AN OVERVIEW OF SMART GRID: A NECESSARY SYSTEM FOR NIGERIAN TODAY AND FUTURE ELECTRICITY

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3rd National Engineering Conference on Challenges of Energy, Transformation, Technical Education and Transfer of Technology on Sustainable Economic Growth in Nigeria,
Organised by the School of Engineering, The Federal Polytechnic, Ilaro, Ogun State. March 7 – 10, 2016.

ABSTRACT

Stable and affordable electrical power is a vital requirement for development and growth of any economy. In about three decades ago, communities provided with electricity enjoys it and tends to develop faster than others in Nigeria but the story has changed. 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 conveyed to points where it will be distributed to various load centers. Power system is more exposed to the environment and thus the rate at which faults or disturbances occurs is high. Apart from the power plants and high transmission lines, every other information acquisition vis-à-vis fault occurrence, detection and clearance is done manually by personnel patrolling the lines. Based on this, 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 needed to solve this problem. The smart grid system is the option. Smart grid system allows for 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 paper looks into the capacity, composition and viability of smart grid system for Nigeria, as a solution to the energy challenges facing the power providing agency. This will make room for affordable and sustainable growth in the economy of the country.

Keywords: Smart Grid, Electricity, Meter, Fault, Plants

INTRODUCTION

Energy is the cornerstone and essential ingredient of any strategic plan in any nation that focuses at achieving sustainable development in all facet of life and its unrestricted access (especially modern energy sources) is a key to unlock any developmental initiative (IEA, 2006). Electricity popularly known and addressed as "NEPA" – an acronym for defunct National Electric Power Authority in this part of the world has proven to be the most convenient and efficient means of delivering electrical energy. Electricity once created and delivered is meant to be consumed at that point of delivery. For electricity to be stored, it must be converted into another form of energy EPN, (2011). As a result, the demand for electricity driven by End-users, must match the supply of it from the available generating stations at all times. Electricity in Nigeria is collected from two main sources – falling water and burning fuel. This industry, committed to providing quality and simplicity for customers, is currently facing three main challenges in the operation of the power grid in Nigeria. These challenges include: Meeting the Demand, Reliability and Quality (EPN, 2011). Additionally, the rapid growth in renewable energy systems as sources of supply and the increase in the use of non-linear loads have become an additional challenge to the utility industry in Nigeria. These trend are increasing the need for an intelligent system that will communicate between the National Transmission Companies and consumers so that renewable energy can be used more efficiently and electric power system run more reliably. Hence, greenhouse gases can be reduced.

For the past four decades, on any given day in Nigeria, roughly 70% of its citizenry are without electrical power and thus costing the Nigerian economy billions of Naira every year (NEP, 2012). This significant impact on the people and economy provides a strong incentive towards this work. The nation's grid infrastructure is ageing and needs to be replaced and that should be concurrently upgraded to take advantage of the latest technologies. Nigeria grid system has been and is still a centralized system with one way electron flow from generation along a transmission wire to distribution conductors and down to the end-users. In Nigeria, apart from the power plants and high transmission lines, every other information acquisition regarding fault occurrence, detection and clearance is done manually by personnel patrolling the lines. This process made the information available to the grid operators very limited in the sense that utility companies have to send workers out to gather much of the data needed to provide electricity. The workers read meters, look for broken lines or cables, fault equipment, etc. By this, grid operators can hardly know where there is fault or probably a blackout. Hence, customer calls becomes their sensors and monitors to define the geographical area affected. Based on these facts, more reliable system of information gathering for utilities is a necessity. Smart grid allows for bidirectional movement and measurement which creates an environment for small localized generations and renewable energy operators to push their unused power back to the grid and get accurately paid for it.

This paper surveys the past and present Nigerian electric grid infrastructure, presents an insight into the smart grid system and the need for the country to develop the dummy grid into smart grid. The remainder of the paper is arranged as follows; section A has the description of past, present and challenges of Nigerian power system. In section B, the smart grid as a solution to the challenges is presented. The associated challenges of deploring smart grid system in Nigeria is highlighted in section C and the paper is concluded in section D.

SECTION A: THE PAST, PRESENT AND CHALLENGES OF NIGERIAN POWER SYSTEM

The electricity generating power plant in Nigeria was first installed in the city of Lagos in 1898 with a generating capacity of 60 kW (Folorunso and Olowu, 2014). From then until 1950, the array of electricity development was in the form of individual electricity power undertaking scattered all over the towns which include Federal Government bodies under the Public Works Department and some by the Native Authorities (Folorunso and Olowu, 2014), (Awosope, 2014). In order to integrate electrical power in Nigeria and make it more effective, the then colonial government in 1950 passed the Electricity Corporation of Nigeria (ECN) ordinance No. 15 of 1950. With this ordinance in place, all those individual electricity power undertaking (popular among them are the ECN and Niger Dam Authority (NDA)) came under one body and become the National Electric Power Authority (NEPA) with effect from 1st April, 1972 (Okoro and Chikuni 2007), (Awosope, 2014). The growth experienced by NEPA is reflected in the number of generating stations shown in Figure 2.

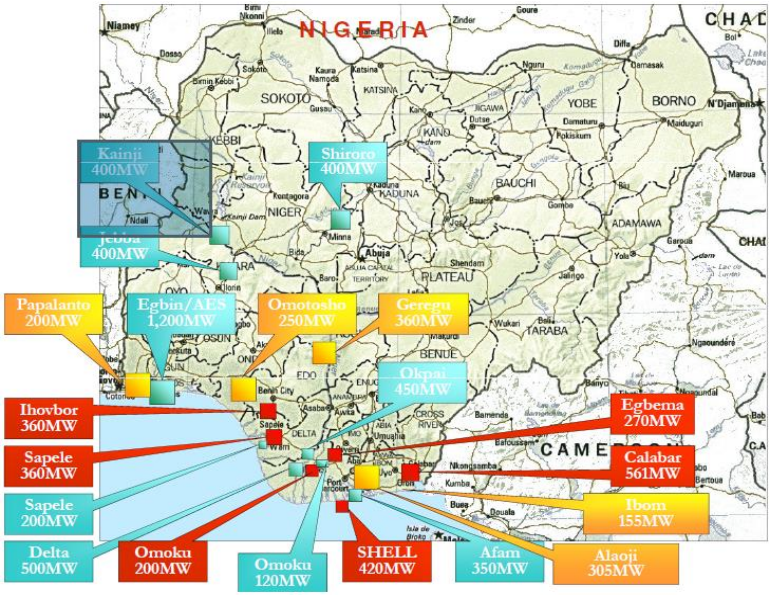

Figure 2: Key Power Stations in Nigeria

Source: Labo**,** 2010.

CHALLENGES OF NIGERIAN POWER SYSTEM

The Nigerian electricity systems face a number of challenges, which ranges from ageing infrastructure, continued growth in demand, the need to improve the energy security and to lower carbon emissions (Sambo, 2015). Despite the problems faced by electricity utility in Nigeria, the authority has played an effective role in the nation's socio-economic development thereby steering Nigeria into a greater industrial society. Though, they are yet to get a breakthrough like their counterpart in other developed and developing countries. Conversely, these challenges within the Nigerian power sector, principally concerning power outages and unreliable service, compelled the Nigerian government to enact the 2005 Electric Power Sector Reform Act (EPSR Act), which called for unbundling (privatization) the national power utility company into a series of 18 successor companies – six generation companies, 11 distribution companies and a national power transmission company called Transmission Company of Nigeria (TCN) Onohaebi and Lawal, (2010). Table 1 shows the names of the six generating and the eleven distribution companies.

Table 1: Nigerian Current Generating and Distribution Companies

Generating Companies	*Distribution Companies*
Egbin Electricity Generating Company	Abuja Distribution Company
	Benin Distribution Company
Sapele Electricity Generating Company	Eko Distribution Company
	Enugu Distribution Company
Afam Electricity Generating Company	Ibadan Distribution Company
	Ikeja Distribution Company
Kainji Electricity Generating Company	Jos Distribution Company
	Kaduna Distribution Company
Shiroro Electricity Generating Company	Kano Distribution Company
	Port Harcourt Distribution Company
Ughelli Electricity Generating Company	Yola Distribution Company

Unfortunately, the challenges for which privatization is targeted are still very much there after privatization (Ebewele, 2011). The power system network presently in Nigeria is still a radial system as against the present day interconnected ring circuit. To facilitate the connection of electrical power sources such as wind power and solar power to the otherwise highly controllable grid and to satisfy both the increasing demand for power, reliability and power quality, we need more sophisticated control systems to handle these challenges in a sustainable, reliable and economic way. Smart grids stands out to meet this rising demand, and increase reliability, quality of power supplied, increase energy efficiency, and is able to integrate low carbon energy sources into power networks (Leeds, 2009).

Nigeria today's electrical grid is a dumb grid and is Old, Dirty, Inefficient and Vulnerable. The grid is ill-equipped to handle both renewables and fossil fuel-based generations. The current state of the grid limits the potential of energy efficiency efforts, as there are significant lags in the system such that users of electricity typically are unaware of their usage level at any given time. Figure 3 is a typical Nigeria 330 kV transmission grid.

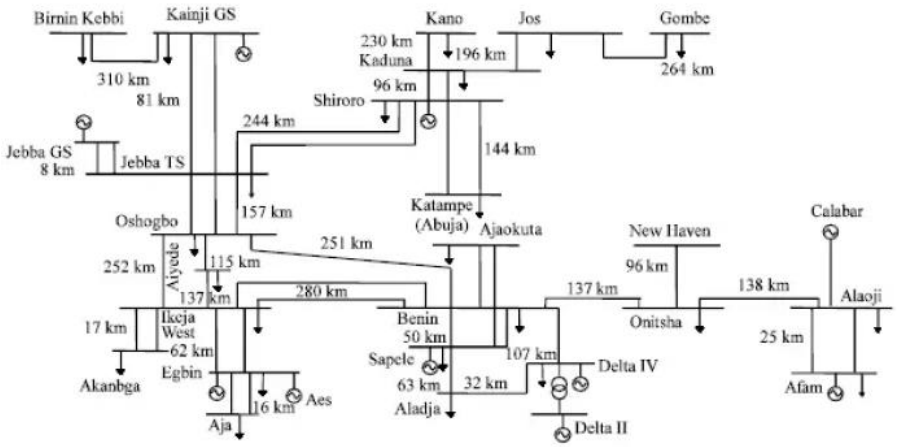

Figure 4: The Nigerian 330 kV transmission grid

Source: (Onohaebi, 2009)

CHALLENGES OF NIGERIAN POWER GRID

- Radial Lines with no redundancies
- Obsolete Substation Equipment
- Overloaded transmission lines and Substations
- Inadequate Coverage of Infrastructure
- Limited Funds for Development projects
- High Technical and Non-Technical loss
- Limited training opportunities
- Community issues during project execution

Means Onward

- Build Transmission Grid that can efficiently evacuate all generated power
- Create adequate network redundancies to ensure at least 99.9% reliability
- Reduce transmission loss to less than 5%
- Pursue Inter connection with neighboring countries for power exchange
- Aggressively, pursue reform of the sector to ensure development of infrastructure.

Critically considering the above challenges and way forward, there is need to build a not-so-dumb grid, and thereafter in about 10 years, an average intelligence grid. Then, within 15 to 25 years after that, it will really be the Smart grid.

SMART GRID

The "grid" amounts to the networks that convey electricity from the plants where it is generated through a transmission conductors to consumer's premises. The grid includes wires, substations, transformers, switches and much more (**Fig. 1)**. Therefore, Smart Grid is an electricity network that uses advanced digital and information and communication technologies to monitor, coordinate and manage the movement of electricity from all generating power plants down to End-users' individual appliances to meet the varying electricity demands of customers. It co-ordinates the needs and capabilities of all generators, grid operators, end-users and electricity market stakeholders to operate all parts of the system as efficiently as possible, minimizing costs and environmental impacts while maximizing system reliability, resilience and stability. Furthermore, Smart Meters, ICT and Energy Management Software are basic devices that make a grid smart. These tools are to be attached to houses, process measurement tools, upgraded transformers, transmitters and plants, and together they give consumers information to help them make intelligent decisions about usage and such decisions are conveyed back to the provider. Hence, allowing distribution and consumption to be done in a friendly manner anywhere via the internet EPN, (2011). An outlook of a smart grid is shown in Fig. 4 while some fundamental characteristics of smart grid are summarized in Table 1.

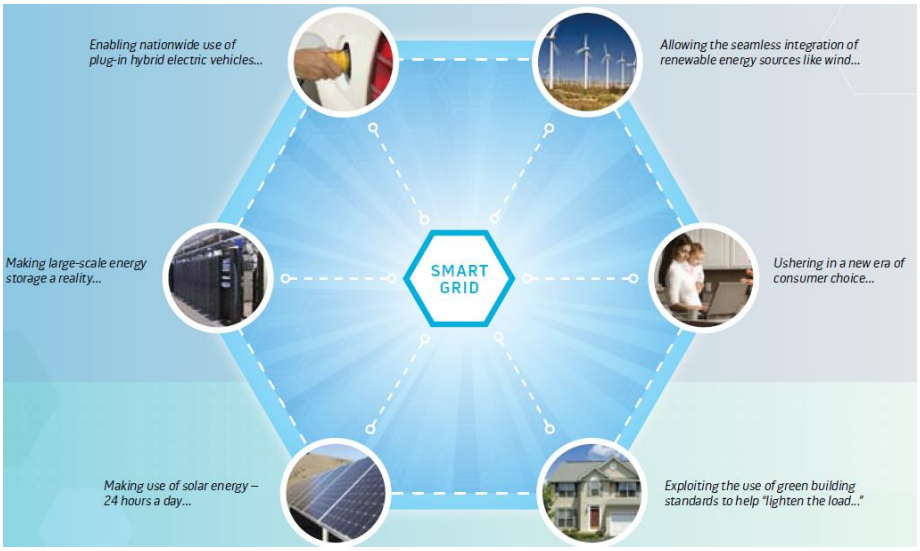

Fig. 4: An outlook of a smart grid

Source: DOE, 2010

Table 1: Characteristics/Advantages of a Smart Grid

Load Handling	The sum of the power grid load is not stable and it varies over time. In case of heavy load, a smart grid system can advise consumers to temporarily minimize energy consumption.
Decentralization of Power Generation	A distributed or decentralized grid system allows the individual user to generate onsite power by employing any appropriate method at his or her discretion.
Demand Response Support	Provides users with an automated way to reduce their electricity bills by guiding them to use low-priority electronic devices when rates are lower.
Enables informed participation by customers	These choices involve new technologies, new information about their electricity use, and new forms of electricity pricing and incentives. These modifications come as a result of consumers having choices that motivate different purchasing patterns and behaviour.
Accommodates all generation options	A smart grid accommodates not only large, centralized power plants, but also the growing array of customer-sited distributed energy resources like renewable, small-scale combined heat and power, and energy storage
Enables new products, services and markets	Some of the independent grid variables that must be explicitly managed are energy, capacity, location, time, rate of change and quality. Markets can play a major role in the management of these variables. Regulators, owners/operators and consumers need the flexibility to modify the rules of business to suit operating and market conditions.
Provides the power quality for the range of needs	Advanced control methods monitor essential components, enabling rapid diagnosis and solutions to events that affects power quality, such as lightning, switching surges, line faults and harmonic sources. Not all commercial enterprises, and residential customers, need the same quality of power. A smart grid supplies varying grades and prices of

	power. The cost of premium power-quality features can be included in the electrical service contract.
Optimizes asset utilization and operating efficiency	A smart grid applies the latest technologies to optimize the use of its assets. Maintenance efficiency can be optimized with condition-based maintenance, which signals the need for equipment maintenance at precisely the right time. System-control devices can be adjusted to reduce losses and eliminate congestion.
Provides resiliency to disturbances, attacks and natural disasters	Resiliency refers to the ability of a system to react to unexpected events by isolating problematic elements while the rest of the system is restored to normal operation. These self-healing actions result in reduced interruption of service to consumers and help service providers better manage the delivery infrastructure.

Source: Adapted from IEA, 2011.

ADVANCED METERING INFRASTRUCTURE

Advanced metering infrastructure (AMI) as a very salient technology, involves the physical smart meter as well as the communications infrastructure. These together will enable two-way flow of information, providing customers and utility's operations and control center with data on electricity price and consumption, including the time and amount of electricity consumed (Leads, 2009). This communication can be done using either of these three main competing technologies namely: broadband over power lines, radio frequency mesh networks, and cellular networks (Hicks, 2012). AMI will provide a wide range of functionalities:

- Remote consumer price signals, which can provide time-of-use pricing information.
- Ability to collect, store and report customer energy consumption data for any required time intervals or near real time.
- Improved energy diagnostics from more detailed load profiles.
- Ability to identify location and extent of outages remotely via a metering function that sends a signal when the meter goes out and when power is restored.
- Remote connection and disconnection.
- Losses and theft detection.
- Ability for a retail energy service provider to manage its revenues through more effective cash collection and debt management.

CHALLENGES OF SMART GRID IMPLEMENTATION IN NIGERIA

Every major change in any facet of life usually entails challenges and the smart grid is not an exception. Drawing from Bichlien, (2012), the following are the major barriers to achieving smart grid in Nigeria:

- Financial Resources
- Government Support
- Compatible Equipment
- Policy and Regulations
- Cooperation

Conclusion

Our nation's electric power grid that has served us for so long had rapidly run up against its limitations. Therefore, there is need for Nigerian utility managers and the entire populace to think Smart and embrace this new innovation "Smart Grid" today since the demand for cleaner and more reliable electricity supply keeps increasing. Though, it seems that the things involved are many but the future is now. Becoming part of it requires the simple installation of meters to monitor equipment more closely. The next could be connecting a network of loads to electricity system operator, thereby allowing companies to respond to the needs of the grid and start offering Grid Balance. Truly, the future to meet the yenning of the people over steady electricity supply is "SMART GRID."

REFERENCES

Murphy, P. et. al. (2010). *Enabling Tomorrow's Electricity System*: Report of the Ontario Smart Grid Forum, http://www.ieso.ca/imoweb/pubs/smart_grid/Smart_Grid_Forum-Report.pdf

Keogh, M. (2009). The Smart Grid: Frequently Asked Questions for State Commissions, The National Association of Regulatory Utility Commissioners, retrieved on October, 2015 from http://www.naruc.org/Publications/NARUC%20Smart%20Grid%20Factsheet%205 _09.pdf,

U.S. Department of Energy, (2010). The Smart Grid: An Introduction, retrieved from http://www.oe.energy.gov/DocumentsandMedia/DOE_SG_Book_Single_Pages (1).pdf

Bichlien H. (2012). Emerging Technology Smart Grid. Retrieved on 26th August, 2015 from http://www.ieee.org/go/emergingtech

Leeds, D. J. (2009). The Smart Grid in 2010: Market Segments, Applications, and Industry Players. Retrieved on August 26, 2015 from http://www.greentechmedia.com/

Hicks, C. (2012). The Smart Grid: Where We Are Today and What the Future Holds. Accessed on August 26, 2015 from http:/www.erb.umich.edu >SmartGridPaper_V7

International Energy Agency, (2006). *Energy and poverty*. IAEA Bulletin, Paris: *International Energy and Democratic Agency*, 24-29. Retrieved on 26th August, 2015 from http://

ENBALA Power Networks, (2011). *Smart Grid: The Future of the Electric Power System*. Toronto, USA. Retrieved on 26th August, 2015 from http:// www.enbala.com

Labo, H. S. (2010). *Current Status and Future Outlook of the Transmission Network.* Investors' Forum for the Privatization of PHCN Successor Companies. Nigeria. From http://www. Transmission/Company/of/Nigeria/Investor/Forum-Presentation

Awosope, C. A. (2014). *Nigeria Electricity Industry: Issues, Challenges and Solutions.* Covenant University 38th Public Lecture Series, Ota.

Niger Power Review, (1985) Development of the Electricity Industry in Nigeria (1960-1985), pp. 1-6.

Sambo, A. S., Garba, B., Zarma, H. I and Gaji, M. M. (2013). *"Electricity Generation and the Present Challenges in the Nigerian, Power Sector",* Energy Commission of Nigeria, Abuja. Nigeria.

Okoro, O. I and Chikuni, E. (2007). *"Power sector reforms in Nigeria: opportunities and challenges"*, Journal of Energy in Southern Africa, 18 (3).

Mohiuddin, A. (2011). *"The Privatization Transaction Process and the Opportunities for Investments in the Nigerian Power Sector."* Electric Power Sector Reform Workshop, Abuja.

Folorunso O. & Olowu T. O. (2014). *The Nigerian Power System till Date: A Review.* International Journal of Advance Foundation and Research in Science & Engineering (IJAFRSE) 1 (5).

Ebewele J. O. (2011). *Electricity Sector Reform and the Challenges of Power Generation in Nigeria*, Paper presented at the Summit on Energy and Sustainable Economic Growth, Ladi Kwali Hall, Sheraton Hotel and Towers, Abuja.

Onohaebi O. S. and Lawal Y. O. (2010). *Poor Maintenance Culture; The Bane to Electric Power Generation in Nigeria*, Journal of Economics and Engineering, pp28-33.