Smart Grid Systems in Nigeria: Prospects, Issues, Challenges and Way Forward

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REVIEW ARTICLE

Abstract -The ability of the power system to deliver to its consumer electrical energy at an expected level of reliability is correlated with the economic development of a country. The Nigerian power system faces many challenges, varying from overdue infrastructure maintenance, obsolete tools and appliances, insufficient electricity supply, corruption, etc. A gradual shift from manual to smart digital technologies include; smart metering, distributed generation (renewable energy and microgrid), and management using Information and Communication Technology (ICT) tools. In response, research, investments, and upgrade to the power sector are fundamental. This paper discusses and analyses the various smart grid technologies utilised in the Nigerian power system with their effects, impacts, deployment, and integration into the traditional Nigerian power grid. Also discussed are issues and challenges of smart grid deployment and ways of mitigating these challenges.

Keywords- Power Smart Grid, Renewable Energy, Microgrid, Nigeria, Digitalization, Electricity

1 Introduction

With a gross domestic product (GDP) of approximately 443 billion dollars, Nigeria is the largest economy in Sub-Saharan Africa (Worldbank, 2020). Despite being one of the world's largest oil and gas producers, it struggles to provide electricity to its 200 million citizens (Center for Democracy and Development, 2020). With just 45 per cent electrification, the country lags behind Ghana and Kenya, with 83 per cent and 64.5 per cent electrification rates with 144 kWh/capita. Self-generation costs more than double grid-based electricity leading to economic losses. With just 25% of potential energy reaching the end-user and about 60% of the population having access to electricity, the country is plagued by an unreliable power supply.

To align peer countries with comparable GDP per capita, Nigeria needs to increase its electricity consumption by around 5 to 6 times. Throughout its value chain, the power sector is beset by systemic problems. Low operating capacity relative to installed capacity and vandalization has crippled gas pipelines, causing gas shortages at power plants—other factors affecting the power transmission system include underinvestment and inadequate maintenance. Nigeria has a total installed capacity of 16,384 MW, with three (3) hydro plants and 22 gas plants producing 2,062MW and 11,972 MW, respectively, wind, solar, and other/diesel/hydrofluorocarbons (HFC) generating 10MW, 7MW, and 2,333MW, respectively.

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Section B- ELECTRICAL/ COMPUTER ENGINEERING & RELATED SCIENCES
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Nigeria has an available capacity of about 9,000MW and an operating capacity of 3,800MW (Center for Democracy and Development, 2020). Over the years, the Nigerian government has tried to address the challenges faced across the electricity power value chain. In 1898, the Nigeria Power System was established, with the creation of the Nigeria Electricity Corporation (ECN) in 1951, while the Niger Dams Authority was created in 1962 to encourage the use of hydroelectric power. The autonomous National Electric Power Authority (NEPA) was consolidated with ECN to float the Authority for Niger Dams (Olatunde & Tola, 2016).

NEPA was eventually modified into Nigeria's Power Holding Company (PHCN) to deal with its failing ability(Ajay & Ibe-Enwo, 2019). PHCN was unbundled into six (6) generating companies (GenCos), one (1) transmission company (TransCo), and eleven (11) distribution companies (DisCos) employing the Reform Act 2005 (Ajao et al., 2016) and introducing a robust regulatory body, the Nigerian Electricity Regulatory Commission (NERC), in 2005. The National Integrated Power Project (NIPP) was developed to solve the difficulties of insufficient electricity generation. Privatisation was implemented in the market to create a better power system. Also introduced in 2001 was the National Electric Power Policy (NEPP), with its Independent Power Plants becoming a critical unit in power generation (Ikem et al., 2016).

1.1 Electricity Generation

Seven (7) of Nigeria's twenty-five (25) generating stations have been outdated and used for over 20 years. Their average daily power production is below the estimated peak (Ekpe and Umoh, 2019). Challenges faced by power generation range from outdated equipment and tools, unregulated facility maintenance, and inadequate power production (Monyei et al., 2018). Nigeria has about 13 gigawatts (GW) of installed electricity generating capacity, but only about half is operational due to gas shortages. Due to these limitations and insufficient facilities, the installed generating capacity is currently 64 per cent lower than the actual generation capacity of 7 GW. According to the 2018 Power Sector Performance Survey, the sector lost NGN 51.519 billion in September 2018 due to a gas supply shortage negatively affecting power supply when combined with infrastructure constraints along transmission and distribution lines. In June 2019, seven gas-fired power plants were idle, resulting in average on-grid power generation falling to about 3.4GW, a substantial drop from the February 2019 generation peak of 5.4GW (Center for Democracy and Development, 2020). This peak indicates slight improvement, but it is still far short of what is needed.

1.2 Electricity Transmission

Nigerian Transmission Company (TCN) was founded after the Nigerian power sector unbundling, and it is split into two, System Operator and Business Operator (Akpojedje et al., 2016). The transmission grid comprises 5523.8 km of 330 kV lines and 6801.49 km of 132 kV lines (Ikem et al., 2016). Notwithstanding the TCN's improved infrastructure and management efforts to reduce transmission losses are still not apparent due to the absence of redundancies in lines, outdated substation equipment, lines, sub-stations overloading, insufficient coverage, unavailability of capital for project implementation, restricted training and development opportunities for staff (Bamisile et al., 2019). Such problems make it difficult to forecast the pattern of losses in the transmission system mathematically (Abanihi et al., 2018; Emodi & Yusuf, 2015).

1.3 Electricity Distribution and Marketing

The distribution process, the final stage of the power supply value chain, is where electricity distribution companies (DisCos) deliver 90% of the transmitted power to customers. Unfortunately, more than half of the country's energy users do not pay for their power. Distributors face significant collection and commercial losses. Metering penetration is low, and tariffs remain unresponsive to market realities, reducing the sector's profitability for potential investors as an end-user interfacing network; maintaining sufficient coverage and optimum quality power supply when effectively promoting and providing utility service to customers is crucial (Otuoze et al., 2017). Voltage drop and high power loss are vital problems faced by the distribution system in Nigeria, varying with the load profile on the distribution network (Aniefiok et al., 2013). The challenges faced include transformer overloading, faulty feeder pillars, inferior distribution conductors, and irregular maintenance activities. Others are illegal manipulation of installed meters, equipment vandalization, unethical practices of personnel, and a lack of appropriate logistical facilities, such as medical instruments and supplies, utility vehicles, telecommunications equipment, and cash collection (Patrick et al., 2013).

1.4 Research Questions

The digitalisation of the Nigerian power system is inherent to solutions to the epileptic power supply. This has prompted the need to deploy a smart grid in the country. Smart Grid (SG) denotes a robust power network that effectively incorporates all connected components via a synchronising process that optimises all phases of the network (Dada, 2014). The bi-communication features of the SG make it possible to control equipment and other data-gathering devices remotely. The key component is its automated device management technology and assisting stakeholders' informed decision-making (Bayindir et al., 2016).

The research questions this paper seeks to answer are:
RQ1: What are the prospects for the successful deployment of smart grid systems in Nigeria?
RQ2: What are issues that would affect the successful deployment of technologies in Nigeria?
RQ3: What challenges would face smart grid systems in Nigeria?

1.5 Review of Some Works of Literature

Tsado *et al.* (2012) addressed Smart Grid technologies. The work presented a model developed to illustrate the Demand Response System (DRS) application in the smart grid distribution network. It also evaluated the benefits of using it in combination with conventional grids. Emodi and Yusuf emphasised the necessity for renewable technology standards in Nigeria to avoid inferior renewable energy technologies (2015). The research examined Nigeria's renewable energy potentials, presented the idea of standardisation, and addressed the implementation of renewable energy technology standards. Arihilam et al. (2014) explored how to tackle the problems of population development, the industrialisation of developing economies, and the protection of fossil fuels in Nigeria through smart grids. The research proposed that efficient data management in this modern energy environment by smart grids be the panacea for the survival of utility companies. The research did not address the different smart grid technologies relevant to the Nigerian Grid division.

Onohaebi & Omorogiuwa (2014) suggested the ideal utilisation of existing and new resources of both Independent Power Producers (IPP) and National Integrated Power Projects (NIPP) to change the country's energy system through the execution of smart grid technology at all power system levels. This is increased proficiency, dependability, power quality, lower risk and repairs costs, energy charge reduction, and overall power loss. Integrating this technology into the Nigerian power network will reduce the building of new generating stations and transmission lines needed to meet the projected growth in loads. It is recommended that if this innovation is considered at generation, especially since the power industry is encountering transformative changes, it will soon make the country match the demand for electricity with the supply.

Ekpe and Umoh (2019) reviewed the literature on the existing condition of Nigeria's traditional electricity grid. Before considering the magnitude, efficiency, and power generation technologies used by some mini-grid systems currently deployed, the grid's generation, transmission,

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and distribution sectors were briefly examined. It is noted that the majority of mini-grid systems developed rely on renewable sources of solar photovoltaic electricity, and these systems are primarily isolated from traditional grids. With significant but focused investments, many current smart grid technologies can incorporate mini-grids into the conventional grid, providing affordable access to electors. The work provided a top-level schematic regarding how and where to deploy such technologies.

It is imperative to have a robust and dynamic generation, transmission, and distribution network to have an efficient power system in Nigeria, achievable by the successful deployment of a smart grid. This paper discusses and analyses the various smart grid technologies utilised in the generation, transmission, distribution, and consumer end, and the prospects, issues, challenges, and solutions of smart grid system deployment and integration into the existing traditional Nigerian power grid. Figure 1 depicts the organisation and taxonomy of the smart grid system in Nigeria.

2 PROSPECTS OF SMART GRID IN NIGERIA

2.1 FEATURES AND CHARACTERISTICS OF THE EXISTING AND SMART GRID

The smart grid has self-healing, active customer engagement, choices for generating and storage, new market penetration, stability, and improved quality of power offerings characteristics. Table 1 summarises the comparison between the existing and smart grids. A smart grid provides further advantages such as knowledge flow, efficiency, reliability, control and communication, making the power grid reliable for adequate power supply (Shaukat et al., 2018).

2.2 SMART GRID TECHNOLOGIES IN NIGERIA

Advanced Metering Infrastructure (AMI), Demand Response (DR), Customer Side System (CSS), Advanced Distribution Automation (ADA), Transmission Enhancement Applications (TEA), Asset / Process Optimisation (AO), Distributed Energy Resources (DER), Information and Communication Integration (ICI), and Wide Area Monitoring and Control (WMC) are leading smart grid technologies. These are discussed in this section.

2.2.1 Information Communication Technology (ICT) Integration

The introduction and integration of communication infrastructure supporting data transmission are essential for applying smart grid technology to the Nigerian grid. With a two-way exchange of network information and data along with collaboration tools and enterprise resource planning software, there would be efficient use and control of emerged smart grid, thereby eradicating significant problems of the present Nigerian grid (Ajayi et al., 2014; Fadel et al., 2015; Patrick et al., 2013).

2.2.2 Wide-Area Monitoring and Control

Wide area monitoring and control (WMC) is a crucial smart grid feature, allowing energy consumers to participate directly in energy use tracking and regulation (Reddy et al., 2014; Saleem et al., 2019; Wang et al., 2019). Sensory instruments like phasor measuring units (PMU), accelerometers, infrared sensors, strain gauges, and magnetic sensors connected to the grid network automatically modify and respond to internal alteration conditions. It allows delivery systems on communication networks to be smart remote agents, generating data transmitted to the control centre. Advanced network management tools help avoid blackouts and leverage variable renewable energy services, while advanced analytics devices support the collection of decision-making data. The deep availability of these data enables an effective measure to minimise wide-area disruptions and boost transmission efficiency and reliability(Akom et al., 2015; Emmanuel & Rayudu, 2016).

Table 1. Comparison of General Features of the Existing Power Grid and Smart Grid System

Basis	Existing Grid	Smart Grid
Customer Interaction	Bounded	Broad & Unbounded
Metering	Analog & electromechanical	Real-Time & Digital
Disturbance/ Fault Restoration	Manual	Automatic & Autohealing
Power Flow Control	Finite	Inclusive & Automated
Reliability	Non-Automated & Reactive Protection	Automated & Pro-active Protection
Losses on transmission & distribution lines	Loss of total power ≥10% (Amuta et al., 2018).	Loss of total power ≥ 2% (Amuta et al., 2018).
Information Flow	Unilateral	Bilateral
Electricity Generation	Central	Dispersed
Environmental Pollution	Extreme	Relatively Low
Grid Overall Efficiency	Low	High
Monitoring	Blind & Manual	Self-monitoring
Energy Quality	Non-Essential	Essential with Price Relation Factor
New Products, Services, & Markets	Limited with Poor Integrated	Mature & Well Integrated wholesale market.
Energy Generation & Storage	Primary generation sources	Renewable Energy Sources
Operating System Integration	Low degree of integration	Full Integration
Price Information	None or Limited	Full Price Information
Switch Connection	Manual	Automated
Communication	Non-interactive	Interactive
Use of Sensors	Limited	Unlimited
Participation	superficial	Intensive
Control	Limited	Pervasive
Fault Response	Failures & Blackouts	Adaptive & Islanding
Communication Method	Non-real time	Real-Time

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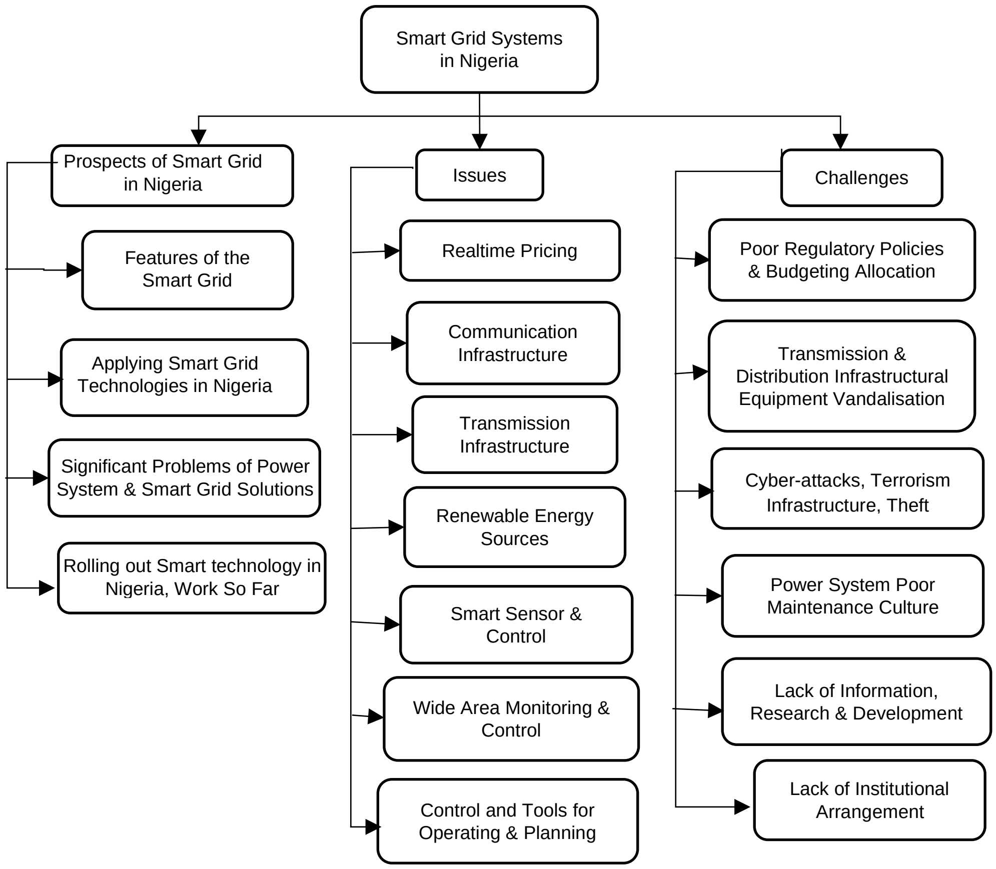

Fig. 1: Taxonomy of Smart Grid Systems in Nigeria

2.2.3 Distributed Generation Energy Resources

Distributed Generation (DG) is widely used to infer comparatively low-scale power generation from renewable energy resources. Renewable energy will play a significant role in enabling distributed generation technology to solve the generation challenges while providing ancillary services (Aliyu et al., 2018). In Nigeria, renewable energy sources such as solar, wind, wind, and hydropower serve as DG sources. Nigeria has abundant solar, biomass, wind, hydroelectricity, and tidal energy sources (Aliyu et al., 2015). In November 2005, with funding from the United Nations Development Program (UNDP), the Nigerian government approved the Renewable Energy Master Plan (REMP) drafted by the Energy Commission of Nigeria (ECN). The Master Plan sets out the framework for developing policies on renewable energy, legal instruments, technology, personnel, infrastructure, and the market to ensure perception, intent, and objectives (Shaukat et al., 2018; Tuballa & Abundo, 2016; Yoldaş et al., 2017).

In fostering renewable energy potential, the country has set a 20-2020 vision for using renewable energy sources in Nigeria to meet the national demand for electricity, including energy initiatives and strategies(Aniefiok et al., 2013; Dunmade, 2016). Some priorities outlined are (Akinyele et al., 2018; Chukwuorji et al., 2019);

1. Contributing hydropower to Nigeria's 15% and 20% power generation mix by 2015 and 2020, respectively
2. 1% inclusion of wind energy in the generation mix by 2020
3. 1% addition of solar energy to the generation mix by 2020.
4. Replacement of 50% cooking firewood usage with renewable energy technology by 2020.
5. Use of locally generated secondary biomass sustainable biofuel, thereby reducing the use of fossil fuel for transport.

2.2.4 Microgrid

The Microgrid (MG) is a collection of integrated loads and distributed energy (DERs) within a precisely articulated electric boundary that functions as a central controllable grid unit (Mohammed et al., 2017). MGs provide mechanisms to incorporate Renewable Energy Sources (RESs) into distribution networks and deliver electricity to remote rural areas when used as a stand-alone system (Akinyele et al., 2018). MGs will play an essential role in overcoming the significant challenges of using RESs in Nigeria by managing power generation from many small power producers, such as rooftop solar panel owners or wind farms, through smart devices and technologies. MGs could also prevent technical problems such as harmonics and losses that arise from the poor integration of DGs in an existing grid (Aliyu et al., 2018; Bamisile et al., 2019; Shaukat et al., 2018).

In reducing power loss from the more comprehensive grid, MG can also be generated for communities to meet their energy requirements (Nawaz et al., 2016). As part of the distribution networks, utility MGs can provide local support for the load under grid failures, peak hours, and low-quality instants (Bamisile et al., 2019).

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2.2.5 Advanced Metering Infrastructure

Advanced metering infrastructure (AMI) technology describes different techniques involving data management systems and smart meters. These allow for information sharing in both directions, thereby providing real-time price and usage for customers and utilities, including the time and units of electrical energy consumed. AMI dispenses a broad range of uses, including distant market price signals, real-time customer energy usage data, and time intervals needed. It improves energy diagnostics through the provision of comprehensive load profiles. It also remotely detects the position and magnitude of outages. It has a retail energy service provider's ability to handle its sales through more efficient cash generation and debt management (Reddy et al., 2014).

2.2.6 Customer-Side System and Demand Response

Customer-side technologies control consumers' electrical energy use, such as energy management systems, storage, smart appliances, and distributed generation(Di Santo et al., 2015; Onohaebi & Omorogiuwa, 2014). This field of the smart grid uses in-home monitors and energy screens, smart devices, and resident storage to improve energy efficiency and reduce peak demand. Demand response includes manual customer response, automated customer response, cost-sensitive tools, and energy management system-connected thermostats (Ajao et al., 2016).

To ensure a balance between supply and demand, the Electric Power Research Institute (EPRI) implemented demand-side management (DSM) in the 1980s. Here, the load is made adjustable to the supply rather than merely changing the supply-side generation level. DSM, an integral part of a smart grid, is a global concept that refers to various activities such as load control, energy efficiency, energy conservation, etc (Akom et al., 2015). The inefficient load-management systems for households, commonly called demand response (DR), will be minimised with a smart grid.

2.2.7 Transmission and Enhancement Technology

Transmission technologies of the Flexible Alternating Current Transmission Systems (FACTS) and High Voltage Direct Current (HVDC) controllers can be introduced into power networks to address the issues associated with the Nigerian transmission power grid system. FACTS can regulate the voltage magnitude of a bus's active and reactive power flows through the power system's transmission line, thereby enhancing control and transmission optimisation and performance. HVDC is more effective for long-distance transmission by offering an active platform for connectivity to offshore wind farms and solar farms (Bhatt et al., 2014). Furthermore, high-temperature superconductors (HTS) will significantly reduce transmission losses and allow higher output to limit the economic fault current. However, there is a discussion about the market preparedness of this technology (Ekpe and Umoh, 2019); Reddy et al., 2014; Tsado et al., 2012).

2.2.8 Asset Optimisation

A smart grid uses the latest technology to optimise its resources. For example, dynamic ratings can achieve optimised efficiency, allowing assets to be used at higher loads by continuously sensing and evaluating their capability (Emodi & Yusuf, 2015; Emodi et al., 2014). Furthermore, condition-based maintenance may increase maintenance efficiency, indicating a need to fix the equipment appropriately. The system-control systems can be modified to minimise losses and remove congestion by choosing the lowest energy distribution system costs available to these system control devices and the operating efficiency (Folarin et al., 2017). Table 3 shows Nigeria's significant electricity supply problems and smart grid solutions.

2.3 Development and Advancement in the Nigerian Power Sector, Work so far

In 2005, the Electric Power Sector Reform Act was passed, founding the Nigerian Electricity Regulatory Commission (NERC) and the Nigerian Power Holding Company. In 2006, unbundling of assets (transmission, distribution, and production) created ten National Integrated Power Projects (NIPPs), the Nigerian Transmission Company's Market Operations Department and the Rural Electrification Agency (REA). In 2008, a committee was established to oversee the progress of unbundled generating and distribution businesses.

A multi-year tariff order was issued, and the national power road plan was introduced, which created the Nigerian Bulk Electricity Trader (NBET). In 2012, the Nigerian Transmission Company signed a management contract with a utility and asset management firm and nuclear energy. Memorandums of Understanding (MoUs) were linked. In 2013, there was an improvement in hydropower plants (with US$1.72 billion set aside for three plants), and MoUs for coal power partnerships were signed, launching the transitional power market.

Seven out of ten NIPP generation asset sales were completed in 2014, indicating a strengthening of renewable energy programs. The Transitional Power Market was founded in 2015. In 2016, NERC required DisCos to finish meeting all maximum power users in their network by November 2016. In November 2017, NERC released the Eligible Customers Regulation, and in March, the Federal Government announced the Power Sector Recovery Program (PSRP), and the NERC enacted the Mini-Grid Regulations. The Meter Asset Provider (MAP) was introduced in 2018 to support the development of independent and competitive meter services, eliminating approximated billing methods and attracting private investment to the metering industry.

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Table 3. Significant Problems of Electricity Supply in Nigeria and Smart Grid Solutions (Dada, 2014)

Major Problems of Electricity Supply in Nigeria	**Smart Grid Technologies**								
	AO	**TEA**	**ICI**	**ADA**	**DR**	**AMI**	**CSS**	**DER**	**MG**
Aging Facilities	*	*	*	*	*	*	*	*	*
Manual Billing, Poor Meter Reading, and Overrated Bills			*			*	*		
Power Theft and Vandalism and Unlawful Disconnections & Connections			*	*		*			
Manual Fault Detection and Documentation		*	*	*		*			
Insufficient Generation Capacity	*		*		*			*	*
Use of Large-Scale Fossil Fuel Generators					*			*	*
Huge Installation Cost for Generation and related Transmission and Distribution systems					*			*	*
Extremely High Power Losses at T&D levels		*	*					*	*
Laden Transformers leading to Frequent Breakdowns		*	*	*	*			*	*
Transmission Bottlenecks	*	*	*	*	*			*	*
Inefficiency & Poor Management		*	*	*	*	*	*	*	
High Degree of Interruptions, Disturbances, and outages	*	*	*	*	*		*	*	*
Low Voltage, Poor Power Qualities at Receiving Ends		*	*	*	*		*	*	*
Absence of Real-Time Data Involvement		*	*	*		*			
High Use of Diesel Generators						*	*	*	*
Lack of Electricity Supply to Rural Areas			*			*	*	*	*

AO- Asset Optimization; TEA- Transmission Enhancement Applications; ICI- Information and Communication Technology; ADA-Advanced Distribution Automation; DR-Demand response; AMI- Advanced Metering CSS – Customer Side System; DER- Distributed Energy Resources; MG- Microgrid

Globally, 313 million smart energy meters were installed in 2013, and 852 million SEMs are projected to be installed worldwide by 2018 (Ezeodili & Adebo, 2018). To fast-track the roll-out of SEMs, Nigeria introduced the Credited Advanced Payment for Metering Implementation (CAPMI) scheme in partnership with EcoBank. However, the project met a restriction on the unwillingness of customers to bear installation costs leading to the termination of the scheme. Complacency in the supply and installation of smart energy meters to consumers who manage to pay for their energy meters by the distribution companies (DisCos) was also a significant reason for the failed CAPMI implementation. In most cases, consumers have to hold on for at least 15 months before being supplied and sometimes have to bribe their way out. The inability to install meters for consumers has led to continual charges based on estimated billing. This deceitful act on consumers encourages consumers to seek other ways to cancel off the effect of the estimated billing by engaging in energy theft (Ndinechi et al., 2011).

Electricity theft is a significant source of loss for utility companies, causing massive financial damages and preventing further investment engagements (Jiang et al., 2014). Moreover, electricity theft has evolved as the most severe security threat worldwide, as huge losses are reportedly incurred by utility operators and governments (Erlinghagen & Markard, 2012).

Nigeria's Kaduna Electricity Distribution Company (KEDC) promised that its manufacturing plant in Kaduna would help achieve its set target by rolling 500,000 meters in 2021. However, findings revealed that of the 10,516,090 registered electricity customers, only 4,234,759 (40.27%) are metered as of June 2020, with Port Harcourt and Benin DisCos accounting for 38.4 and 54.2%, respectively (Nigerian Electricity Regulatory Commission-NERC, 2021) Fig. 2 shows the distribution of meters by the DisCos presented in the 4th quarter for 2017, 2018, 2019 and 2nd quarter for 2020. Since distribution companies tend to generate more revenue with estimated billing than having customers with SEMs, thus frustrating efforts on SEMs distributions, deploying SGs in a country such as Nigeria poses challenges requiring innovative and homegrown solutions.

Ikeja Electric 2017 reported that energy losses had been reduced from 46% to 11% in five years, resulting in Huawei's Advanced Metering Infrastructure (AMI) solution. The AMI system was sorted to provide billing problems, asset management, and business efficiency. The company initiated 600,000 meters installation and successfully connected 592,000 with faulty and burnt meters accounting for the disparity. As a result, Ikeja Electric witnessed improved bill collection rates and significantly reduced energy loss on metered distribution transformers (Ahmad, 2019).

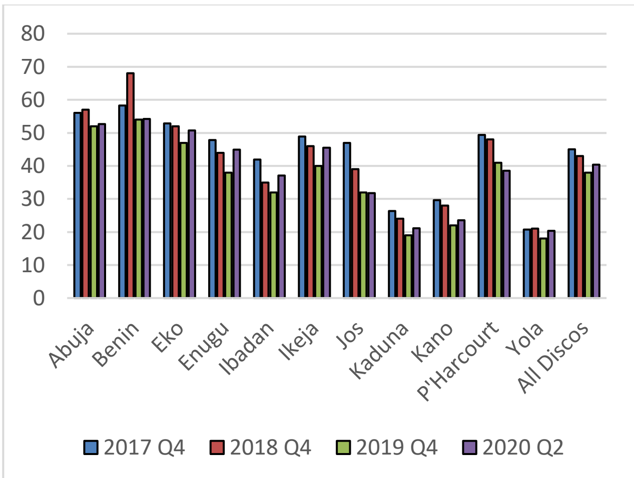

Fig. 2: Percentage Distribution of Meters by the Eleven DisCos. Source: *(Nigerian Electricity Regulatory Commission-NERC, 2021)*

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3 Factors Affecting Smart Grid Implementation In Nigeria

A. Cyber-attacks, Infrastructure Theft, and Terrorism

Cyber-attacks are global phenomena that impact nations, companies, organisations, security services, and infrastructures. They can damage hardware and software facilities that control the smart grid. In addition, SG relies on information technology, making it vulnerable to cyber threats (Reddy et al., 2014). Globally, an estimated US$ 445 billion is spent annually in the war against cybercrimes (Jiang et al., 2014), with many developing nations like Nigeria budgeting little to nothing to counter cybercrimes. Therefore SG deployment in Nigeria must be accompanied by well-structured cybersecurity for a secure and resilient system (Otuoze et al., 2017).

B. Poor maintenance culture

Of significant concern is the poor maintenance culture demonstrated over time in the power sector, the only evident maintenance performed by utility workers is the clearing of fault. In contrast, scheduled maintenance is non-existent for power infrastructure's optimal functioning and life cycle elongation. As such, even with an increase in generating capacity with the deployment of an intelligent grid, capacity may still be limited. (Akpojedje et al., 2016).

C. Poor regulatory policies implementation and low budgetary allocations

Poor regulatory policies and implementation in most developing nations serve as a barrier to SG deployment since consistency and a well-driven strategy are essential for the sustainable execution of projects. Regulatory bodies such as the Nigerian Electricity Regulatory Commission (NERC) are placid in performing their primary responsibility to regulate the power sector as the relevant power stakeholders do not follow the rules (Akpojedje et al., 2016). Considering the price of SGs deployments, many developing nations' low budget allocations are another barrier to increased funding. Excellent and consistent regulatory policies will be helpful in the implementation of SGs (Otuoze *et al.*, 2017).

D. Renewable Energy Sources Production Volatility

Renewable energy sources are based on natural phenomena, which vary based on weather, time of the day, and season of the year, among other factors. These variations would make it challenging to generate constant power throughout the day, month, and year. The generated electricity would be safely absorbed into the grid if the frequency is kept within an appropriate range using the Ancillary Frequency Support Service (FSAS). This would complement the recurrent energy generation changes (Aliyu *et al.*, 2018). Depending on the regular environmental forecast, a dispatch strategy for FSAS can be built to absorb changes in renewable energy generation. (Microgrids and distributed energy resources can be utilised to create a network that minimises the adverse effects of power quality problems on present power systems while enhancing sustainability, supply synchronisation and distributed power generation in emergent power systems (Emodi et al., 2014).

E. Transmission and distribution infrastructure and equipment vandalization

Before the recent power sector reforms, Nigeria's transmission infrastructure and distribution equipment vandalism were typical. Most times, power brokers who import power generators are blamed for such saboteurs. Vandalism of Nigeria's electrical infrastructure is one of the significant issues that could stymie the country's deployment and integration of the smart grid. (Emodi & Yusuf, 2014).

F. Insufficient research, information, and merchandising of smart grid technology

There is currently no access to records about Nigeria's green energy potential. Hence prospective investors will find it difficult to make business judgements about the exploration and use of renewable energy sources. Therefore, generating and managing such reliable data is paramount to proper system planning and execution. However, there is still much progress in facilitating research to gather data on methods, practices, and techniques that can be used to deploy smart grid technology in Nigeria (Sambo et al., 2012).

Incorporating DER into the network would involve innovation in the research and merchandising of smart sensors, secure relays, and control devices. Lower cost sensors and controls will decrease the amount of installing DER, guarantee the reliability of interconnected DER systems, and protect line crews and the public during maintenance and reconstruction. However, more technical know-how of smart grid technologies will increase as autonomous operation increases. (Amuta et al., 2018; Rehmani et al., 2018).

G. Lack of institutional arrangement

Failure to enforce clean energy policies and coordination among various government agencies has created inconsistencies that hinder the growth of renewable energies. Nigeria's renewable energy sector appears dwarfed compared to smaller countries such as Kenya due to a lack of apparent government supervision and direction, weak regulatory systems, and insufficient human capital, compounded by limited government backing. There is currently little hope of a fast change to a green economy, as there is no effort to empower rural folks with education and awareness of simple renewables (Ikem *et al.*, 2016).

H. Corruption

The problem of corruption has backtracked the nation among its contemporaries. Corruption is an all-pervasive epidemic that has devastated every segment of Nigeria's economy, including the power industry. Numerous corruption instances have caused uproar in the power sector (Ndinechi *et al.*, 2011). In most developed nations, corruption has become a way of life for government officials and some highly placed private individuals. Corruption also translates to improved theft, and a strict government penalty against corruption would help deploy SGs (Otuoze *et al.*, 2017).

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4 Way Forward

Despite advances, significant hurdles still exist in every section of the power sector value chain. If electricity is to meet demand in the foreseeable future, these issues must be handled appropriately. The sector's long-term success is dependent on the health and sustainability of all stages of the value chain, from production through end-user payment. As a result, the government must enact cost-reflective tariffs that reflect market reality. Policies encouraging the use of renewable energy should also be implemented to supplement existing energy sources. Energy regulatory bodies should create frameworks that promote transparency and accountability. This will make it easier for entities like REA and NERC to collaborate and coordinate their efforts. The role of state and municipal governments in supporting and enabling mini-grid development is critical. They should take on more responsibility for advancing the process. To empower private players to realise the off-grid market potential, create an enabling environment for off-grid development, including more explicit criteria for mini-grid development, assistance for skills and training, and more supportive legislation. Existing regulations should be used to clarify provisions. For example, policies around distribution firm development plan reporting should be explicit and adequately implemented to alleviate operators' uncertainty.

Based on the prospects, issues, and challenges of smart grid deployment in Nigeria, some policy and regulatory changes would need to successfully introduce renewables and smart grid technology into the Nigerian Power Grid. This will contribute to energy supply and economic changes. Here are some guidelines and steps:

i. Develop renewable energy standards and standard compliance with international standard renewable energy cooperation bodies.
ii. Promote specialist training through the development of programs, create uniform databases, and appoint a permanent agency or commission to promote and enforce standards for renewable energy products.
iii. Implementing renewable energy standardisation policy, organisation, budget, and human resource development laws would ensure that any renewable energy product imported by an importer into the country is provided with after-sales customer support (ASS).
iv. Energy data study research should be conducted on: off-grid power generation, customer consumption profile and renewable energy.
v. Establish an updated National Energy Archive to adequately assist the Nigerian government and global organisations in evaluating the energy situation.
vi. Energy education programs should be mandated at all levels of schools in Nigeria.
vii. Energy quality criteria for household, office and industrial appliances and equipment are improved by requiring the exclusive and mandatory use of low-energy appliances, electric lights, and equipment.
viii. A priority is to integrate distributed generation into the national grid and introduce wide-area monitoring and control technologies into the national network.
ix. Infrastructure upgrades, deployment of transmission enhancements solutions, and a transmission policy framework that encourages off-grid renewable solutions.
x. Establish research and development centres in educational institutions.
xi. Create a nationwide smart grid network that is interconnected.

5 Conclusion

The unbundling of PHCN, coupled with smart grid technology, would open up the prospect for electricity consumers and suppliers to explore renewable energy sources and distributed energy to meet power needs. SG provides competencies to defy and solve various challenges facing Nigeria's power sector. Aside from confronting these challenges, the smart grid would immensely benefit the country's electricity stakeholders by providing paybacks in various aspects of security, economy, and reliability of the power system in the country.SM-G would also provide accurate data that power system planners can use for forecasting power system load at every aspect of the power system. The role of power system planning cannot be overemphasised as it serves as the basis for any development in the power system**.** However, it will be impossible to ground the whole country for an extended time to make the existing grid network setup smart with a complete change of existing power equipment with intelligent ones. Low interruption areas such as smart metering, distributed generation, and ICT should start implementing smart technology while tending towards a gradual overhaul in avoiding a total breakdown of the power sector. The application of a decentralised system such as microgrid and distributed generation should be utilised. The use of microgrids would also bring about reduced power losses. However, to ensure the smooth deployment of the smart grid in Nigeria, the following factors should be considered:

i. Strict adherence should be made to standardising technologies for smart grid applications.
ii. Regulatory bodies must be brave enough to perform their statutory duties, and discipline investors misled or harmed by the existing law.
iii. In the future, the power industries must be compelled to do research and collaborate with scholars in carrying out research.
iv. Important deadlines must be set and met, as laid down in the regulatory policies related to the implementation of Smart Grids.
v. Scholars should be mandated to carry out developmental research that can contribute to the nation's growth.
vi. The distinct gap in the technical know-how of smart grid technology could impede the deployment of an intelligent grid. To support smart grid engineering, there has to be a significant restructuring and training of engineers and technicians in integrated skills of the developing and emerging technology area of the smart grid. As such, the skill gap should be closed.
vii. The government needs to raise public awareness about the need for citizens to protect public infrastructure jealously.

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viii. Storage should be carried out securely to avoid cyber-attack issues emerging from information and communication technology integration.

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