SMART GRID TECHNOLOGY INTEGRATION IN NIGERIA'S POWER SYSTEM

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Abstract

Stable and affordable electrical power is a vital requirement for development and growth of any economy. In Nigeria, electrical power is generated from two major sources – Hydro source and Thermal source and deposited in the National grid from where it is transmitted and distributed to consumption centres. Power system is more exposed to the environment and thus the rate at which faults or disturbances occurs is high. Beside the power plants and some high transmission lines, every other information acquisition vis-à-vis fault occurrence, detection and clearance is done manually by personnel patrolling the lines. Hence, a long period of time is wasted and minor fault can degenerate into severe fault. Therefore a system that is more reliable and responsive is required to arrest this problem. The smart grid system is the option to adopt. Smart grid system facilitates bidirectional movement and measurement which creates an environment for small localized generations and renewable energy operator to push their unused power back to the grid and get accurately paid for it. This research article examines the capacity, composition and viability of smart grid system for Nigeria, as remedy to energy challenges facing the power providing companies. This will not create but transform the existing opportunities for affordable and sustainable growth in the economy of Nigeria.

Keywords: *Electricity, Smart Grid, Power System, Renewable Energy, Nigeria*

Introduction

The necessity and benefits of electricity to any nation cannot be over emphasized. The power utility is the bedrock for the growth and development of any nation because it will stimulate the development of every other sector thereby leading to rapid social and economic growth.

The purpose of exploiting smart grid in developing countries such as Nigeria is to examine the sustainable means of providing power system that is automated and intelligent technology based; which will take care of the power problem, thereby combating unreliable grid.

Smart grid is also called other names including "Smart Electric Grid," "Intelligrid," and "Future Grid". The smart grid increased efficiency and reliability is expected to reduce consumers' cost and carbon (II) oxide emission.

The idea of smart grid is fast growing in the power industry. The smart grid technology can gradually be introduced into the national grid that is not reliable and consumer friendly so as to put an end to the increasing struggle for reliable electricity supply necessary for sustainable development in the country. Therefore to achieve this sustainable development, the power system must move to the emerging smart grid technology.

The main aim of smart grid is to increase customer participation and be involved in decision making so as to create a reliable operational system whereby both utilities and consumers can interact.

It is imperative to have a robust and dynamic generation, transmission, and distribution network to have an efficient power system in Nigeria which is achievable by the successful deployment of a smart grid based system. This paper discusses and analyses the various smart grid technologies utilised in the generation, transmission, distribution and the prospects, 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 a typical smart grid system.

Figure 1: Different Elements of Smart Grid Architecture

SOURCE: *Padmanaban S., Bhadoria R.S., Blaabjerg F., Holm-Nielsen J.B. and Nathani S. (2019)*

Objectives

This study examined the impact of integrating Smart Grid Technology into Nigeria power transmission and distribution system. Specifically, the study;

1. Examine the importance of smart grid technology for effective development of Nigeria power transmission and distribution.
2. Review the challenges that may hinder the integration of smart grid technology in Nigeria power system.

Guidelines

1. The prospects for the successful deployment of smart grid systems in Nigeria.
2. The challenges that may possibly impede the successful deployment of smart grid technologies into Nigeria's power transmission and distribution system?

Basic Elements of a Smart Grid

Smart Grid architecture is very important to help manage the complexity of visualizing the challenges associated with system implementation and operation. Taking precautions prior to implementation helps reduce risks.

The implementation of smart grid infrastructure is pretty much sophisticated and complex. This also is very costly as compared to conventional electricity distribution system which is readily available with us. The architecture of smart grid as depicted Figure 2 is majorly composed of following.

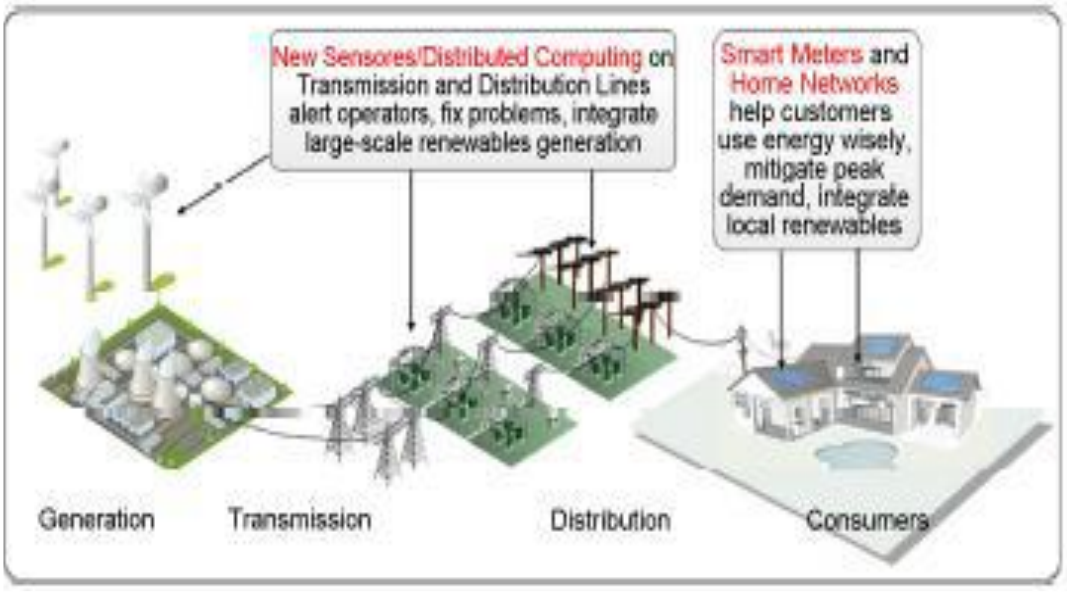

Fig. 2: A Simple Smart Grid Architecture

Source: *Ayaz k, Sulemani M.S. and Ahmed N. (2017).*

Transmission Stations: A transmission stations is where electric power is transferred from different generation sources to the distribution centers. The power generated is sent via the transmission lines to the distribution centers for further supply to the final consumer (user). This section of a typical power system requires the integration of smart devices in order to ensure a more effective operation that can minimize energy losses.

Distribution Centers: This is the place where a lot of operation takes place. Distribution centers receive power from transmission stations and redirect them to the consumers. Important tasks like fault detection, energy theft, load balancing and distribution and switching between various transmitting stations of thermal, tidal, hydro-electric power plants takes place in this section. The integration of smart monitoring devices will ensure proper operational efficiency.

IoT Devices: Smart Grid system cannot be realized without IoT devices. These devices (like sensors, actuators, smart meters) can be installed at each strategic point in the complete setup depending on the function it has to perform. They are useful in the process of energy transmission, metering and distribution and serve purposes that reflect the feelings and responses of the consumers. The data collected in the devices is highly treasurable for future pattern predictions and customization of supply.

Review of Some Previous Literature

The digitalisation of the Nigerian power system has been proposed to be the solution to the epileptic power supply (Ezenagu A.O., 2021). This can be actualized through the deployment of smart grid based system 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). Tsado et al. (2012) addressed some basic smart grid technologies. The work presented a model developed to illustrate the Demand Response System (DRS) application in the smart grid distribution network and also evaluated the benefits of using it in combination with conventional grids. 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 however did not address the different smart grid technologies that will be relevant to the Nigerian grid division.

Onohaebi and Omorogiuwa (2014) proffered the ideal utilisation of existing and more recent resources of both Independent Power Producers (IPP) and National Integrated Power Projects (NIPP) to improve the country's energy system via 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. The adoption and integration of this technology into the Nigerian power system architecture will reduce the building of new generating stations and transmission lines necessary to meet the projected growth in loads. It is recommended that if this innovation is accepted at generation plants, 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) analysed some literatures 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, and distribution sectors were briefly reviewed. 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 integrate mini-grids into the conventional grid, providing affordable access to citizens. The work provided a top-level schematic regarding how and where to deploy such technologies.

Prospects of successful Smart Grid Integration in Nigeria

Smart Grid is the utmost need of the currently existing out-of-date and obsolete electrical supply system which is vulnerable to frauds and wastage of energy. Building smart grid is the necessity of this present time not only because is almost fraud-proof but also cost efficient and eco-friendly. Therefore, bringing customers into the picture is one of the most prominent features of smart grid system. This technology also deploys renewable sources of energy like wind, tidal, solar and many more. It blends it with other non-renewable sources of energy like thermal. The system is smart enough to switch according to the demand and automatically lowers the load, hence saving money. According to Dahunsi F.M., Abd-Lateef A.O., Melodi A.O., et al (2022), smart grids have been established through research to save 30% more energy than conventional grids. Fault detection still remains one of the burdensome aspects of conventional energy grids because to detect the exact location and kind of fault is a very tedious task which can be made pretty easy by smart grid. Smart Grid automatically detects the fault and location on its own and tries to handle it with pre-defined measures. Other advantages of Smart grid are as follows;

- **Robustness**: Smart Grids is a more robust technology. It means that they are less prone to attacks and easy to manage.
- **Requires less Costs and Expenditure**: Managing and providing the load and power according to the demands lowers the cost and cuts expenditures.
- **More Compatible:** The fact that smart grid utilises various smart devices and other technologies proves this technology is interoperable.
- **More Environmental Friendly**: Since smart grid makes use of both renewable and non-renewable sources, it lowers the harmful emissions and reduces the risk of global warming**.**
- **Provides Smart Storage Facilities:** In a situation where the power generated is more than what was demanded, it also provides smart facilities, which can be utilised as and when required.
- **Suitable Load Balancing Technique**: It has the ability of balancing the load with techniques like switch-configuration. Smart Grid load balancing techniques via simultaneous switch/tie-line/wire configurations and tie-line addition helps save power by storing it when not needed.
- **Highest Security:** Security will be integrated into the design of the smart grid and this will require the implementation of practices and procedures by individual stakeholders. In this regard, the physical and cyber security risks can be managed to the highest standards possible.

This novel technological transformation has been highly impactful and has generated great momentum. There have also been a tremendous number of innovations coming up which would never have been possible without electricity.

These inventions when combined with the smart grid technology would completely revolutionise the way we view and operate events in the world. As the large cities are growing larger, the challenges which lie ahead are becoming much bigger. Integrating the infrastructure according to the digital age is where the major benefits of smart grid rest. This technology can be used to establish the basic foundation of smart city whose underlining facets contain water and gas supply, remote light monitoring, traffic control, public safety, efficient utility management and many more. This makes the economic and social system not suitable for the citizens until and unless the electricity distribution system is efficient and robust.

Features and Characteristics of the Existing and Smart Grid

The smart grid has self-healing, adaptability for energy generating and storage, active customer engagement, new market penetration, improved quality of power offerings characteristics and better system stability. Table 1 summarises the comparison between the existing grids 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).

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

Basis Consideration Factors	Existing Grid	Smart Grid
Customer Interaction	Bounded	Broad
Metering	Analog and Electromechanical	Digital, Real Time and Automated
Fault Detection and Correction	Manuel	Automatic, Auto-Restoration
Power Flow Control	Finite and limited	Automated and Comprehensive
Reliability	Reactive Protection	Pro-active Protection
Losses on Transmission and Distribution Lines	≥ 10% (Amuta, E., Wara, S., Agbetuyi, A. and Matthew, S., 2018)	≥ 2% (Amuta, E., Wara, S., Agbetuyi, A. and Matthew, S., 2018)
Information Flow	Single Direction	Bi-Directional
Power Generation	Central	Distributed
Environmental Pollution	Very High	Relatively Low
Grid Overall Efficiency	Low	High
Monitoring	Manuel	Automated
Energy Quality	Non-Essential	Essential with Price Relation Factor
New Products and Services	Limited Power Integrated	Full Power Integrated
Energy Generation and Storage	Primary Sources	Renewable Energy Sources
Operating System Integration	Low Degree Integration	High Degree Integration
Price Information	Not Reliable and Available	Reliable Full Price Information
Switching Method	Manuel	Automated
Communication	Non-Interactive (Non-Real Time)	Interactive (Real Time)
Sensors Usage	Few (Limited)	Many (Unlimited)
Participation	Superficial	Intensive
Control	Limited	Pervasive
Fault Response	Failures and Blackouts	Adaptive and Islanding

Source: *Dahunsi F.M., Abd-Lateef A.O., Melodi A.O., Ponnle A.A., Sarumi O.A. and Adedeji K.A. (2022)*

Challenges of Smart Grid Integration in Nigeria

A. Lack of Routine Maintenance Culture: The significant concern is the poor maintenance culture demonstrated over time in the power sector. The only evident maintenance performed by utility workers is getting rid of immediate identified fault. In contrast, scheduled maintenance is non-existent for power infrastructure 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).

B. Poor Regulatory Policies Implementation and Low Budgetary Allocations: Poor regulatory policies and implementation in most developing nations serve as a barrier to smart grid deployment because consistency and a well-driven strategy are imperative 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 smart grid deployments, many developing nations (like Nigeria) low budget allocations are another barrier to increased funding. Excellent and consistent regulatory policies will be helpful in the implementation of smart grid technology (Otuoze *et al.,* 2017).

C. Cyber-attacks, Infrastructure Theft, and Terrorism: Cyber-attacks are global phenomena that affect nations, companies, organisations, security services, and infrastructures. They can damage, corrupt hardware and software facilities that control the smart grid. In addition, smart grid relies on information technology, making it vulnerable to cyber threats (Reddy et al., 2014). Globally, developed countries spend billions of resources are spent to combat the menace and adverse effect of cyber-attacks with many developing nations like Nigeria budgeting little to counter cybercrimes. Therefore, smart grid deployment in Nigeria must be accompanied by well-structured cyber security for a secure and resilient system (Otuoze et al., 2017).

D. Transmission and Distribution Infrastructure Vandalization: Before the recent power sector reforms, Nigeria's transmission infrastructure and distribution equipment vandalism were at a very high occurrence rate. 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 et al., 2014).

E. Renewable Energy Sources Production Volatility: Renewable energy sources are based on natural phenomena, which vary based on environment (vegetation), time of the day, weather condition, 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).

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 and invest on the exploration and use of renewable energy sources. Therefore, generating and managing such reliable data is paramount to suitable and beneficial system planning and execution.

G. Corruption: The problem of corruption has backtracked Nigeria development among its counterparts. 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 many African 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 improve the deployment of smart grid system (Otuoze *et al.,* 2017).

H. Lack of Institutional Coordination and Organisation: 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 other countries such as Egypt, Kenya and South Africa 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).

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 anticipated long-term success of power sector is dependent on the sustainability at all the stages of the value chain, from generation 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 Nigeria Electricity Management Services Agency (NEMSA) and National Electricity Regulatory Commission (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 sector. This will contribute to energy supply and economic improvement.
Here are some guidelines and steps:

1. Develop renewable energy standards and standard compliance with international standard renewable energy cooperation bodies.
2. 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).
3. Energy data study research should be conducted on off-grid power generation, customer consumption profile and renewable energy.
4. Establish an updated National Energy Archive to adequately assist the Nigerian government and global organisations in evaluating the energy situation.
5. Energy education programs should be mandated at all levels of schools in Nigeria which will incorporate good maintenance culture.
6. 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.
7. Infrastructure upgrades, deployment of transmission enhancements solutions, and a transmission policy framework that encourages off-grid renewable solutions.
8. Establish research and development centres in educational institutions.
9. Government should establish a special commission that will collaborate with National Security Civil Defence Corp to counter corruption, vandalization, theft, cyber-attacks against electricity infrastructure nationwide.

Conclusion

The unbundling of PHCN, coupled with smart grid technology inclusion, would open up the prospect for electricity consumers and providers to explore renewable energy sources and distributed energy to meet power needs. Smart grid 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. Smart grid 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 Nigeria energy sector**.**

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. Some important 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.

Suggestions

To ensure the smooth deployment of the smart grid in Nigeria, the following factors should be considered.

1. Strict adherence should be made to standardising technologies for smart grid applications.
2. Regulatory bodies must be brave enough to perform their statutory duties, and discipline investors misled or harmed by the existing law.
3. In the future, the power industries must be compelled to do research and collaborate with scholars in carrying out research.
4. Important deadlines must be set and met, as laid down in the regulatory policies related to the implementation of Smart Grids.
5. Scholars should be mandated to carry out developmental research that can contribute to the nation's growth.
6. 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.
7. The government needs to raise public awareness about the need for citizens to protect public infrastructure jealously.

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