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Smart Grid Technology Potentials in Nigeria: an Overview

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Abstract

In recent time electricity system in Nigeria has suffered lots of difficulties that have led to the epileptic electricity supply without any solution improvement. The poor power system has affected the economic development of the nation. Despite all the different strategies of reform embarked on by the Nigeria government, the energy sector is still not efficient or reliable. This poor power system is as a result of the inadequate and inefficient power generation, poor transmission and distribution facilities, and out worn metering system used by electricity consumers.

This paper strives to present the way forward for the Nigerian epileptic electricity by reviewing the power sector as a whole and smart grid potential.This paper compare the traditional grid with the smart grid, looking at the smart potentials that the Nigeria grid can achieve reliability and efficiency. Several benefits can be achieved by the power supplied to the Nigeria masses to have a good quality and reliable supply if the smart grid potentials are considered.

Smart grid is an emerging technology that can lead to the modernization of the electrical power system, comprising of communication systems with different storage technology, distributed generation and loads. The content of this paper is to manage energy use more efficiently, save money on electricity, and provide technology and processes that are integrated into the appliances and devices consumers use in their everyday lives, all without causing significant disruption.

Keyword: Smart grid, Smart building, Epileptic Electricity, Power Sector, power system, Smart Meters

INTRODUCTION

The importance of electricity to any nation cannot be over emphasized. The power utility is the bedrock for the growth of the nation because it will enhance every other sector thereby leading to rapid social and economic growth[1]..

The reasons for exploiting smart grid in developing countries such as Nigeria is to look into providing power system that is computer, information and technology base. Which will take care of the power problem, thereby combating unreliable grid? [2].

Smart grid is also called other names including “Smart Electric Grid,” “Intelligrid,” and “Future Grid” [3]. The smart grid increased efficiency and reliability is expected to reduce consumers cost and also reduce CO2 emissions.[4].

The idea of SG is fast growing in the power industry. The smart grid technology can gradually be introduce into the national grid that is not reliable and consumer friendly so as to put an end to the increasing struggle for electricity, for sustainable development in the country and have a smarter electricity grids[5].

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 the operation system whereby both utilities and consumers can interact. [6]. Thus this paper describes an overview of the SG technology potentials in Nigeria that can improve the utilities.

THE OVERVIEW OF NIGERIA POWER SYSTEM

The Nigeria power system started in 1898. By 1951, the Electricity Corporation of Nigeria (ECN) was established. The Niger Dams Authority was also established 1962 which was to develop hydroelectricity. It was merged with ECN to form National Electric Power Authority, NEPA. NEPA operated as monopoly marketer in providing electricity to the population, but was not meeting with the demands for electric power [7]. NEPA was later transformed into PHCN when discovered that it was failing [8]. Through Reform Act 2005, PHCN was unbundled into the 18 companies; 6 generating companies, 1 transmission Company and 11 distributing companies[8]. *This* ushered in privatization so as to bring about the much needed improvement in the sector.

National Electric Power Policy (NEPP) also came on board in2001, with the Independent Power Plants forming an integral unit as a move by the federal government to increase capacity generation[9].

We have three major subsectors in the Nigeria power system which are; Generation (NESI), Transmission (TCN) and Distribution (DISCOS).

Generation

The currently generating plant has a capacity of 10,396 MW but as at December with less than 6056 MW capacity available. We have twenty-three generation stations and seven of them are over 20 years old, with average daily power generation that is less than the peak estimate for the present existing

The total installed capacity of the currently generating plants is 10,396 MW, but the available Capacity is less than 6056 MW as at December 2013. Seven of the twenty-three generation stations are over 20 years old and the average daily

power generation is lower than the peak forecast for the current existing facilities [7]. The present status of the Nigeria power generation in faces challenges ranging from delayed facilities maintenance, old-fashioned equipment/tools, in-sufficient generation [10].

Transmission

Transmission Company of Nigeria (TCN) was formed from the splitting which was a successor of the PHCN. It is divided into two departments namely System Operator and Market Operator [11]. The capacity of transmission is made up of about 5523.8 KM of 330 KV lines and 6801.49 KM of 132 KV lines [9.] This can be seen in Figure .1

Figure 1: Nigeria's Transmission Line System (Source: (Nnaji, 2011))

Distribution & Marketing

Distribution is the third sub-sector which is comprises of eleven electricity distribution companies (DISCOS).

The DISCOS include [1].

• Abuja Distribution Company

• Benin Distribution Company

• Eko Distribution Company

• Enugu Distribution Company

• Ibadan Distribution Company

• Ikeja Distribution Company

• Jos Distribution Company

• Kaduna Distribution Company

• Kano Distribution Company

• Port Harcourt Distribution Company

• Yola Distribution Company [12]

In some locations in Nigeria, the distribution network is very poor, the voltage profile is also poor which then makes the billing to be inaccurate.

Distribution department inter-faces with the public directly, hence the need to put in place adequate network coverage and provision of quality utility supply with efficient marketing and customer delivery of service cannot be over emphasized [1].

Challenges identified includes, weak and inadequate network coverage, overloaded transformers and bad feeder pillars, substandard distribution lines, inappropriate billing system , unfriendly practices between staff and power customers , inadequate logistic facilities such as tools working vehicles, telecommunication equipment[13].

SMART GRID INITIATIVE

The idea of a smart or intelligent grid has been around for over some years now.

Smart grid is an overhauled electrical grid that uses information and communication technology to bring together and act on information, such as information about the conducts of suppliers and consumers, in a computerized manner so as to improve the efficiency, reliability, economics and sustainability of the generation and transmission and distribution of electricity [14].

Smart grid technology observes the status of electric power system and intelligently take decisions, swiftly clear faults, restores power and monitor demand to maintain the stability and implementation of the electric power network formerly done by engineer [15].

The smart grid can increase the efficiency of the network system by using higher technology imaging diagnostic methods and hence allows for self-healing structures. The technology also carries out, remote monitoring and control which increases efficiency and in cases of human error or natural disasters, it minimize losses by anticipating problems [16][17]. The deployment of a smart grid [18]. The balance of the system improves and costs is reduced.

Smart grid systems are made up of two sections: hardware and software. The hardware includes counters, home equipment and big systems while the software include data sub-blocks and internet-based systems[19].

We have many alternatives for communication network structure, and the most important technologies are, wireless, WiMax and Broadband over Power Line Systems[20] [21]. Numbers of studies on Broadband over Power Line systems are constantly on the increase[22].

Smart grid technology delivers electricity from suppliers to consumers using robust two-way digital communications to control appliances at consumers' homes; this would reduce energy usage, increase reliability as well as transparency as seen in figure 2.

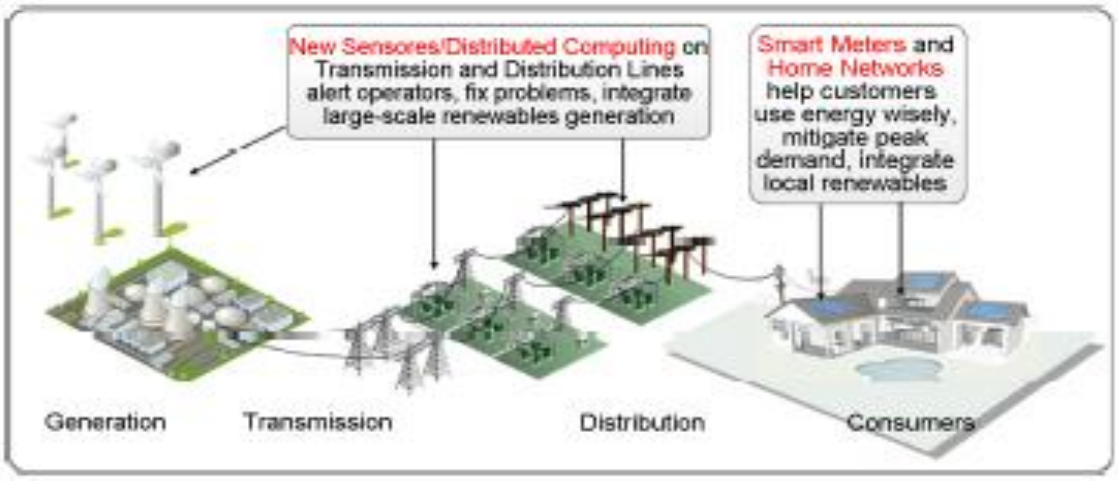

Figure 2: A concept of smart grid [3].

It is also the integration of communications networks with the electrical power grid in a manner to create an electricity-communications super-highway that is capable of monitoring its own health at all times, alerting the utility immediately when any problems arises, and automatically take corrective actions that can enable the grid to fail gracefully and prevent a local failure from spilling out of control [15].

The conventional grid includes centralized power generation, and at the distribution level unidirectional power flow and weak market integration. But Smart grids technology includes centralized and distributed power generation that is produced greatly by renewable energy sources. The technology integrates distributed and active resources including generation, loads, storages and electricity vehicles into the energy markets and electric power systems. It is the electricity network that smartly integrates producers and consumers to efficiently deliver electricity that is sufficiently capable of delivering safe, economic, reliable, efficient, and sustainable system [4]. Smart grid technology has a propensity to be driven by one of the two principal visions for enhancing electric power inter-communication for both energy suppliers and the end user customers [6].

Smart grid technology could be applied to all areas of the power system which include generation, transmission, distribution and consumption [13].

Several authors, government organization and bodies have given a lot of definitions of smart grid. A smart grid can be referred to as an upgraded electricity grid network that enables two-way information and power exchange between electricity suppliers and consumers, due to the prevalent incorporation of intelligent communication monitoring and management systems. [22] [16]. Accessing Smart Grid Benefits and Impacts: EU and U.S Initiatives.]. The US Department of Energy (DOE) defined smart grid as a system that will incorporate digital technology to improve reliability, efficiency and security of the electric system[23].

The International Energy Agency Technology Roadmap Smart Grid referred to the technology as an electricity network that uses digital and other advance technologies to monitor and manage the transport of electricity from all generation sources to meet the varying electricity demand of end-users. It will organize Several capabilities and needs of the grid operators, generations, end-users and electricity market stakeholders to operate all the different parts of the system as efficiently as possible, thereby reducing environmental impacts and cost while improving system reliability, resilience and stability beyond the smart grid being able to match supply with demand, it will also reduce the emission of greenhouse gases (GHG) by reducing the heavy dependence on fossil fuel plants through the integration of renewables that will make the electric system flexible and also usage will be more efficiently utilized[1].

Smart grid delivers electricity from suppliers to consumers using digital technology through control automation, continuous monitoring and optimization of distribution system, in order to save energy, reduce consumer cost and improve reliability [8].

GENERAL FEATURES OF SMART GRID

Smart grid can be characterized in the follows ways as in figure 3:-

- Interactive with users and markets
- Adaptive and scalable to varying situations
- optimized to make the best use of resources and equipment
- Pro-active instead of reactive to prevent emergencies
- Self-healing grids with advanced automation
- Integrated, merging monitoring, control, protection,
- Maintenance, EMS, DMS, AMI, etc.
- Having plug-and-play –features for network equipment and ICT solutions
- Secure & reliable Cost efficient
- Provides real time data and monitoring [6].

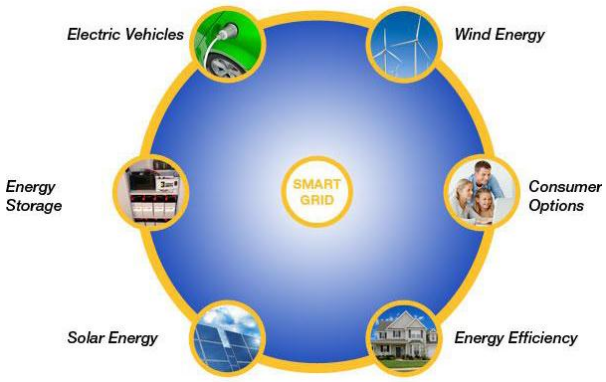

Figure 3: Smart grid features[24]

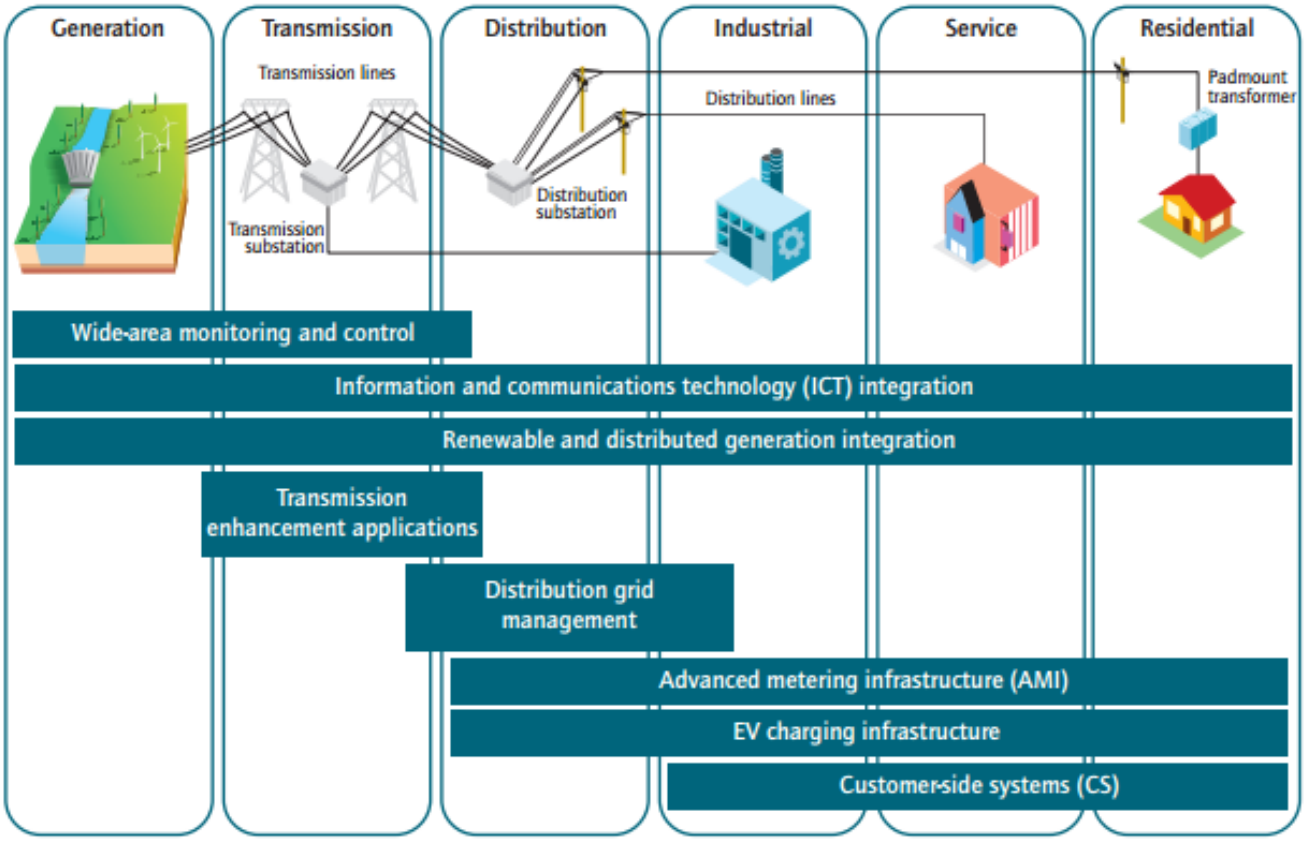

Figure 4: Smart grid technology areas [1]

SMART GRID TECHNOLOGIES SGT AND ITS BASIC REQUIREMENT

Technologies in the conventional grid are relatively outmoded when compared to developments experienced in locality like ICT. Smart grid concepts encompass a wide range of technologies [25] as in figure 4.

The technology will operate in a duplex communication system, encouraging better efficiency. It has been reported as a win-win situation for stakeholders. Consumers will get involved in power management decisions with the aid of household devices which will also profit Utilities in the long run. Initial cost estimates are huge but with returns on better efficiency and improved billing systems alongside many other improvements.[26].

Wide Area Monitoring and Control

WAMC is a reproving component of the smart grid that opens the door for energy consumers to become directly involved in monitoring and controlling energy use [14].

When these sensory device such as, phasor measurement units (PMU), accelerometers, infrared sensors, strain gauge and magnetic sensors, are connected in the Nigerian grid System, it can be monitored properly and this will help to allow the system to automatically adapt and respond to changing conditions within.

This will also enable the distribution devices to become intelligent remote agents on communication networks thereby providing data collected through these sensors back to the operator at the control centers.

The present technology on the conventional grid cannot monitor power flows throughout the distribution grid since measurements are only accessible at the distribution substations. Sensors and the smart metres located throughout the network will enable the collection of information [9].

Smart grid technology will enhance Real-time monitoring and display of utility components and performance, across interconnections and over large geographic areas. This will help system operators to understand and optimize power system components, behavior and performance. The Advanced system operation tools will help to avoid blackouts and facilitate the integration of variable renewable energy resources. Some monitoring and control technologies and advanced system analytics such as wide area situational awareness (WASA), wide-area monitoring systems (WAMS), and wide-area adaptive

Protection, control and automation (WAAPCA) contributes to the generation of data to inform decision making, lessen wide area disturbances, and therefore improve transmission capacity and reliability [26].

Other Modern means of monitoring data includes.

Supervisory Control and Data Acquisition Systems (SCADA) has been launched into Nigeria Power System by PHCN, used for data collection and monitoring of the generating station.

Visualizing Energy Resources Dynamically on Earth (VERDE) this is similar to Google Earth; the simulation allows grid modeling with geographical information using real-time sensor data and weather information.

GridLAB-D this is a flexible kind of simulation environment it, can be integrated with a variety of third-party data management and analysis tools. The GridLAB-D system has modules that can support the implementation of the following system simulation functions which includes: power flow controls, including distributed generation and storage, end-use appliance technologies, equipment, and controls,

consumer behavior including daily, weekly, and seasonal demand profiles, price response, and contract choice, energy operations, which also include distribution automation, load-shedding programs, and emergency operations, business operations, such as retail rate, billing, and market-based incentive programs. [9]

Oracle Utilities Meter Data Management, this software can monitor smart meters, primarily processing meter data. Other oracle software are Oracle Utilities Customer Care and Billing, Oracle Utilities Load Analysis, Oracle Utilities Meter Data Management, Oracle Database [13, "Oracle White Paper: Smart Grids-Strategic Planning and Development," [13].

Information Communication Technology Integration

In smart grid technology the undisclosed communications infrastructure support data transmission, if using private utility communication networks such as radio networks, meter mesh networks or public carriers and networks which entails Internet, cellular, cable or telephone, for deferred and real-time operation, and during outages. Along with communication devices, significant computing, system control software and enterprise resource planning software support the two-way exchange of information between stakeholders, and thereby enable more efficient use and management of the conventional grid [1].

Distributed Generation

DG Generally, is used to mean generation of a comparatively small-scale. Smart grid would enable distributed generation technology, with the aims to solve challenges related to generation as it currently is while providing ancillary services. The DG technologies which are currently being used for improved overall efficiency include: micro turbines, fuel cells, and reciprocating engines. Renewable energy sources such as PV cells, wind turbines and solar could also serve as DG source. DG systems could provide an economical alternative to peaking plants by helping reduce peak loads. Energy storage systems, both electrically and for thermally based, can ease the problem of dispatchability and controllability of these resources at the distribution level and small scale on commercial or residential building by decoupling the production and delivery of energy. Smart grids will help through automation of control of generation and demand (in addition to other forms of demand response) to ensure balancing of supply and demand. Storage technologies are the popular battery and flywheel. this helps to postpone the need for extra capacity infrastructure[27].

Transmission and Enhancement Technology

Most Equipment mostly found in PHCN substations include: switch gears, high rupturing capacity fuses (HRC), air-cored ring shielded reactors, lightening arresters, circuit breakers, power transformers, isolators, and bus bars, among other items, while the network components include power lines, cables, circuit breakers, switches, transformers, large size conductors, steel lattice towers, steel tubular poles, wooden poles, earthing equipment.

In Nigeria the conventional grid, transmission power system, will become important to fully utilize the existing transmission facilities instead of raising new power plants and transmission lines that are expensive to implement and takes long construction time. The Flexible Alternating Current Transmission

Systems (FACTS) and High voltage DC (HVDC) controllers' transmission technologies can be introduced into power systems to solve the above problems. FACTS make it achievable to control the voltage magnitude of a bus, active and reactive power flows through transmission line of a power system hence help to improve the control and transmission optimization. While HVDC is more efficient for long distance transmission, thus providing the platform for transmission of off-shore wind and solar farms to load centers. The smart grid allow for various concept and system that actually brings about it actualization. These concepts serve as the intelligent features of the grids and may integrate various technologies to help achieve the conclusive smartness [9].

With Line sensors used by Dynamic line rating (DLR), real time situations of the Network can also be monitored without the risk of causing overloads. [9]

High-temperature superconductors (HTS) can remarkably reduce transmission losses and enable economical fault-current limiting with higher performance, though there is a discussion over the market preparedness of the technology [18].

Distribution Grid Management

This smart grid technology involves Distribution and sub-station sensing and automation which can reduce outage and repair time, maintain voltage level and improve asset management. Advanced distribution automation processes real-time information from sensors with meters for fault location, automatic reconfiguration of feeders, voltage and reactive power optimization. Integration of Demand-Side

Management, Distributed Generation.

Advance Metering Infrastructure

Advanced metering infrastructure (AMI) technology is used in describing combination of a number of technologies which comprises of data management systems, smart meters that enable two-way flow of information, thereby providing consumers and utilities with data on electricity price and consumption, including the time and amount of electricity consumed. AMI will dispense a wide range of purpose which will include; distant consumer price signals, it has ability to collect, store and report customer energy consumption data for any required time intervals or near real time, it improved energy diagnostics from more detailed load profiles, it also has ability to identify location and the extent of outages remotely through a metering function that will sends a signal when the meter goes out and when power is reinstated, remote connection and disconnection, losses and theft detection, it has ability for a retail energy service provider to manage its revenues via more effective cash collection and debt management Technology Road Map on Smart Grids. International Energy Agency [20].

Customer-Side System

Customer-side systems, which are used to help manage electricity consumption at the industrial, service and residential level, these include energy management systems, energy storage devices, smart appliances and distributed generation. This part of the smart grid involves Energy efficiency gains and peak demand reduction which can be accelerated with in-home displays/ energy dashboards, smart appliances and local storage. The Demand response involves both manual customer response and automated customers, price-responsive appliances and all thermostats that are connected to an energy management system or controlled with a signal from the utility operator [1]

Smart Meters

A smart meter in a smart grid replaces analogue mechanical meters with digital ones that records usage in real time. Smart meters are like the advanced metering infrastructure meters that provides a communication path extending from generation plans to electrical outlets (smart sockets) and other smart grid-enabled devices. Through smart meters, the utility companies able to get ever increasing amounts of information on how customers are using electricity. [13]

CONCEPTUAL SMART HOME

Smart houses is becoming a reality in the developed world with Energy effectiveness and reduction in Carbon foot prints riding high on the agenda of most of the Governments and States. The authors in

[28], gave model set of it is as shown in Figure 5 .

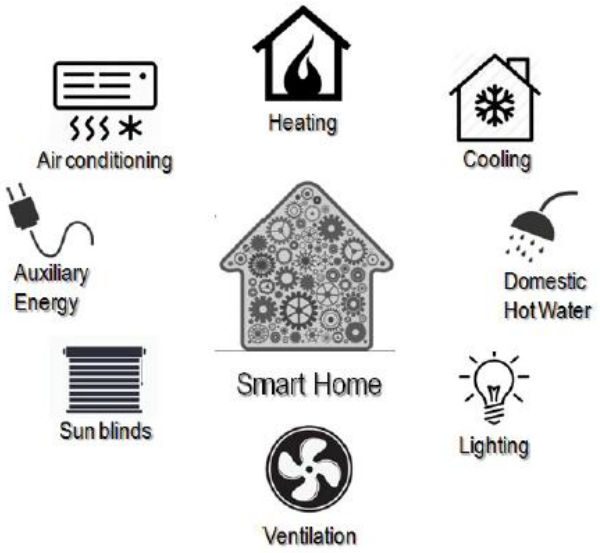

Figure 5: Smart Home Network

With The technological advancement in Smart meters, internet communication a smart devices, it is achievable and sustainable.

The lists of Smart devices we can find in a smart grid include:

- Smart Electricity meter.
- Gas Smart meter (more likely to communicate via Electricity Smart Meter).
- Water Smart meter (more likely to communicate via Electricity Smart Meter).
- Home Automation Gateway (more likely to communicate over internet and radio).
- Home Smart Appliances (more likely to communicate over radio).
- Heating, Ventilation and Air-conditioning, Lightning, Robotics [4].

Smart Grid Technology benefits

The Smart Grid Technology will be of benefit in various ways to Nigeria and her citizens can benefit from the proposed integration of smart grid technology.

- The smart grid will absolutely fuse many types of electrical generation and storage systems with a easier interconnection process that is equivalent to "plug and play" technology of the retail computer industry and accommodate all generation and storage options.
- Since the smart grid uses the latest technology optimize assets, it will optimize the usage efficiency
- With the data side management of the smart grid, it will be able to supplies varying grades (and prices) of power and ensure the level of power quality

desired to consumers

- The modernized smart grid can also do self–healing performing self-assessment so as to respond and restore the grid in case of fault, to maintain reliability.
- The grid will prevent attacks and reduce physical and cyber vulnerabilities on the power system because of its design operation.
- The grid technologies enable consumers to have choices that prompts different purchasing patterns and behavior. The Consumers help balance both supply and demand on electricity because they have new information about their electricity use, and new structure of electricity pricing and incentives [1]

From The significance of the smart grid potentials and its technologies highlighted, it is crystal clear that when the Nigeria traditional grid system is compared with the smart grid, the smart grid technology has better potentials to make the Nigeria grid more cost-effective, energy-efficient and reliable hence providing polished power system with active consumers participation. [6]

The smart grid will have an all over the place sensors for monitoring network, equipment and power quality. Thereby, improving power quality, reduction of system losses and the overall system efficiency will also be strengthen

Smart grid will be able to curtail time of used energy pricing so that price of energy during high demand periods is comparatively higher than that of low demand periods [27].

SMART GRID AND THE TRADITIONAL POWER GRID

Table 1 shows the disparity between Smart Grid and the traditional power grid

The Smart grid technology integrates communication technology and information technology with power systems engineering to allow ubiquitous control and operation. The major constraint between traditional grids is also shown[15].

Table 1: Disparity between Smart Grid and the traditional power grid [Source: [15].

Criteria	Traditional grid	*Proposed Smart Grid potential*
Customer interaction	Limited	Extensive
Metering	Mainly electromechanical	Digital (enabling real-time pricing and net metering)
Restoration following Disturbance	Manual	Self-healing
Power flow control	Limited	Comprehensive, automated
Reliability	Prone to failures and cascading outages; essentially reactive	Automated, pro-active protection; prevents outages before they start
Transmission/Distribution line Losses	Above ten percent (10%) loss of the total power in the transmission/distribution lines.	About two percent (2%) loss of the total power in the Transmission/distribution lines.
Flow of information	One-way	Two-ways
Generation of electricity	Central	distributed
Pollution of the environment	Very high	Low
Efficiency of the overall grid	Poor	excessive
Ability to monitor	Blind	Self- monitoring
Topology of the grid	Spiral	networked

Everybody talks about vision 2020; this vision might be a mirage if smart grid is not allowed to take over the conventional grid gradually. The former United State President Barack Obama once said that "We will fund a better, smarter electricity grid and train workers to build it – a grid that will help us ship wind and solar power from one end of this country to another" [13]. He talked about smart grid and how it will gradually take over the exiting grid as the technologies advances. Therefore, as there is advancement in technologies, there is need for an energy management system. [14]

CONCLUSION

Nigeria is currently struggling in its energy sector with effects visible in the socio-economic life of her populace. The good news however is that potentials are to remedy the situation. the concept of the smart grid becomes imperative. Smart grid has a demanding and critical role in the future of efficient power generation and distribution.

Renewable energy system is an innovative option for electricity generation, especially the PV system as it is a clean energy resource. However, to achieve this goal, a lots of issues need to be solved or addressed. These issues are basically related to the design and size of the system, the suitable and effective model which can cover the technical and financial aspects of PV smart grid to supply electricity, and the equalized electricity price for integrating PV in a smart grid system. Further nanotechnology based solutions and applications in the devices/components could help us in near future for improving the efficiency using smart grid..

Smart grid will open up the potential for entirely new services (or improve on the existing ones) such as fire alarms, phone systems, etc. and new markets in areas of systems components related to plug-in hybrid electric vehicle (**PHEV**), advanced storage systems, communication system, power flow control systems, etc. Fourthly, it will provide improved power quality. The Nigerian electric grid is characterized by so many unreliability issues ranging from brownouts to rolling blackouts and uncontrolled blackouts. In fact, the problem in our energy sector is not only how little we generate but also the power quality at which the little generated is being delivered to the consumers.

To achieve this, monitoring system infrastructure (MSI) would be used to gather information vis a vis the operating of the network, state of equipment and quality of product. With the smart grid being able to maintain correct local balance between production and consumption, overvoltage and under-voltages would be mitigated and hence customers can then enjoy improved voltage quality. Smart grid will be able to heal itself – expects and instantly responds to system problems in order to mitigate or avoid power outages and improve power quality.

The goal of a smart grid, as it relates to consumers, is to manage energy use more efficiently, save money on electricity, and provide technology and processes that are integrated into the appliances and devices consumers use in their everyday lives, all without causing significant disruption. A successful smart grid will allow consumers to receive valuable and understandable information that enables them to make intelligent and informed choices about how they use energy, all while minimizing consumer cost and out-of-pocket expenses that could arise with the implementation of the smart grid. The willingness of consumers in Nigeria to accept and participate in the smart grid could be severely impaired if the cost outweighs the benefits.

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