An Overview of the Composite Design of Smart Grid with Cognizance to Power Demand, Power Production and Power Deficit in Nigeria

O. C. Igwilo*, O. Oodo, C. P. Nnabugwu, G. K. Ojikpong, P. O. Anyasi, I. A. Adesina

National Center for Energy Efficiency and Conservation (Energy commission of Nigeria), Faculty of Engineering, University of Lagos
Lagos, Nigeria

Corresponding author's email: ossyigwilo [AT] gmail.com

ABSTRACT---- ***In past decades, Nigeria's power grid has been suffering from epileptic power supply due to the load demand as a result of population increase without creating a solution for grid expansion. If this trend continues, it will lead to more frequent grid collapse. There are also other challenges caused as a result of short circuit issues, system over load, high voltage surge, over voltage, weather hazards such as rain storms that cause the falling of trees on power lines interrupting power and solar storms that cause electromagnetic interference. Therefore, there is need to decentralize Nigeria's national power grid system and incorporate a central smart grid system and interconnect them by exploiting the regional power resource potential in every region of the country including Niger state and connecting them in such a way that they will use automation control with the deployment of the smart grid to detect faults after rain storms, absorb electromagnetic interference from solar storms, detect system overloads and also provide grid expansion infrastructure to buffer the increasing population that could cause grid collapse or system overload that is, if more people are added to the region without increased energy access. The result of this research work designed a power grid system of central smart grid monitoring system, a mini grid automation control system to be able to distribute power adequately or limit power when there is reduced load usage. The design also has three power mini grid systems strategically placed in different locations of the country that has a significant power resource potential. If this smart grid infrastructures are deployed this will tackle and solve the power problem in the Nigeria.***

1. AIMS AND OBJECTIVES

The general aim and objectives of the research is to demonstrate an overview of the composite design and emphasis of the implementation of an effective and efficient smart grid power system that will address the challenges of epileptic power due to power demand, power production and power deficit in Nigeria.

2. INTRODUCTION

A Smart grid is any grid that is completely automated. Humans are usually referred to as "smart people" because of the capability to respond quickly to changes in the surrounding. In the same way, Smart grids have the ability to respond automatically to the variations in electrical parameters responsible for the smooth functioning of the grid. This is possible with the help of sensors and micro-controllers. The smart grid forms a network of interactive systems operated by automation protocols for effective management, controlling and conserving or re-routing the power that can be saved at minimal level. Moreover, at power peak levels, the micro-controller sends a signal for the concentration of power to targets which have higher power demand.[1]

Definition of a smart grid system

It is a network of an integrated transmission lines, substations, transformers, conventional and unconventional power sources including every component that deliver electricity from the power plant to homes or businesses. It is a concept regarding digital technology application and electric power network. It offers a lot of valuable technologies. Smart grid includes electric network, digital control appliance, and intelligent monitoring systems. All these can deliver from producers to consumers, control energy flow, reduce the loss of electricity and make the performance of the electric network more reliable and controllable.[1]

Such modernized electricity networks are being promoted by many governments as a way of addressing energy independence, global warming and emergency resilience issues. Smart meters may be part of smart grid, but alone do not constitute a smart grid.

A smart grid includes an intelligent monitoring system that keeps track of all electricity flowing in the system. It also incorporates the use of superconductive transmission lines for less power loss, as well as the capability of integrating renewable electricity such as solar and wind. When power is least expensive, the user can allow the smart grid to turn on selected home appliances such as washing machines or factory processes that can run at arbitrary hours. At peak times, it could turn off the selected appliances to reduce demand and cost.

Significance of smart grid

The smart grid can respond appropriately to different types of incidence, such as weather issues or failing equipment. It can also identify a tree branch that is falling on an electric line and then alert the producer, thereby extending the life of the equipment.[1]

Equipment could remain in operation with a smart grid, until a computer detects its failure, thereby saving unnecessary equipment replacement cost. The smart grid can also solve power outages and other service interruptions. When the smart grid overlays the electrical grid, computerized devices monitor and adjust the quality and flow of power between its sources and its destinations. The devices recognize peak usage hours when most people are in their homes and also detect energy wasting appliances**.**

Characterization of Smart grid system

Smart grid must produce power from multiple and widely distributed sources.

A smart grid must integrate the characteristics or deliver the activities described below:[1]

- Self-healing from power disruption events.
- Enabling active participation by consumers in demand response.
- Operating resiliently against physical and cyber-attacks,
- Providing power quality for 21st century needs.
- Accommodating cell generation and storage options.
- Enabling new products, services and markets
- Optimizing assets and operating efficiently

Characteristic components of a smart grid include: intelligent appliances capable of deciding when to consume power based on pre-set customer preferences.

3. MOTIVATION

The Traditional Power Grid

From 1439 to 1886, there were industrial revolutions which gave rise to new technologies like the development of printing press by Gutenburg in 1439.The first commercially steam engine was developed in 1712. In 1882, gas powered automobile was patented by Karl Benz.[3]

Furthermore, in 1879, Thomas Edison invented the electric bulb which formed the foundation of the current modern light bulbs. In 1882, Edison switched on the first electric grid in lower Manhattan. Few years later, electricity was widely made available using robust grids on every continent on earth.[2]

The twentieth century witnessed the emergence of internet which transformed communication and information exchange globally.[2]

Currently, many of the electrical grid systems have become obsolete. The current high demand for electricity has resulted in the generation of new supply sources of electric energy. This situation has transformed into a new technological innovation, which still exists under an infrastructure that is more than a century old.

The current grid system is faced with inefficiency issues, security threats, inhibited alternative energy including power quality disturbances and black outs probably caused by extreme weather or overload.

Smart grid is the solution that is desperately required in solving many global energy problems. Like the printing press, automobile and light-bulb inventions which preceded the creation of electricity grid and have been greatly improved, the current grid system is also enhanced through innovation, designing new electrical interactive system and implementing the new smart grid system. [3]. Comparative analysis between the traditional power grid (conventional) and smart grid (unconventional) (3) is presented in Table 1.

Table 1: Comparative analysis between Traditional power grid (conventional) and Smart grid (unconventional)[3]

	Traditional power grid	Smart grid
1	Radial topology	Network topology
2	Manual recovery	Semi-automatic and automatic recovery
3	Handling emergency through staff and telephone	Decision support system and reliable prediction.
4	Limited pricing information	Complete pricing information.
5	Fewer user options.	More user options.
6	One way communication.	Two way communication
7	Mechanization	Digitization
8	Pays attention to failures and disruptions	Adaptive protection measures.
9	Finite control	Pervasive and intensive control system

History of Smart Grid

Commercialization of electric power began in the 19th Century. With the incandescent bulb revolution and the promise of the electric motor, demand for electric power exploded, sparking the rapid development of an effective distribution system. At first, small utility companies provided power to local industrial plants and private communities. Some larger businesses even independently generated their own power seeking better efficiency and distribution. Utility companies pooled their resources, sharing transmission lines and quickly forming electrical networks called grids. George Westinghouse boosted the industry with his hydroelectric power plant in Niagara Falls. His power plant was the first to provide power over long distances, extending the range of power plant positioning. He also proved electricity to be the most effective form of power transmission. As the industrial utility businesses expanded, local grids grew increasingly interconnected, eventually forming the three national grids that provide power to nearly every inhabitant of the continental United States of America.[4]

The Eastern interconnect, the Western interconnect, and the Texas interconnect are linked and form what is referred to as the national power grid. Technological improvements of the power systems were largely raised after the World War II. Nuclear power, computer controls and other developments helped fine tune the grid's effectiveness and operability. However, the national power grid has not kept up pace with modernization. The grid evolved little over the past fifty years.[4]

The USA government is serious about overhauling the current electrical system to 21st century standards. With today's technology, the power grid can become a smart grid, capable of recording, analyzing and reacting to transmission data, allowing for more efficient management of resources and more effective powering of appliances for consumers. This requires major equipment upgrades, rewiring and implementation of new technology. The process will take some time, but improvements have already begun towards making it a reality. Miami, Florida is among the first major cities with smart grid system, a new stage of technological evolution, leading to a more brighter and cleaner future.[4]

Smart grid technologies have emerged from earlier attempts at using electronic control, metering and monitoring. In 1981, Automatic meter reading (AMR) was used for monitoring loads from large customers and this evolved into the advanced metering infrastructure whose meters could show how electricity was used at different times of the day. Smart meters have continuous communications/ interactions with the systems so that monitoring can be done in real time and can be used as gateway to demand- response-awareness devices called "smart sockets" in the homes. Early forms of such demand side management technologies were dynamic devices that passively sensed the load on the grid by monitoring changes in the power supply frequency. Devices such as industrial and domestic air conditioners, refrigerators and heaters adjusted their duty cycle to avoid activation during the periods the grids were suffering peak condition effects on power consumption.[4]
Beginning in 2011, Italy's Telegestore project was the first to network large numbers of homes using Smart meters connected via low Bandwidth power line (BPL) communication. Recent projects use Broadband over bandwidth power line (BPL) communications or wireless technologies such as mesh networking that is advocated as providing more reliable connections to disparate devices in the homes as well as supporting metering of other utilities such as gas and water.[4]. A design of the smart grid system is shown in Fig 1

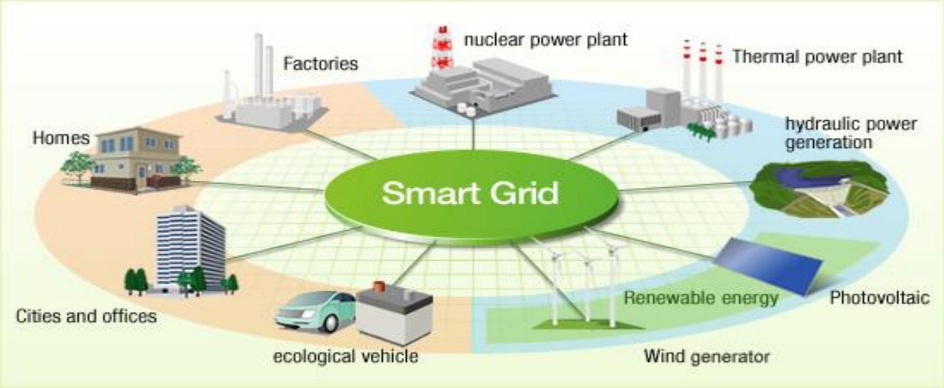

Fig1: A design of the smart grid system

Monitoring and synchronization of wide area networks were revolutionized in the early 1990s when the Bonneville Power Administration expanded its smart grid research with prototype sensors that are capable of very rapid analysis of anomalies in electricity quality over very large geographic areas. The culmination of this work was the first operational Wide Area Measurement system (WAMS) in 2011. Other countries are rapidly integrating this technology. [4]

Denmark Experience

The smart grid operation has been an issue earlier on, due to prior development of wind energy, as well as an overall ambitious climate policy. In 2008, the Danish government installed a commission on climate change policy with the task of showing how Denmark can phase out fossil fuels by 2050 (Danish Commission on climate change policy, 2010). This is in line with the goal of the Smart Energy for Europe Platform(SEFEP), which is to have a fully decarbonized, reliable and predominantly renewable power supply in Europe before 2050.[5] The new government, in office in October 2011, formulated mile-stones for its energy policy as follows: 50% of electricity consumption covered by wind in 2035, and by 2050, all energy needs will be predominantly covered by renewable energy (The Danish government, 2011). An energy agreement voted in Parliament with a vast majority has confirmed these goals, provided financing, announced a smart grid strategy for 2012 and stipulated a thorough revision of electricity market regulation.[6]

The Danish state is in a good position to organize a smooth transition since it owns a national Transmission System Operators (TSO)

Italian Experience

The situation in Italy is characterized by

- A dominant role in generation, distribution and sales of the former national monopoly ENEL (Italy's national power company) with 30 million customers in Italy and 30 million abroad, mainly in Spain.
- An independent national TSO, Terna spa. The largest grid operator in Europe.
- A dense and relatively reliable grid.
- An important and rapidly growing role of distributing generated power from wind and recently also solar (2nd largest Photo-Voltaic market globally in 2011).
- A relatively flexible mix of conventional centralized generation with an important role of hydro-electricity, a dominant role of natural gas and the absence of nuclear power.
- High electricity prices.

The general conditions are therefore rather favorable to a sustained growth of renewables and smart grid projects. Effectively, Italy is one of the leading countries in relation to smart grid investments.

Italy has been a pioneer in smartening its grids and especially in installing smart meters. Between 2001 and 2006, Enel deployed smart meters (bi-directional communication, power measurement and management capabilities, software controllable switch) to all its 30 million customers. Obtaining considerable cost savings, Enel achieved the return on investments (EUR 2.1 Billion) in just four years. [7]

The earliest and still largest example of a smart grid is the Italian system installed by Enel S.P.A of Italy. Completed in 2015, the Telegestore project was highly unusual in the utility world because the company designed and manufactured their meters, acted as their own system integrator, and developed their own system software. The Telegestore project is widely regarded as the first commercial scale use of smart grid technology to the homes and buildings, and delivers annual savings of 511 million euro at a project cost of 2.1 billion euro.[4]

United States of America (USA) Experience

In the USA, single states had an element of competence in handling its own grid system. Liberalized markets, state monopolies, different kinds of market systems co-existed. The federal jurisdiction is only concerned with interstate exchange.

In 2011, generally, coal produced 42% of electricity generated, natural gas produced 25%, nuclear produced 19% and hydro-power source produced 8%.

The problems with grid reliability and capacity such as distribution system, automation, peak saving with demand side management, rapid detection and isolation of grid failures, as well as energy conservation have been key concerns driving the interest in smart grid technologies. The prospect of growing distributed power generation and e-mobility are strongly contributing positively to this interest. Smart grid development in the USA has been enhanced by the allocation of USD 4.5 Billion to grid modernization under the American Recovery and Re-investment Act in 2009.[8]

In the USA, the city of Austin in Texas has been working on building its smart grid since 2013, when its utility first replaced 1/3 of its manual meters with smart meters that communicate via a wireless mesh network. It currently manages 21,111 real- time devices (smart meters, smart thermostats and sensors across its service area) and expects to be supporting 511,111 real time devices in 2019 servicing 1 million consumers and 43,111 businesses.[4] Boulder, Colorado completed the first phase of its smart grid project in August 2017. Both systems use the smart meter as a gateway to the home automation network (HAN) that controls smart sockets and devices. Some HAN designers favor decoupling control functions from the meter, out of concern of future mismatches with new standards and technologies available from the fast-moving business segment of home electronic devices.[4]

The Canadian Experience

Hydro One power station, in Ontario, Canada is in the midst of a large-scale smart grid initiative, deploying a standard compliant communications infrastructure from Trilliant Power Company. By the end of 2011, the system addressed 1.3 million customers in the province of Ontario. The initiative got the "best Automatic Metering Reading (AMR) - initiative in North America," an award from the Utility Planning Network. [4]

The city of Manheim in Germany is using real time Broadband power line communications in its model city Manheim called the "MoMa" project. [4]

Adelaide in Australia also plans to implement a localized green smart grid electricity network in the Tonsely park re-development. [4]

China Experience

China is ready and determined to play a leading role in the global market grid industry. China's state grid corporation has decided to invest $250 billion in electric power infrastructure upgrades in five years; another 240 billion will be spent between 2016 and 2020. In each period, 45 billion are designated to implement smart grid technologies. [9] According to Green Tech Media (GTM) forecast for 2016,[10] the smart meter market would account for $8 billion and the distribution automation market for $6 billion. With this plan, the state grid corporation pursues a double objective: strengthening the local grid and empowering a corresponding Chinese equipment industry.[10]

The Chinese grid needs upgrading and smartening for two reasons: The first one is that electricity consumption is expected to double over the next decade, while supply is already grappling to meet demand, also due to coal shortages. In 2010 annual utility revenues exceeded $300 billion[10]. The second reason is that fluctuating renewables and electric vehicles are going to play a vital role. Total wind generating capacity is expected to be 100 GW in 2016. Moreover, energy supplies (coal, gas, hydro-power, wind farms) are more abundant in the west, thousands of kilometers apart from the large consumption centers. [10]

Portugal Experience

InovGrid is an innovative project in Evora in Portugal that aims to equip the electricity grid with information and devices to automate grid management, improve service quality, reduce operating costs, promote energy efficiency, conservation and environmental sustainability and also increase the penetration of renewable energies. It will be possible to control and manage the state of the entire electricity distribution grid at any given instant, allowing suppliers and energy service companies to use the technological platform to offer consumers in formations and added-value energy products and services. This project is to install energy grid places.

Portugal is at the cutting edge of technological innovation, advancement and service provision in Europe.[4]

The developed nations are planning ahead in ensuring that there is sufficient transmission capacity to interconnect energy resources, especially renewable sources; developing the suitable and efficient connections for offshore and other marine technologies as well as enhancing intelligence of generation and demand in the grid to ensure sustainability of the grid. The traditional grid power system of some developing nations, such as Nigeria, are still cumbered with many challenges including epileptic power, overload , power theft, weather issues, failing equipment (e.g. Transformers and many other issues). The latter gave rise to the justification of the present research

4. JUSTIFICATION

There are three reasons why the traditional grid should be converted to smart grid.[21]

- **The increased energy demand**: The energy demand rapidly increases owing to the new technologies and regional developments such as: new residential areas, high potential industrialization and electric motors that can soon be introduced to Nigeria.
- **Decreasing the losses and illegal usages**: The losses and illegal usages seen in transmission and distribution lines will be reduced by smart grid by detecting any additional and illegal load.
- T**he increased production and carriage capacity in the existing plant**s: In order to meet the increased energy demand there is need to integrate the distributed energy sources such as solar and wind to the system.
- **Due to the current poor metering issues**: There is need to introduce advanced metering infrastructure business plan for adequate and optimized monitoring and tariff plan.

The present state of the Nigerian National Grid

In the past decades in Nigeria, the populace has been suffering from epileptic power supply. However, recently power production has increased to 7000MW in 2018. Nevertheless, this is a very tiny fraction of what is required for the Nigeria's power demand which was about 31,240 MW in 2015. Furthermore, the national grid generated 4389 MW and sent out 4038MW.[11, 12] This transmitted power lacks wide coverage as many part of Nigeria are not covered by the grid and still in darkness. Some of the earlier transmission lines have been damaged by road construction and vandalism. However, there is increase in power demand that is far greater than supply, due to the increasing population and development. This has resulted to overload, leading to power fluctuation and thus results in epileptic power and shutdowns. Also, Power production has been cumbered with instability for a very long period due to shortage of gas supply to generating plants including power theft and wastages. There are many communities in Nigeria where there is no power grid coverage indicating future high demand for power. Again, power produced is not properly distributed based on demand/supply approach. There is poor consumer metering such that most residential consumers are billed by estimation. There are very few metered houses and industries that could have improved the power generated revenue. The current Nigerian power distribution grid is ineffective and inefficient; hence, power theft and wastages are encouraged. Lack of proper power monitoring system in Nigeria is affecting the achievement of optimized generation, transmission, and distribution/marketing. Also, the current power price is discouraging investors while the price for supplied gas for power is discouraging to the oil and gas operators thereby forcing the latter to prefer supplying to Liquified Natural Gas plant and to other industries than to power companies, especially during peak demand periods. The fiscal policy structure for grid management in Nigeria is not creating an enabling environment for an effective and efficient grid system.

For these reasons there is need to enhance the current conventional grid system and to introduce other alternative sources like photovoltaic, fuel cell and wind energy, in order to optimize and close this energy demand/supply gap in Nigeria. Furthermore, the power fiscal policy structure should be reviewed and enhanced.

Consequently, from the above discussion, due to increased power demand, to meet up with the industrial and commercial requirements, coupled with the deficit in power generation, there is therefore an urgent need to adapt a better system that must seamlessly provide adequate and cost effective electrical energy to power residential, industrial, business and other outfits in the nation. This leads to the smart grid system.

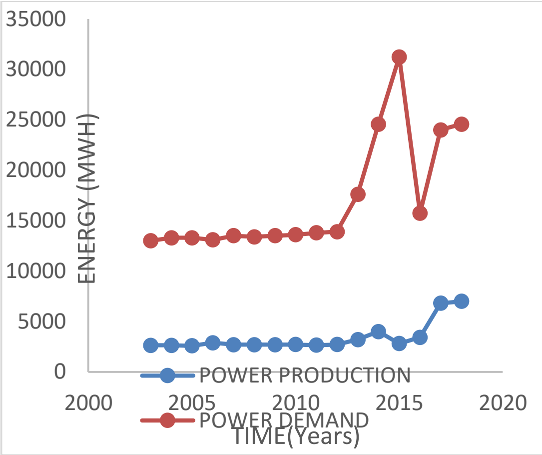

Fig 2: Composite Plot of Nigerian Power Production/Demand against time [11-20]

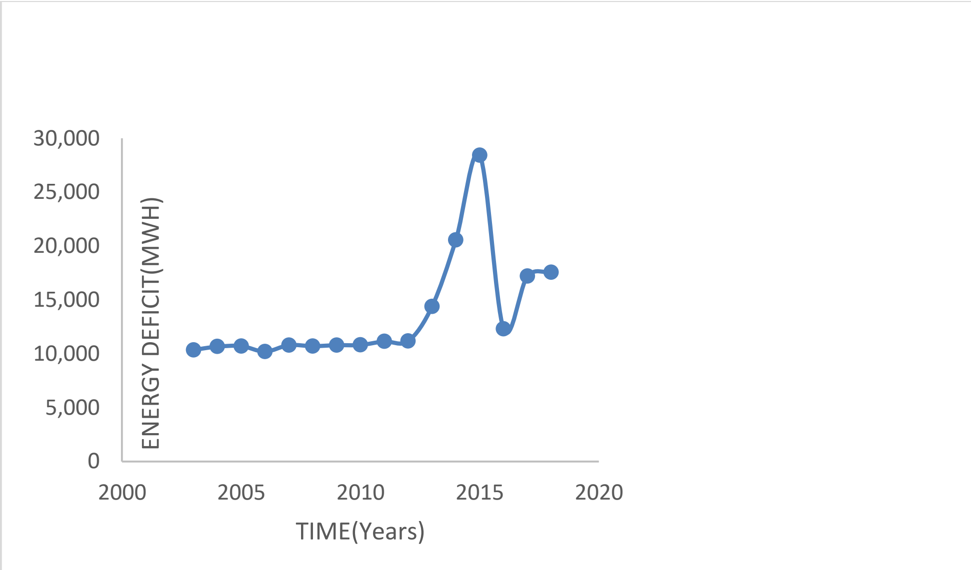

Fig 3: Plot of Power Deficit against time

(Deficit is the difference between demand and production)

Nigerian historical power deficit analysis

The above Fig 3 is showing the energy deficit profile against time. The plot history showed that there was a period when the demand for power peaked despite very low supply. This could be due to investors influx followed by increase in area developments with minimum power generation, transmission and distribution. Later, the supply increased while the demand dropped resulting to a sinusoidal behavior in the energy deficit plot around 2014 followed with a sudden plunge in 2015. This latter behavior could be attributed to the exit of investors, decrease in developments, and industrial shutdowns and yet there was improvement in supply. This may be due to increase in gas supply, higher number of working independent power stations, improved water level for the hydro power sources resulting to improved generation, transmission, and distribution. Yet in all these developments, many customers are given estimated bills and they are not happy or satisfied. There are many loses due to vandaliza0tion, developmental damages, undetected and unauthorized connections within the grid system. It should be noted that many parts of Nigeria are not connected to the grid and therefore are in total darkness. The renewable energy source connection to the grid has not taken off. Smart Grid system is almost non-existent. The metering and other monitoring system in the power web can be improved to be smart.

5. METHODOLOGY

The first activity was to identify a community to be used as a model such as the University of Lagos which is to be modified and replicated.

The power requirement of each electrical appliance was determined in each approved sampled house of the community.

The university model was modified and replicated but this time incorporating a smart grid system which University of Lagos do not employ. Using the University power grid situation, a more robust system was developed to give a composite smart grid system after much research and understanding of the University of Lagos power grid model.

The major emphasis is to decentralize the National grid and divide them into smaller mini grid networks to address the needs of increasing population. It should be noted that the smart grid system can also be expanded due to increased load needs.

A central smart grid can be simulated to be placed around Niger state to feed other mini grids in the North, south west, south east and south-south.

The smart grid is designed to detect faults in the power system and make corrections. There is also the automated control system to monitor the distribution of power when there is more or less load in the system. The three mini grid power systems represent the region power resource potential which is controlled by the mini-grid automation control system and the smart grid system for the generation, transmission and distribution of power.

This model can actually be replicated in the entire Nigeria and will be very effective. The power smart grid systems in fig 4 below are similar to the grid networks used in first world or western world and have been proven and tested to be sustainable.

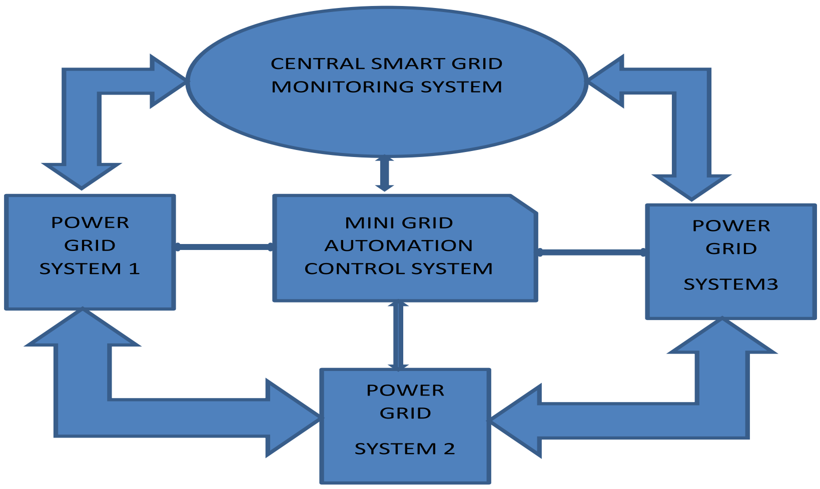

Fig 4 below shows this research output of an overview of smart grid architecture design that agrees with the conventional design.

6. CONTRIBUTION OF THE RESEARCH TO KNOWLEDGE

The design of the effective smart grid power system in Nigeria will be an additional innovation in the power industry that will significantly lead to cost saving, reduced power theft, and outages.

It will ensure effective monitoring and management of power supply/ consumption.

The research will add to power data base system of Nigeria.

7. OUTLINE OF RESEARCH/PLAN WORK

The conduct of the research will involve extensive literature search for the previous and present states of power usage in developed Nations and in Nigeria, with a view of simulating the most appropriate model design for the Nigerian nation. The results simulated will be benchmarked prior to the research conclusion.

8. RESEARCH SUPPORT

The National Center for Energy Efficiency and Conservation provided both technical support and time periodically for the study. Additional support was received from the discourse with Engineer Ajayi, the Operations Engineer at the University of Lagos Power Station..

9. RECOMMENDATION

Smart energy pre-paid meters should be incorporated into the smart grid systems for energy consumption control, tariff billing and for return on investment.

10. CONCLUSION

If the smart grid system can be implemented in Nigeria, this will revolutionize the power sector, transforming the National grid into a sustainable level of efficiency, reliability with also uninterrupted power supply deliverables which will become the new reality and the years of epileptic power supply will be a forgotten issue.In 2011, the United Nations had a plan to implement smart grid systems in sub-Saharan Africa.This is still in progress and with time it could be successful.[22]

11. REFERENCES

1. *Why the smart won't Have the Innovations of the internet Any time soon*. 2006; Available from: <http;earth2tech.com/2009/06/05/why-the-smart-grid-wont-have-the -innovations-of-the-internet-any-time-soon/>.
2. Omotosho T.v., A.T.J., Achuka J.A., Olawole O.O, , *Smart grids and the Renewable Energy component.* Physics department, Covenant University, 2015: p. 243.
3. Association, T.N.E.M. 2011; Available from: < www.nema.org/ smart grid>.
4. IEA, U., Siemens *brief history of smart grid.* 2010: p. Pg GS4.
5. Ruggero .S, R.P., *Learning from the Public consltation on the German network development plan*, in *SEEP working paper*2012, Smart energy for europe platform. p. 1-47.
6. Agency, D.E. Global Cooperation; Available from: http://www.ens.dk/da-Dk/politik/Dansk-klima-og-energy-politik/ politiskeaftaler/Documents/Accelerating% 20green% 20 energy%20 towards % 2202020.pdf.
7. Energy, U.S.D.o., *The Smart Grid: An Introduction.* 2010: p. 1-48.
8. Markets, F., *Fierce energy an smart grid news.* 2015.
9. Hart, M., *China pours Money into Smart grid Technology.* Centre for American progress,Washington DC 2011.
10. Media, T., 2016.
11. Imo E.E., C.B.C., Abode I.I., , *Statistical Analysis of Electricity generation in Nigeria using multiple linear transgression model and Box Jenkins Auto-regressive model of order".* International Journal of Energy and power Engineering 2017. **6**(3): p. pp 28-33.
12. Ezennaya O.S., I.O.E., Okolie U.O.,Ezeanyim O.I.C, , *Analysis of Nigeria's National Electricity Demand Forecast (2013-2030).* International Journal of Scientific and technology Research, 2018. **3**(3).
13. Vision(REV), E., *Metering New York state Reforming the Energy Vision(REV)*
14. PSU.
15. Times, P., *https://www.premiumtimesng.com/business/182309-nigerias-power-generation-drops-to-2800mw.html*.
16. TV, C., *https://www.channelstv.com/2014/04/23/nigeria-power-generation-hits-4100mw/*.
17. Data, W., *https://www.worlddata.info/africa/nigeria/energy-consumption.php*.
18. hub, E., *http://www.nigeriaelectricityhub.com/2016/09/14/fg-gives-update-on-current-power-generation/*. 2016.
19. Times, P., *https://www.premiumtimesng.com/news/more-news/240258-nigerias-current-electricity-generating-capacity-6803-mw-fashola.html*, 2017.
20. Mundi, I., *https://www.indexmundi.com/g/g.aspx?c=ni&v=81https://www.indexmundi.com/g/g.aspx?c=ni&v=81*.

21. B, R., *Smart grid technologies and applications.* Gazi University,Ankara,Turkey, 2016.

22 Manuel Welsch United Nations UnIversity 2011 "Smart and Just Grids: options for Sub -Saharan Africa" <https://ourworld.unu.edu/en/smart-and-just-grids-options-for-sub-saharan-africa>