International Journal of
Innovative Research in Technology, Basic and Applied Sciences
p-ISSN: 2465-7301 | e-ISSN: 2467-8171

IJIRTBAS
Vol. 6, No. 1
December, 2020

A Review of Nigeria's Electricity Crises: The Smart Grid

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Article DOI: 10.48028/iiprds/ijirtbas.v6.i1.01

Abstract

Energy is surely important for Nations development in the present century and in sufficient availability. For Nigeria to fast-track its developmental processes, the lack of stable electricity most be resolve with significant improvement. Al though, electricity was first produced in this country fifteen years after it was introduced in England, Nigeria electricity generation per capital stands at a little above 100KWh while UK is at around 323 TWhin 2019. Huge spending reported by various Governments during the present civilian administration in Nigeria still left the situation in worst state, as well as a recent upward review of electricity tariff in the midst of COVID-19. The irony is the enormous potential available to generate electricity all over the country at low cost with quick return of investment. This paper is aimed at reviewing workable solution in Policy making and looking at the situation in a different perspective, rather than continuous dependant on gas for thermal plants and building standalone solar electrification but investing more on the existing National Grid system to make it smarter, which allows integration of other power source as well as a road map in achieving such.

Keywords: *Renewable energy sources, Internet of things, COVID-19, Grid, Smart grid*

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Background to the Study

Having a stable electricity supply is paramount to every nation's development but in Nigeria it is always absent or in epileptic supply. The first electricity generation in Nigeria as reported by (Onochie et al., 2015; Okoye, 2014; Olatunji et al., 2018) was in 1896 while (Awosope, 2014) reported that the first power plant was installed in 1898, in Marina, Lagos. Both set claim this date was fifteen years after electricity was produced in England and (Tucker, 1977; Therkelsen, 2018) reported that it was in 1881, a street in England benefitted for the first time the experimental outcome of public electrification which collaborated or ascertain the correctness in figure of references (Onochie et al., 2015; Okoye, 2014; Olatunji et al., 2018). Nevertheless, electricity generation in Nigeria was in the late 18th century, although during this initial stage, its demand was quite low as electricity was simply used for lighting with just some few houses powered. The utilization was somewhat below 60000W in total and of course the Country's total Capacity installed was at 60 kW. All through this early period there was no meaningful improvement until the end of Northern Governance in 1914 which give birth to the new Nigeria that some few states decided to provide electricity to its immediate locality. The first two states to achieve this status were Port Harcourt and Kaduna while other states keyed in accordingly: Enugu and Maiduguri followed, then Yola, which was at that time the Capital of Gongola State, next was Zaria in Kaduna State, after which came Warri and Calabar (Awosope, 2014).

This period mostly involves the individual electrification by various states but by 1929 it provided the avenue to create the body having an acronym NESCO, Nigeria Electricity Supply Company, as an electric utility company saddled majorly with the process of constructing power stations using hydroelectric technology which was situated at Kurra, near Jos a state in the North central part of the country. The individual electrification did not change much either until the British Government passed the ECN ordinance No. 15 of 1950, that empowers the Electricity Corporation of Nigeria together with Niger Dam Authority to take control of all electricity facilities in the country there by incorporating all generating, transmitting and distributing power utility (Awosope, 2014). Its main breakthrough was in 1962 when it constructed 132 KV power lines that connected the power station at Ibadan to that in Ijora. A desire to have a single body to handle power generation and its effective supply was again initiated in 1972 and by 1973 the two bodies became one with the appointment of a GM, General Manager as well as a trade mark name NEPA, National Electric Power Authority (Awosope, 2014; Olatunji et al., 2018; Onochie et al., 2015). Electricity generation and supply appreciated significantly during these eras of revitalizing the energy sector in Nigeria, that resulted in the inauguration of some committees to look into ways of providing electricity to majority focusing more on local poor communities and new urban settlements (Awosope, 2014; Onochie et al., 2015). Unfortunately, Nigeria's power infrastructure faced serious setback during the Military regimes as it virtually allows all the Hydro-Electric generating dams to decay including the transmission and distribution equipment to go into disuse majorly due to wrong policies and corruption. These resulted in the stagnation, of all the electrification systems in the country. To overcome this problem maintenance effort must be improving upon in addition to workable policies adoption and most importantly moving the Nations' electric grid to smart grid to make way for renewable sources inclusion to the sources of electricity generation with compulsory overhaul of the existing sources.

Of course the past administration did well in its privatization steps that reshuffle the energy institution again significantly which bring in private investor in Power Holding Company of Nigeria, some GENCOs and DISCOs but unfortunately not a thing has change. The Government's attitudes need to be critically looked into, terms of privatization scrutinized as the issue of tariff upward review is creating issues in already challenging post COVID-19 era.

The next sections will discuss the sources of generating electricity in Nigeria, generating plants and its present nature, the nation grid type, micro grid and smart grid connection, renewable energy integration, policies review, recommendation and conclusion.

Sources of Generating Electricity

Nigeria, even after major neglect in power generation from hydro, has currently two types of electricity generating power plants which are;

a. Hydro – Electric Power
b. Fossile Fuel / Thermal Power Plant

Of these two sources of generating power there is the domination of gas-fired. Even though thermal base is 81% (Okoye, 2014) while Hydro provides very little percentage when it is not new that Nigeria has huge potentials, in hydro-power, to generate over 11 ,250MW of electricity, and 3500MW from several (277) small identified hydro sites (Ahmed Abdulkadir and Al-Turjman, 2018; *Nigeria Energy Situation - Energypedia. Info*, n.d.). Nigerian potentials in renewable sources is quite enormous for solar and wind mainly in the northern region of the country as well as along its coastal line (Ahmed Abdulkadir and Al-Turjman, 2018). This is excluding the facts that, Nigeria also have in stock magnitude of potential in other sources of energy generation referred to as conventional resources (Awosope, 2014; Onochie et al., 2015). Nigeria is among the top great oil producing countries worldwide with the highest reserves for Natural gas in the whole of African and it presently occupies the ninth spot in world list of leading exporters of (LNG) Liquefied Natural Gas since 2012(*The World's Biggest Natural Gas Reserves*, 2013), even with these resources and the significant financial commitment by the present civilian administrations the situation is still very bad.

Generating Plants

In Nigeria, presently there are over 30 generating plants with different status of existing, ongoing and new projects (Sambo et al., 2012). Table 1 below shows some few power plants and their locations. The table did not capture some power plants such as Mambilla and Zungeru Hydro power plants expected to be built in Taraba and Niger States respectively as well as Obajana and Omoku Thermal power plants to be located at Kogi and Rivers State respectively (Sambo et al., 2012).

Table 1: Power Generation Plants

S/N	Name of Power stations	Location
1.	Egbin Thermal Station Power Plant	Egbin
2.	Geregu 1 Power Plant Station	Geregu
3.	Geregu Station II Power Plant	Geregu Kogi State
4.	Ibom Station Power Plant	Ikot Abasi Egbin
5.	Aba Station Power Plant	Aba Abia State
6.	Afam IV – V Power Plant Station	Afam Rivers State
7.	Afam VI Power Plant Station	Afam Rivers State
8.	Alaoji Power Plant Station	Abia State
9.	Calabar Power Plant Station	Calabar
10.	Egbema Power Plant Station	Imo State
11.	Ihovbor Station Power	Benin State
12.	Okpai Station Power	Okpai
13.	Olorunsogo Power Station	Olorunsogo
14.	Olorunsogo ll Power Plant Station	Olorunsogo
15.	Omotosho l Power Plant Station	Omotosho
16.	Omotosho ll Power Plant Station	Omotosho
17.	Sapele Station Power Plant	Sapele
18.	Sapele II Station Power Plant	Sapele
19.	Ughelli Power Plant Station	Delta State
20.	Kainji Power Station	Kainji Lake
21.	Jebba Power Station	Lake Jebba
22.	Shiroro Power Station	Lake Shiroro
23.	AES Power Plant	Lagos
24.	Odukpani Power Plant	C / Rivers
25.	Azura Thermal Station Power Plant	Benin city
26.	Papalanto Thermal Station Plant	Abeokuta

Present Situation of Power Plants

In March 2005 when the power sector reform bill was signed into law by the civilian administration of President Obasanjo, huge resources was pumped to the sector that resulted in the construction of smaller power plant creating a total of about 1,200MW aiming to achieve the national target of 6500MW of 2006 (Sambo et al., 2012; Ahmed Abdulkadir and Al-Turjman, 2018). The stated target of 6,500MW was not achieved rather there was report of significant drop in power generation by the end of 2009 to about 2,700MW from installed capacity of 8,900MW due to aged power plants (Sambo et al., 2012). Although IAEA in its Country Nuclear Power profiles, for Federal Republic of Nigeria 2018 edition, reported 6,056MW was generated by 23 grid-tied power plants with an installed capacity of 12,522MW (Erepamo, 2018). The summary below indicates the performance of the 23 power plants connected to the national grid, generating a total of 3,977MW from installed capacity of 12,067MW.

1. AES (Constructed in 2001, capacity Installed 270 MW and at 0 MW capacity)
2. AFAM IV-V (Constructed in 1982, capacity Installed 580 MW and at 0 MW capacity)
3. AFAM VI (Constructed in 2009, capacity Installed 980MW and at 559MW capacity)

4. ALAOJI (Constructed in 2015, capacity Installed 335 MW and at 110 MW capacity)
5. DELTA (Constructed in 1990, capacity installed 740 MW and at 300 MW capacity)
6. EGBIN (Constructed in 1985, capacity Installed 1320 MW and at 502 MW capacity)
7. GEREGUI (Constructed in 2007, capacity Installed 414 MW and at 138 MW capacity)
8. GEREGU II (Constructed in 2012, capacity Installed 434 MW and at 90 MW)
9. IBOM POWER (Constructed in 2009, capacity Installed 142 MW and at 92 MW)
10. IHOVBOR (Constructed in 2012, capacity Installed 450 MW and at 225 MW)
11. JEBBA (Constructed in 1986, capacity Installed 570 MW and at 255 capacity)
12. KAINJI (Constructed in 1968, capacity Installed 760 MW and at 181MW)
13. OKPAI (Constructed in 2005, capacity Installed 480 MW and at 391 MW)
14. OLORUNSOGO (Constructed in 2007, capacity Installed 335 MW and at 232 MW)
15. OLORUNSOGO II (Constructed in 2012, capacity Installed 675 MW and at 87MW)
16. OMOKU (Constructed in 2005, capacity Installed 150 MW and at 0 MW)
17. OMOTOSHO (Constructed in 2005, capacity Installed 335 MW and at 178 MW)
18. OMOTOSHO II (Constructed in 2012, capacity Installed 450 MW and at 90 MW)
19. RIVERS IPP (Constructed in 2009, capacity Installed 136 MW and at 0 MW)
20. SAPELE (Constructed in 1978, capacity Installed 900 MW and at 81 MW)
21. SAPELE II (Constructed in 2012, capacity Installed 450 MW and at 116 MW)
22. SHIRORO (Constructed in 1989, capacity Installed 600 MW and at 350 MW)
23. ODUKPANI (Constructed in 2013, capacity Installed 561 MW and at 0 MW)

Out of these numbers only three are hydro power plants with the remaining twenty gas fueled type of thermal turbine. These as well provide clear information on the grid connected actual capacity available for distribution; compare to a value of 12,067MW in Installed Capacity what is actually ready for distribution is a total of 3,977MW which is quite below half the Installed capacity with five plants not generating at all.

The statistics, from the data above confirmed that the present electricity generation in Nigeria is not only stagnant but increasingly worsening even after on-grid generation was increased by over 5000MW between 1968 and 1991. These make it difficult to understand all the claimed investments on infrastructure and its maintenance, as there is still no meaningful change in electricity generation. Similarly, the on-grid generation is affected by shortage of gas supply, inadequate security provision to utility generally from transmission to final distributing and again the losses encountered due to far distance between power plants, substation and residences or industries. It can also be inferred that the major problem is the fact that the Government have completely neglected other source (hydro) and focus fully on thermal based even as it is not yielding result. For example, 58 licenses were approved for electricity generation of 26,000 MW, all thermal based with the primary advantage of being cited in close proximity to oil and gas fields, just about 12,000MW generation capacity was built out of which less than 4,000 MW are generated at the end of 2019 (Awosope, 2014).

The Grid

It took about ten years to build the first power grid 1885-1895. And at present there are 9200 power grids all over the world producing and supplying consumers with around 1 million MW of electricity on daily basis. The power grid is the main supply route consisting of a network of transmission lines, substations and transformers including all required accessories that combines together to supply electricity to various region at the same time (Awosope, 2014; Faizan, 2017; Olatunji et al., 2018; Onochie et al., 2015). The grid starts from a traditional (conventional) grid, then improves to micro grid and finally the smart grid (Ahmed Abdulkadir and Al-Turjman, 2018).

Traditional (Conventional) Grid

The traditional grid is simply the combinations of power stations, transformers, transmission lines, several substations, distribution lines and variety of loads. The power source in this type of grid is only conventional electricity; it cannot accommodate renewable (non-conventional) energy and is referred to as a one-way electric network (Ahmed Abdulkadir and Al-Turjman, 2018; Faizan, 2017; Khan and Riaz, 2016).

Micro grid

Micro-grid is a localized electric system having high control ability and connects with traditional grid system. It can as well stand alone (island-mode) working autonomously. The electric source includes all forms of renewable energy type and conventional energy from traditional grid (Tan et al., 2013). In other words, Micro-grid is a distinct or separate energy system compressing distributed energy sources, (such as generation, storage and requirement management) with loads that is capable of being operated parallel with the main power source (grid) or separately from it.

Smart Grid

Smart grid can simply be defining upgrade of the traditional grid from a one–way power source to a two-ways sources of electricity generation, that is also digitalized, modernized withwelldetailedautomationforthe21st Century electricity transmission and distribution (Ahmed Abdulkadir and Al-Turjman, 2018). The source of electricity includes conventional and nonconventional with real-time computerized monitoring.

The Nigerian national grid is a one-way traditional grid system which is made up of long transmission lines about 224,838km, comprising 33KV, 11KV and LV lines overheads and cables. This grid system causes significant power loss or wastages as a result of heat introduced in transmission and distribution power lines. Even after spending billions of dollars to improve on electricity generation, Nigeria is the worst in terms of electricity consumption globally with 149kWh energy consumption per capital (Olatunji, Akinlabi, Oluseyi, Abioye, Ishola, Peter and Madushele, 2018). For Nigerian electricity generation to improve, spending must be concentrated in making its National grid a smarter one, which will involve adding sensors as well as enriched internet of things to the existing traditional grid. Internet of Things (IoT) mainly is referred to certain concept of adding devices together which allows it sensing and collect data from all over the world that can as well be later shared across the Internet transformations and utilizations for other exciting goals (Patrick et al., 2013; Al-Turjman, 2017; Ahmed and Al-Turjman, 2018; Al-Turjman et al., 2013).

The main purpose of constructing Grid was to interconnect generating power station in the same region and to provide local backup whenever required, but when consumption of electricity increased it became obvious that the present grid had to be extended as the grid was no longer adequate and a 'Super-grid' was constructed in 1964 in UK which was initially 275kV but upgraded to 400kV with pylons of 42meters average height twice as long as the former 132kV lines and carries six times more power (*Electricity pylons in areas of Natural Beauty (Hansard, 17 November 1964)*, 1964).

Connecting Nigeria Energy to Smart Grid

In general, for a country to effectively manage, utilize, secure and give the end user the opportunity to choose when to use the electricity and of course reduce peak period overload, it must upgrade its grid system to a smarter one. Smart grid has so much advantage for Nigeria power crisis, such as sufficient in capacity and area coverage, accessible, safer, economical, reliable, efficient and sustainable. Whenever a fault occurs in a traditional grid system, the fault is not knowing by the service provider until a costumer called to make a complain about such a fault and will have to send someone physically to respond to such while in a smart grid system immediately a grid shuts down the service provider will be notified with all details regarding such (Faizan, 2017; Suryanarayanan et al., 2010). Also with the recent advancement in synchrophasor technology, there comes a common advantage of dynamic monitoring of all interconnected system, this allows service providers know of an event even before it occurs by simply deploying a lot of synchrophasor all over its infrastructure (Liserre et al., 2010; *Renewable Energy | Statistical Review of World Energy | Energy Economics | BP*, 2018; Ahmed and Al-Turjman, 2018).

The most important advantage of migrating to a grid that is smarter is in providing stable, qualitative and effective electricity from generation to distributed houses which also incorporate generation from other sources such as solar and wind, some other benefits includes:

1. Allowing active participation of consumers,
2. Provide alternative for storage,
3. Anticipates problems then response in a self healing way,
4. Connects with electric vehicles in distribution networks
5. And makes shifting of loads more economical
6. The securing infrastructures from external attack

These will automatically solve the general disturbance in Nigeria electricity generation, transmission and distribution and what will remain in improvement in capacity generation output that will of course be provided simultaneously be by the renewable sources option that can connect its generation to the smart grid, this not possible in the traditional grid. The ageing situation of the Nigerian grid will also be overcome and the need to worry building a new Grid is covered in the sense that smart grid evolves gradually with joining together two important infrastructures in the energy industry which are:

i. Electrical Infrastructure and
ii. The Intelligence Infrastructure

The merging of these two is achieved by the use of Sensor or Controllers. For Nigeria to achieve greatness among other nation, it needs to develop and provide efficient power all over nooks and crannies, which requires some sincere steps first of them is to move the grid to a smarter one. There are several technologies to adopt for Nigeria electrification to become a smarter one, such as deployments of sensors on transmission lines for example, phasor Measurement Units, magnetic sensors, accelerators, infrared sensors, so also some strain gauges and software such as SCADA in other words-Supervisory Control and Data Acquisition, Smart metering, like Advance Metering Infrastructure, and the utilization of estimators sensors and communication technologies at substations, models in generating stages to monitor the variation in loads most importantly from renewable sources (PV and Wind) and control for effective energy integration(Ahmed and Al-Turjman, 2018; Patrick et al., 2013).

The communication aspect can be overcome with equipments such as power line carriers, WIMAX, HAN, WAN, GSM, Routers, several computers, safety and power conditioning equipments for renewable sources (Patrick et al., 2013). Actualizing these in the Nigeria Grid means having a smarter grid which will eliminate issues of vandalism of infrastructures and reduce significantly losses of energy during transmission and of course the provision of electricity will be effective and efficient.

Conclusion and Recommendations

Energy in this present generation is fundamental the stage at which a country is categorized as either developed, developing or under developed nation. Nigeria still remains under developed, years after the initial unbundling of its energy sector that was strongly hoped will move the nations' energy sector forward. This clearly indicates that the steps being taken are actually not working and government must take seriously the issues at stake. Government continues to promise her citizens better electric supply with huge spending in the electric sector and the outcome has been the same over the years. It is our belief that the present government need take a different look at the situation must importantly as it is reviewing the rejected electricity tariff increase. A more accommodating policy must first be address in which the grid problem will be holistically settle by having a better, more efficient one –Smart Grid as well as create policies that will allow investors, home owners the opportunity to integrate energy into it utilizing the advantages of net-metering or feed-in tariff which will significantly increases the energy generation for the country. Should these recommendations be followed at the end of this administration it is possible to resolve the electricity outages, vandalism of electricity infrastructures and issue on shortage supply of gas that is tantamount to lack of regular electricity generation at various generating plant.

The Government can take the issue of fixing the grid head on and allow investor the part of increasing generation and as well demand the input of high institution in generating part of energy it consumes which should be renewable, thus there will be significant improvement in employment, Smart Grid is expected to create over FIVE HUNDRED THOUSAND JOBS, and the price of installing a roof top solar panel will drop significantly.

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