certain times in the country. A variation and a fluctuation have been observed in the production and consumption of gas in the country and this has been attributed to several challenges including insecurity and corruption. From the studies carried out in this work, it has been also observed that gas has been exported from Nigeria to other countries while the local demand has increased drastically. Solutions have also been proffered on how gas production and utilization can be effective in order to improve the power generation in the country. In the research work in [16], the authors have undertaken a comprehensive review on the factors responsible for the low power generation in Nigeria. The research has revealed that the major challenges confronting power generation in Nigeria are poor plant maintenance, obsolete equipment, and pipeline vandalization. In curbing these challenges, the authors have proposed that energy mix, structured maintenance methodology, corruption elimination, and adequate funding are possible solutions to the issues of poor power generation in the country. In a bid to enhance the electric power generation in Nigeria, the authors in [17] have employed the renewable energy mix method. They have proposed the use of wind, solar and small hydro renewable energies as a way to improve the electricity generation capacity in the country. When the analysis of the capacities of the proposed renewable energy mix has been carried out, it has been showed that an additional total of 26,298.8 MW of power can be added to the existing power generation. This is presumed to act positively on the socio-economic development and energy security in the country. Another paper, [18], has presented a general overview, potentials, and possible integration of Nigeria's renewable energy for power generation and it has evaluated the energy sector policies and reforms. The authors have gone further to highlight the research trends on renewable energy hybridization for power generation, the major renewable power systems project and the main drivers and challenges of renewable energy utilization to meet the energy demands in the country. From the findings of the research, it has been revealed that there is abundance of renewable energy resources in Nigeria. It has been further revealed that when these resources are harnessed, there will be about 1,182.4 GWh of additional energy available per day. The authors have finally concluded that renewable energy mix should be extended and deployed in various municipal and industrial areas of the country in order to boost power generation. Lastly, in [19], the authors have used artificial neural network technique in order to solve fault detection on a 132 kV transmission line on the Nigeria power system. The aim of the research has been to boost and ensure steady power supply in the country by creating a controllable fault recognition process for the Uyo-Eket transmission line. Although there have been quite some meaningful works done in providing alternative sources of energy in the Nigerian context, only a very few have considered smart grid as a promising solution to the plaguing issues in the Nigerian power sector. In this work, the potential benefits in employing smart grid in the Nigerian Energy sector, the present situation of Nigeria regarding this technology and the challenges regarding its implementation will be identified. This paper will be the first of its kind to propose such technology to the country's energy sector.

The structure of the paper is organized as follows. Section III studies the concept of smart grid. Section IV evaluates the Nigerian energy sector as it relates to infrastructures and strategies. Section V focuses on the benefits of smart grids to the Nigerian energy sector. The current state of smart grid development in the country is examined in section VI while challenges and recommendations are documented in section VII. Section VIII concludes the paper.

III. Concept of Smart Grids

The traditional power grid is considered as a power generation network that is centrally controlled and distributed over a large geographical area comprising of various systems and devices that lack any sort of automation. However, this conventional electricity grid is faced with many challenges including power quality issues, increasing demand in electricity supply, reliability, and security of the grid, outdated infrastructure amongst others [20]. The availability of new advanced digital technologies has transformed this conventional grid into a more sustainable grid that is energy efficient making it much smarter and reliable thereby evolving from a static design into a more dynamic one. Advanced technologies and ubiquitous computing have also transformed this traditional grid from a system with which the producer centrally controls the network to a smarter and intelligent, customer interactive electrical power system as it relates to power generation, transmission, distribution and billing, which is known as smart grid [21]. Lately, smart grid has been regarded as the next generation of power grid since it can establish a link between consumers of electricity and its suppliers. Smart grids employ a two-way communicative flow of electricity and information to produce an intelligent, distributed, and automated advanced energy delivery network. Smart grids possess the capability of combining power generation, transmission and distribution systems together with power utilization and scheduling into one smart and intelligent network. Smart meters, intelligent appliances sensors, Electric Vehicles (EVs) and other smart devices are all interconnected in a typical smart grid network in order to deliver real-time information that is crucial for control, grid management, as well as demand response management. One of the main objectives of SGs is to make available an ideal amount of information and load control to users, distributors as well as grid operators in order to decrease system demands and cost while increasing energy efficiency. The deployment and the introduction of renewable energy systems is very adaptable to SGs since it promotes social benefits like lower energy cost, greater flexibility and reduced emissions as seen in the Figure 1.

A major characteristic of smart grid is the Active Network Management (ANM) it possesses, which has emerged as an ideal solution for the operation and connection of Distributed Generation (DG). It has a good efficiency in terms of network development for connecting increased levels of Renewable Energy Systems (RES) and DG [22]. In a typical smart grid system, energy can be put back into the grid by users.

This means that users can generate their own electricity utilizing various sources like a solar panel at home and it can be fed back into the grid. Smart vehicles can also provide power to assist in load balancing by "peak shaving" (transferring power into the grid in a case when there is high demand).

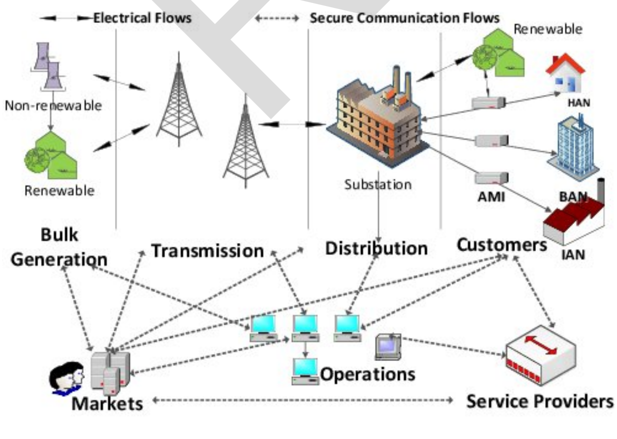

Fig. 1. Conceptual model of smart grid [24]

This back flow of energy is vital and can be extremely relevant in microgrid situations [23], where a microgrid has been "islanded" because of power failure. However, the microgrid can operate even at a reduced level with the aid of the energy put back into the grid by customers.

IV. The Nigerian Energy Sector – Infrastructures and Strategies

In relation to energy, Nigeria stands out as an energy giant in Africa. The country has petroleum as its main source of energy, which was discovered around the late 1800s.

Nigeria is one of the continent's biggest oil producing country and alongside with Libya and both countries account for about 67% of Africa's crude oil reserves and Nigeria is ranked second to Algeria in terms of Natural gas production [25]. The country has an estimated oil reserve of nearly 36.2 billion barrels and proven reserves of about 5,000 billion m^3 around the Bight of Bonny, Niger-Delta, and Gulf of Guinea areas.

It is ranked sixth on the list of the world's largest reserve of crude oil.

The country is also rich in coal and lignite with reserves of over 2 billion tons. Its biomass resources are huge enough to satisfy both conventional and modern uses as well as electricity generation [26]. Nigeria's energy reserves and its potentials are depicted in Table I where there has been an enormous gap in the demand and supply due to poor development and mismanagement in the energy sector. It is worthy of note that the electricity supply, which is Nigeria's most utilized energy resource, has been unstable and erratic.

In the Nigerian Electricity Supply Industry (NESI), there are presently 23 grid-connected power generation plants currently operational with a combined installed capacity of 10,396 MW and an available capacity of 6,056 MW.

TABLE I
ENERGY RESERVE POTENTIAL IN NIGERIA AS RELEASED IN 2007 [27]

Types of Resource	Reserves	Reserves (billion tonnes of oil equiv.)	Reserves (x 10^7) TJ
Crude oil	36.2 billion barrels	4.896	20.499
Natural gas	166 trillion standard cubic feet	4.465	18.964
Coal and lignite	2.7 billion tonnes	1.882	7.879
Tar sands	31 billion barrels of oil equivalent	4.216	17.652
Subtotal fossils		15.459	64.724
Hydropower (large scale)	11,000MW		0.0341/year
Hydropower (small scale)	3,250MW		0.0101/year
Fuel wood	13,071,464 ha		
Animal waste	61 million tonnes/year		
Crop residue	83 milliom tonnes/year		
Solar radiation	3.5 to 7.0 kWh/m^2/day		
Wind	2 to 4 m/s (anuual av) at 10m in height		

A huge percentage of this generation is thermal-based with an installed capacity of 81% of the entire generation (8,457 MW) and an available capacity of 48% (4,996 MW). Three major generating plants are hydro power-based contributing to 1,941.2 MW of the total capacity with an available capacity of 1,071 MW. As at April 2020, only 3,759 MW of the total power generation is being transmitted. The Nigerian national grid consists of a 4,889 km of 330 kV line, 6,319.33 km of 132 kV line with a transformer capacity of 6,098 MVA at the 330/132 kV line and a transformer capacity of 8,090 MVA at the 132/33 kV line. The fifty percent of the generating stations in Nigeria are over 26 years old resulting to a low daily power generation. However, this has brought a massive load shedding all over the country. In terms of transmission, there have been a couple of problems in this sector, since the transmission system adopted in Nigeria does not cover the whole part of the country. The transmission system is also technically weak and prone to major disturbances and challenges. With a capacity of about 3,759MW for onward transmission to consumers, this is certainly not enough to meet the energy demands of the country. The total electricity consumption of the country as at 1970 was 145.3 MW/h and this rose to 536.9 MW/h in 1980. In the year 2005, the total electricity consumed in the country had grown to 1,831.2 MW/h [28] and this figure has risen to 3,855.1 MW/h as at September 2019. In terms of achieved total electricity generation, 176.6 MW/h was generated in 1970 and increased to 815.1 MW/h in 1980 [29]. In 2005, the figures increased to 2,993 MW/h and towards the end of 2019 electricity generation was at 3,468.8 MW/h. Positioning the Nigerian power generation framework in a global scale and when compared to other countries in terms of the per capita power generation, Nigeria ranks amongst the least as shown in Table II with countries likes the United States of America topping the list of per capita electricity generation. In terms of distribution and marketing of electricity in Nigeria, several problems and concerns plague this sector. In most parts of the country, the energy distribution network is very weak with a poor voltage profile and inaccurate billing. Other problems that this sector faces are obsolete and inadequate communication equipment, low and weak network coverage, substandard and limited distribution lines, overloaded transformers and feeder pillars, poor logistics facilities and maintenance system and a very poor customer relations coupled with insalubrious practices by staffs and lack of on-the-job training. In a bid to devise means and strategies to boost the country's energy generation, transmission and distribution sectors, the Federal Government of Nigeria has privatized the power sector in the country with a transaction cost of about $3bn [30]. This has been regarded as one of the most audacious privatization schemes in the power sector globally over the last few decades. According to the power privatization road map plan, the Federal Government still retains the ownership of all the transmission assets while the generation and distribution sectors are fully privatized. In order to improve on the state of power supply in the country, the Nigerian Electricity Regulatory Commission (NERC), a body responsible for granting licenses to electricity generators in the country has granted licenses to independent power producers in order to manage and own their own power plants. The most notable of these independent power producers are Agip-Okpai (480 MW), Shell-Afam VI (642 MW) and AES barges (270 MW). Another effort taken by the Federal Government of Nigeria to reduce power shortages in the country is the National Integrated Power Projects, which was developed in 2004 in order to increase the generation capacity of the Nigerian electricity supply system. This project has been meant to introduce additional capacity to the existing grid through extra electricity transmission and distribution systems and natural gas supply infrastructure. There are currently 10 National Integrated Power projects scattered all over the country with a joint capacity of 5,455 MW scheduled for completion and privatization.

V. Benefit of Smart Grid to the Nigerian Energy Sector

Despite the fact that the energy sector in Nigeria is plagued with a series of issues and problems, Smart grid technology can be regarded as one of the most viable solutions in tackling and solving these issues. The smart grid technology has sprung up because of the need to revolutionize and enhance power quality supply and to make it greener. The prime advantage is that it allows Renewable Energy Sources (RES) to be incorporated into the grid thus transforming the current grid into a grid that is more reliable, responsive and cooperative which is a big advantage that the Nigerian energy sector can fully exploit. Smart grid has the ability of providing a suitable platform to optimize the efficiency, reliability, availability, and robust security from both attacks and natural occurring power disruptions for increased economic performance [31]. Typical smart grid communication network architecture can be seen in Figure 2. Modern smart grids comprise of three structured layers namely the Power System layer, Communication layer and the Application layer in which various applications can be deployed via this layer.

TABLE II
PER CAPITAL ENERGY CONSUMPTION AND ELECTRICITY GENERATION AMONGST COUNTRIES [29]

Country	Population (million)	Generation capacity (MW)	Per capita consumption (kW)
United States of America (USA)	250	813,000	3.2
United Kingdom (UK)	57.5	76,000	1.10
Ukraine	49	54,000	1.33
South Korea	47	52,000	1.10
South Africa	44.3	45,000	1.02
Egypt	67.9	18,000	0.27
Iraq	23.6	10,000	0.42
Cuba	10.54	4,000	0.38
Nigeria	140	<4,000	0.03

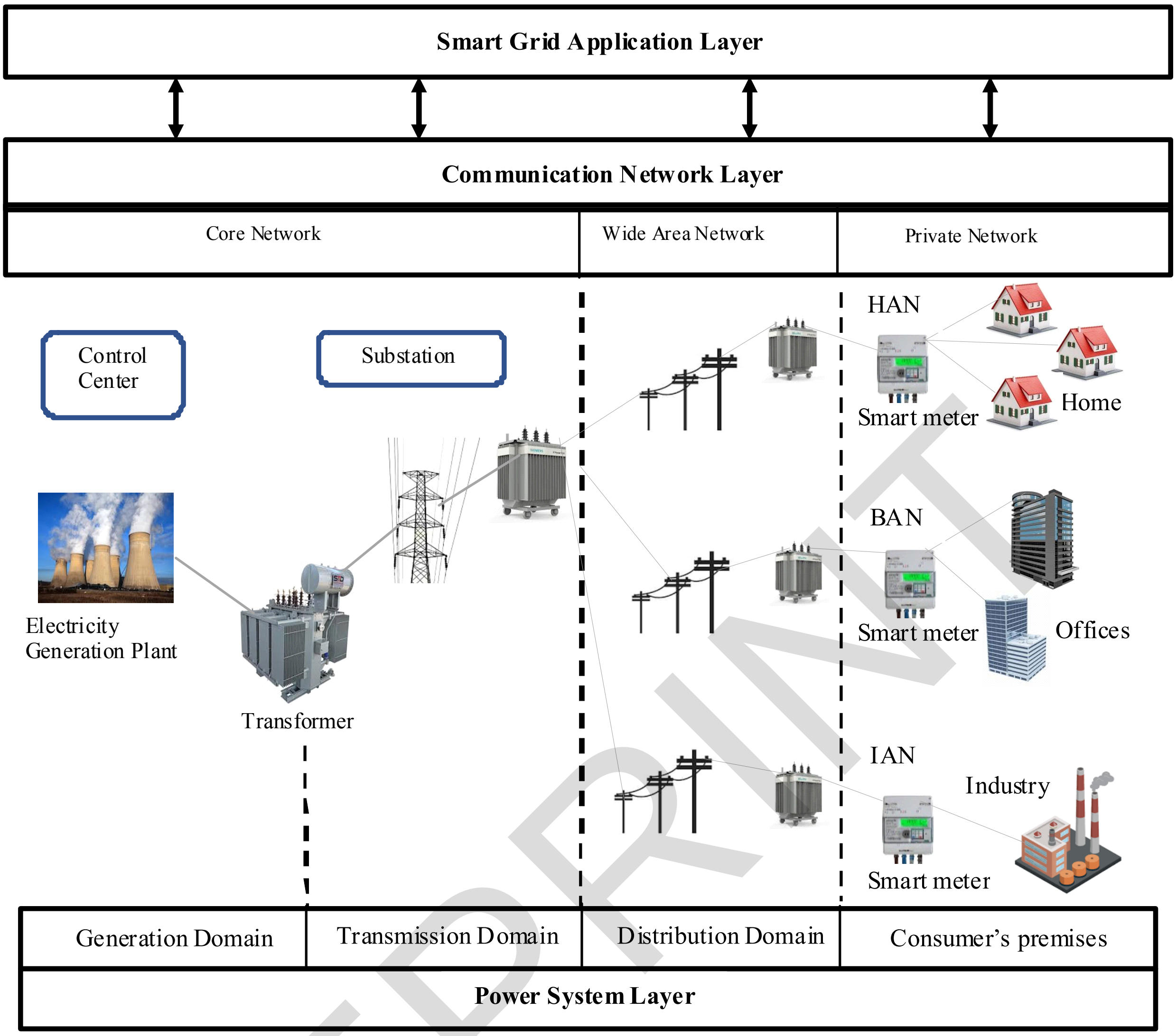

Fig. 2. Smart Grid end-to-end Architecture

The power system layer consists of four major domains, namely the generation, the transmission, the distribution and the consumer's domains. A core advantage of the communication layer is that it offers interconnections between all the devices and the corresponding systems. It is divided into two core networks: Wide Area Network (responsible for connecting the infrastructure with the control center) and the private network (consisting of Home Area Network HAN, Building Area Network, BAN, and Industrial Area Network IAN). The current energy distribution system in Nigeria is unidirectional and employs simple energy meters that deliver static customer tariffs and do not enable a two-way data communication and information exchange. This is a huge limitation since the distribution system lacks bi-directional digital communications network and cannot enable the consumer to play a pivotal role in the energy distribution and consumption process. With the introduction of smart grids, Advanced Metering Infrastructure (AMI) is employed into the grid. It helps to ensure that remote meter reading for load profiling, error free data, network problem identification, energy auditing, and partial load reductions in place of load shedding. However, smart meters can replace the simple and outdated meters installed around the country in order to enable consumers to monitor electricity usage in real-time by making available price dynamic information and their contributions on carbon emissions thereby aiding consumers in making more intelligent and cost-effective decisions [32].

At the same time, it will also assist the country's energy suppliers to manage effectively their energy demand and supply using peak demand management.

There are many benefits and advantages smart grid have over the current electric grid as detailed in Table III.

With the various functionalities and benefits smart grid has to offer, the one with utmost importance to the Nigerian energy sector is the modernizing of the power systems through the automation of substations. In a typical smart grid design, substations are automated by means of a M2M communications that assist in facilitating advance protection, real-time monitoring, and self-controlling functions for transmission and distribution substations and feeder equipment.

TABLE III
BENEFIT AND ADVANTAGES OF THE PROPOSED SMART GRID OVER THE CURRENT NATIONAL GRID

Criteria	Present National Grid	Proposed Smart Grid Potential
Metering	Electromechanical based	Digital based (enabling real-time pricing and net metering)
Generation of electricity	Central	Distributed
Restoration following disturbance	Manual	Self-healing
Customer and User Interaction	Limited	Extensive
Flow of Information	One-way flow	Two-way flow
Power Flow Control	Limited	Fully automated (comprehensive)
Monitoring Ability	Blind	Self-monitoring
Reliability	Prone to failures and cascading outages	Automated, pro-active protection, outages are prevented before they start
Pollution of the Environment	Very high	Low
Losses in Transmission and Distribution lines	More than 10% loss in total power from transmission and distribution lines	About 2% loss in total power from transmission and distribution lines
Grid Topology	Spiral	Networked
Efficiency of the overall grid	Poor	Excessive

Intra sub-station and inter sub-station communication protocols are mostly adopted for communication services. The Intra sub-station communication handles control and communication in the station level, bay level and process level. Communication between different bays occurs through the station bus while communication with external networks involving other sub-stations and the utility control center is handled by a gateway to the substation. The inter sub-station communication is responsible for communications in the distribution domain and requires data transmission application to enable communication from the sensors to an aggregator [33]. With the employment of an IP and internet based integrated smart grid communications network into the country's power systems, power transmission, and distribution will be much smarter and will provide advanced protection and control schemes. Another significant benefit smart grid has to offer to the country's energy sector that might assist in eradicating some current power issues is the enabling platform for the incorporation of Distributed Energy Resources (DER). It has gained a considerable amount of popularity due to the availability of installation materials and reduced installation cost. Other renewable energy resources are also becoming trendy and widely used due to its several advantages including low carbon emissions even though some of these RES require energy storage devices for low generation periods. These energy storage devices provide additional controllable power that can be used to boost the reliability and capability of the country's supply of power. The communication bandwidth required for extracting instantaneous information from the point of generation is within the range of 9.6-56 Kps, while its latency is 300 ms to 2 s [34]. EVs can also be introduced into the country's energy system with its advantages fully exploited. Although EVs require a driving power that ranges from 10-200 kW usually supplied from fuel cells and batteries, using the Vehicle-to-grid (V2G) mode, the stored energy can be put back into the grid whenever it is needed. In other words, EVs can function as a mobile DER while the power stored in the batteries or the power generated from the kinetic energy of the vehicle can be put into the grid. In this way, the EVs can serve as an alternative source of power capable of boosting the country's power generation during peak times and enhance its back-up capacity and the reliability of the power system. In addition, RES can be used alongside with V2G where the EVs can act as storage devices in order to provide adequate energy back-up for renewable energy generation. The communication requirement of V2G applications is highly dependent on the vehicle's speed. However, Zig-Bee or Wifi can be used in parking areas while mobile cellular communication can be used for moving vehicles [35].

The communication bandwidth required for V2G applications is in the range of 5-10 Kps while its latency is about 2 s [34].

VI. The Situation of Nigeria in Energy Growth Sustainability and Smart Grid Development

The energy sector is an important aspect of any economy and it plays a key role in balancing social and economic developments while achieving a sustainable developmental environment. Energy is also centered on most economies because it is the main driver of all the economic activities since all the economic processes or activities require some form of energy. There is no country in this new age that has succeeded in transforming its economy or substantially reducing poverty without sufficiently boosting the provision of energy in order to make material progress [36]. In a developing country like Nigeria, the supply of maximum energy services to a significant portion of the country's population has proven to be a real challenge. However, Nigeria is grappling to deliver domestic energy demands and this leads to a bit of a problem not just for households and individual users but for big and small businesses located across the country. Most of the big companies in the country like Procter and Gamble and Coca Cola have resorted to running generators in order to produce power to run 100% of their operations. This has pushed production cost by 10-20% higher than other neighboring countries, without any doubt. This has also stirred other foreign companies to move their operations to neighboring countries in order to earn savings in energy cost. In [37], Local Nigerian manufacturers have been instructed to rank their firm's constraints in carrying out their activities. Voltage fluctuations and power outages have been identified as the top two problems that eventually confirm energy as an important factor for growing businesses and an essential ingredient in achieving a sustainable Nigerian economy. The reforms of the country's energy sector are key and crucial in achieving a sustainable growth in Nigeria.

However, this will comprise the review and reforming of subsides, establishing credible regulatory frameworks and creating various market-based approaches [38].

Several countries around the world have already or are in the process of developing policies and strategies to facilitate a sustainable growth in their energy resources thereby contributing to its economic and social development while minimizing greenhouse gas emissions and air pollution. Countries like China, United States, Japan, Spain, and South Korea have already put in place smart grid technologies in order to ensure green energy consumption and supply in the long term [39]. For a country like Nigeria, the introduction of smart grid will assist in ensuring that various means of energy generation proposed by different energy companies and the ones already in existence work collectively to the benefit of individuals and businesses. It will also ensure that uninterrupted power is delivered to Nigerians and businesses in order to afford them the opportunity to be competitive with other foreign nations. In terms of integrating other energy sources into the grid, Nigeria possesses a superior solar power potential than most of the world leaders in solar power utilization (United States, Spain, China and Germany). Unfortunately, there are no solar power plants operating on a commercial basis in the country, although the Nigerian Government signed a power purchasing agreement with 12 companies to produce 975MW from solar power plants in 2016 [40].

This project is yet to deliver the expected outcomes.

The Federal Government of Nigeria (FGN) is more than capable of using modern technologies to solve the nation's energy crisis. However, at present, the Government has no laid down framework for the implementation of smart grid into the nation's current electric power grid. In order to employ gradually this technology into its existing grid, certain state governments can be lobbied to establish their own statewide smart grids. In doing this, these states will have an incredible competitive edge and advantage over others while benefiting the state's economy. With other states employing this technology, a national smart grid or a collection of statewide smart grid can be achieved thereby catering for the energy needs of the present and the future.

VII. Challenges and Recommendations

There has been an abundance of opportunities obtainable from the unbundling of the Nigerian power sector and these opportunities have been advantageous to both investors and consumers. These opportunities span across the generation, transmission and distribution sectors as companies have taken that bold step to put in some investments in the energy sector. Although the Nigerian government has also initiated some programs to assist in transforming and reforming the Nigerian Power sector, there still are some challenges that energy consumers currently face in the country. These major challenges and recommendations are highlighted below.

VII.1. Funding, Economic and Social Issues

The aim of the Federal Government of Nigeria in terms of tackling energy issues is to improve and boost the efficiency of the nation's power sector as well as provide affordable energy to teeming Nigerians.

However, these can be achieved by creating more generating stations in order to produce more power to the national grid and awakening the already dysfunctional ones across the country. This venture is no doubt capital intensive and much finance will be needed to construct new power stations and constantly maintain the existing ones. In most of the cases, in order to finance this venture, investors are called to invest in the sector and this eventually leads to high power rates and tariffs for consumers since the primary motive is to make profit as evident in the research paper written by the authors in [41]. With the smart grid approach, energy consumers can easily adjust their consumption in order to reduce the cost and peak demand of electricity to a more convenient time based on energy production information available to the consumers in advance. Consumers can also apply energy reduction strategies by optimizing both active and reactive powers in the electrical grid [42].

VII.2. Technical and Manpower Issues

Generating more power, adds to the capacity of an existing grid but there is also the need to ensure an efficient way of transmitting the already produced electricity and also strengthening the capabilities of existing transmission lines in order to enable consumers and licensed companies to utilize the provided power.

With the construction of additional transmission lines and the reinforcement of substations, energy can be easily distributed to various areas in the country and it can be easily evacuated from the area where independent power producers are concentrated due to the proximity to energy sources [43]. A major challenge that arises from this is the unavailability of adequately skilled work force to handle the technicalities involved and the maintenance of machines. This can easily be solved by proper training of personnel on the latest advancements in the energy sector and establishing various technical schools to train and develop young personnel in this field.

VII.3. Environmental Challenges

Environmental factors remain an issue in the energy sector in Nigeria and this happens because there is a high level of Carbon monoxide (CO) emissions from thermal power plants. In order to control this, the government can set up an Environmental Control and Inspection Agency (ECIA) to control, regulate, and monitor the degree of damage brought about by pollution to the inhabitants and the environment. In addition, independent power producers might be dissuaded from erecting power plants in certain locations in the country due to the high compensation fees posed to them.

VII.4. Lack of Supply and Pricing Framework and Inadequate Gas Infrastructure

A suitable supply and pricing framework remains one of the key challenges facing the energy sector in Nigeria even when the country's natural gas reserves currently seat at 5 trillion cubic meters [25]. It is estimated by the Nigerian National Petroleum Cooperation (NNPC) that more than 40% of the gas produced in the country do not end up in the market but they are being flared. This is because the key oil and gas producers have been unenthusiastic about investing in gas production and processing infrastructure thereby making generation companies deficient of gas to fire their power plants. In recommending a solution, companies flaring up gas can be taxed heavily for gas flaring in order for them to seek alternatives and adequate gas infrastructural facilities in order to enable gas production and processing.

VII.5. Political Tribal and Corruption Issues

In terms of inviting independent power producers and other stakeholders within and outside the country to invest in the energy sector, a level playing ground and a conducive political atmosphere is expected to be created so that the objectives can be achieved. A large number of independent power producers in Nigeria are mostly concentrated around the Niger-Delta area of the country due to the proximity to most energy sources and the bountiful availability of fuels required to run their plants. In that light, hopefully, the government would be rational enough not to repeat the same act that has led to the positioning of a refinery in the far North (Kaduna State) which is unfortunately thousands of kilometres away from energy sources due to political, tribal and corrupt dealings. On the same note, the youth restiveness, the ethnic unrest, and the hostilities in the Niger-Delta region of the country should be put to a complete halt in order to create an enabling environment for potential and current investors.

VII.6. Acts of Vandalization

The vandalization of power equipment and facilities remains a key challenge in the energy industry thereby leading to high technical losses and breakdown of the system [44]. The vandalization of installed facilities and infrastructures has led to serious financial and cost implications and unbudgeted funds diverted to the repairs of the resulting breakdown of the grid or system. In order to mitigate vandalization, adequate security measures need to be put in place to guarantee that most of the power facilities are safe guarded and free from vandals.

Table IV displays a summary of the most recent vandalization in the country and how much effecting repairs costs to the government.

TABLE IV
RECENT ACTS OF VANDALIZATION IN NIGERIA

Location of Vandalization	Date of Vandalization	Nature of Vandalization	Cost of Repairs in Nigerian Naira (~~N~~)
Delta-Benin 330kV line	March 2019	Tower No. 61 collapsed due to vandalization	Estimated cost 5,000,000
Alaoji-Owerri 132kV line	February 2018	Two spans of conductors, insulators and accessories were vandalized	Estimated cost 9,500,000
Oronta 132/330kV	August 2015	Transmission tower hacked down	Estimated cost 40,000,000
Jos-Bauchi 132kV line	April 2008	Towers No. 133-137, 160-170, 177-179, 221-225 and 333-337 were all vandalized	Estimated cost 15,000,000
Benin-Ikeja West 330kV line	December 2006	Towers No. 114, 117, 214, 220 were all vandalized	Estimated cost 25,000,000

VIII. Conclusion

The currently existing centralized power system in Nigeria is not solving the country's power problem and it is failing the Nigerian economy in terms of proving constant and uninterrupted energy supply. Despite numerous efforts and initiatives from the government and other relevant stakeholders in recent times, improvements in the energy sector have not been impactful. However, there is a great potential to remedy this situation, which is the smart grid approach. A decentralized, smart multidirectional network that possesses the ability to incorporate RES (wind and solar) in which the country has in abundance, becomes imperative to boost the country's power generation and energy sector.

With the aid of distributed generation in which smart grid possesses, large load centers can be eliminated and this will ensure an easier accessibility to power in areas where build a generation station it is not a viable option. In addition, areas that cannot be connected to the grid can get access to power supply from nearby generation stations established solely for the delivery of power to those consumers in these locations, preferable via energy sources around areas with abundance of solar energy in the North and wind farms around the coast in the Southern part of the country bordering the ocean.

With the constant power surge and uncontrolled blackouts plaguing the country, the self-healing characteristics of smart grid will boost the reliability of the energy system and circumvent fault occurrences.

There will also be a potential for new services and markets (such as advanced storage systems, EVs, communication systems and power flow control systems) to open up and improve on the country's power quality.

With the Nigerian electric grid being characterized by many challenges and issues, a monitoring system infrastructure would be of utmost importance in order to gather information ranging from quality of product, state of equipment and operation of the network. This will immeasurably assist in maintaining an accurate local balance between energy generation and consumption, improve the voltage quality, and mitigate overvoltage and undervoltage issues. The main objective of implementing the smart grid approach in the Nigerian energy sector is to manage the use of energy more efficiently, promote energy savings, provide valuable and understandable information to consumers in making intelligent decisions, and offer technologies and services that can be implemented into devices for consumer's utilization. Unarguably, smart grid has a demanding and key role to play in the nation's future in ensuring an efficient power generation, transmission, and distribution. The willingness for the country to implement the smart grid approach wholly depends on the government's ability to weigh its immense benefits and further strengthen the implementation of renewable energies and energy efficiency programs while setting aside a suitable budget for its start-up.

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