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Smart Grid and Energy Management in Nigeria Integrated Power System

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Abstract – **This paper proposes maximum utilization of existing and current assets of both Independent Power Producers (IPP) and the National Integrated Power Projects (NIPP) in transforming the energy system of the country at generation, transmission, distribution and utilization stages by the application of smart grid technology. These are in terms of improved efficiency, stability, power quality, lower risk/maintenance cost, reduction in electricity charge and overall power loss reduction. It was found that upon incorporation of this technology into the Nigeria power system through Power Holding Company of Nigeria (PHCN), there will be reduced rate of building new generating stations and transmission lines that is required to meet the anticipated load growth. It is recommended that if this technology is considered at the planning stage, especially now that there is serious evolutionary changes in the power industry, it will make the country match electricity demand with supply in near future.**

Keywords – **Smart Grid, Nigeria, NIPP, IPP, PHCN.**

I. INTRODUCTION

An overview of the challenges faced in Nigeria power industry indicates that there is increasing electricity demand that is yet to meet supply from inception till date (ref?). More so, the conventional grid network still currently being operational till date in Nigeria involves flow of power from central generating stations such as Kainji, Shiroro, Jebba etc, to consumers via the grid. It is characterized by high power losses, damping oscillations, systems instability at both the steady and transient state in the generation, transmission and distribution stations (3). Considering the current level of investment by Federal Government of Nigeria (FGN) in the power industry through NIPP and IPP and also the deregulation plans on ground, it is therefore pertinent to deviate from the conventional means of power management to smart grid technology. However, smart grid technology integrates information technology (IT) and power system equipment and facilities for real-time monitoring and control to achieve an intelligent energy management scheme (1, 2). This technology allows real-time communication with the grid especially with the increasing growth rate of the communication industries in the country. Smart grid technology uses real-time information to anticipate, detect and respond to system problems in order to avoid or mitigate power quality and outages and prevent overall power system losses (3,4). Implementation cost for this technology is not considered in this work.

II. REVIEW OF CURRENT NIGERIA INTEGRATED POWER SYSTEM

Currently, only about 40 percent of Nigeria's total population has access to public electricity supply due to inadequate transmission and distribution networks (ref?). Also ageing infrastructure, weak and radial network configuration, and overloaded transformers result in frequent system collapse, with high transmission and distribution losses and poor voltage profile. Currently, with some of the completed integrated power projects, the Nigeria national grid is an interconnection of 9,454.8KM length of 330kV and 8,985.28km length of 132kV transmission lines with seventeen power stations (4). The grid interconnects these stations with fifty two buses and sixty four transmission lines of either dual or single circuit lines and has four control centers (one national control center at Oshogbo and three supplementary control centers at Benin, Shiroro and Egbin).The current projection of power generation by PHCN is to generate 26,561MW as envisioned in the vision 20:2020 target. Presently, of the seventeen (17) active power generating stations, eleven of these are owned by the Federal Government of Nigeria (FGN), with installed capacity of 6,904.6MW and 2,271MW is available. The remaining six (6) is from NIPP with total designed capacity of 4,775MW, of which 1,483MW is available. These generating stations are sometimes connected to load centers through either very long or inadequate transmission lines. The transmission network is overloaded with a wheeling capacity of less than 4,000MW. It has poor voltage profile, inadequate dispatch and control infrastructure, radial and fragile grid network, frequent system collapse, exceedingly high transmission losses which is as high as 25 per cent compared with 3 per cent in the US, 0.5 in Japan and 0.4 in South Korea due to low transmission grid voltages and long distances over which electrical energy is distributed in the country. Nigeria Power industry deregulation (and re-regulation) has started the dismantling of the traditional utility business structure so that generation, transmission and distribution are becoming owned and operated by different entities. Table 1.0 shows the seventeen (17) generating stations, consisting of the existing, NIPP and IPP while Table 2 shows the stations that are yet to be completed and table 3.0 shows the bus numbers in the integrated network.

Table 1: Shows Existing, NIPP and IPP Stations in the Nigeria 330KV integrated power network currently been operated (4)

S/N	Station	State	Turbine	Installed Capacity (MW)	Available Capacity (MW)
1	Kainji	Niger	Hydro	760	259
2	Jebba	Niger	Hydro	504	352
3	Shiroro	Niger	Hydro	600	402
4	Egbin	Lagos	Steam	1320	900
5*	Trans-Amadi	Rivers	Gas	100	57.3
6*	A.E.S (Egbin)	Lagos	Gas	250	211.8
7	Sapele	Delta	Gas	1020	170
8*	Ibom	Akwa-Ibom	Gas	155	25.3
9*	Okpai (Agip)	Delta	Gas	900	221
10	Afam I-V	Rivers	Gas	726	60
11*	Afam VI (Shell)	Rivers	Gas	650	520
12	Delta	Delta	Gas	912	281
13	Geregu	Kogi	Gas	414	120
14*	Omoku	Rivers	Gas	150	53
15*	Omotosho	Ondo	Gas	304	88.3
16*	Olorunshogo phase I	Ogun	Gas	100	54.3
17*	Olorunshogo phase II	Ogun	Gas	200	105.5
Total Power				**9,065**	**3,855.5**

Table 2: NIPP and IPP Stations yet to be completed in the Nigeria 330KV integrated power network(4)

S/N	Station	State	Turbine	Installed Capacity (MW)	Available Capacity (MW)
1	Calabar	Cross River	Gas	563	Nil
2	Ihorvbor	Edo	Gas	451	Nil
3	Sapele	Delta	Gas	451	Nil
4	Gbaran	Bayelsa	Gas	225	Nil
5	Alaoji	Abia	Hydro	961	Nil
6	Egbema	Imo	Gas	338	Nil
7	Omoku	Rivers	Gas	252	Nil
Total Power				**2,989**	**Nil**

Table 3: Buses in Nigeria 330kv Integrated Power Network(4)

S/NO	BUSES	S/NO	BUSES	S/NO	BUSES
1	Shiroro	21	New haven south	41	Yola
2	Afam	22	Makurdi	42	Gwagwalada
3	Ikot-Ekpene	23	B-kebbi	43	Sakete
4	Port-Harcourt	24	Kainji	44	Ikot-Abasi
5	Aiyede	25	Oshogbo	45	Jalingo
6	Ikeja west	26	Onitsha	46	Kaduna
7	Papalanto	27	Benin north	47	Jebba GS
8	Aja	28	Omotosho	48	Kano
9	Egbin PS	29	Eyaen	49	Katampe
10	Ajaokuta	30	Calabar	50	Okpai
11	Benin	31	Alagbon	51	Jebba
12	Geregu	32	Damaturu	52	AES
13	Lokoja	33	Gombe		
14	Akangba	34	Maiduguri		
15	Sapele	35	Egbema		
16	Aladja	36	Omoku		
17	Delta PS	37	Owerri		
18	Alaoji	38	Erunkan		
19	Aliade	39	Ganmo		
20	New haven	40	Jos		

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III. Evolution of Smart Grid

Smart grid technology pave way for increased utilization of green power though renewable energy sources (7). It is an evolution of conventional grids in areas such as: transitioning the grid from a mostly unidirectional radial system to a multi directional grid, converting from an electro mechanical system to a primarily digital one and moving to an interactive grid that actively involves end users (or at least improve data and flexibility of end users). Smart grid is going through an evolution. This evolution can basically be segmented into distinct versions of the smart grid. These include

- Smart Grid V 0.0: This could even be classified as a smart network since each network used proprietary protocols to read meters on isolated networks. This phase typically associated with Automated Meter Reading(AMR)
- Smart Grid V 1.0: This is the advent of "Advanced Metering" a smarted version of AMR. Not only meters automatically read, but standard based solutions are used to provide applications like demand response and time used billing. In addition utilities now have the ability to interact with energy usage through direct load control and controllable thermostats.
- Smart Grid V 2.0: The next phase of the smart grid is when the consumers become directly involved with energy utilization.
- Smart Grid V 3.0: The future of the smart grid where Plug in Hybrid Electric Vehicles (PHEVs) and micro grids of distributed generation interact with the grid to balance energy supply and demand.

Nigeria as a country is yet to advance its power industry to any of the stages.

IV. Principal Characteristics of Smart Grid

Principal characteristics are the attributes of a fully integrated Smart Grid. These describe what the Smart Grid is and what it can enable (8,9, 10). Principal characteristics of the Smart Grid include the following:

Self-Healing: The grid routinely or automatically detects, analyzes, responds to, and restores grid elements or network sections to maintain reliability, security, affordability, power quality, and an efficient state.

Empowers and incorporates the consumer: The consumer becomes an integral, active part of the electric power system.

Tolerate security attacks: It is critical for the Smart Grid to address security from the outset, making security a requirement which ensure an integrated and balanced approach across the system.

Provides enhanced power quality: Sensitive loads represent an increasing portion of the total power system load. Future power quality must “smooth” power in generation, delivery, and load, while enabling loads to better tolerate distorted power.

Accommodate a wide variety of generation options: The Smart Grid will accommodate a portfolio of diverse generation types, necessitating a greatly simplified interconnection process analogous to the “plug and play” in today’s computer environment, particularly at the distributed energy resources level.

Fully enables electricity markets: The Smart Grid will integrate electricity markets into the fabric of the electric system because operations, planning, pricing, and reliability are dependent on how open-access markets are designed and instituted. For this reason, it will not only support wholesale electric markets, but also retail markets where applicable.

Assets will be managed in concert so that, as a system, they will deliver functionality at a minimum cost. For example, advanced sensing and robust communications will allow early problem detection and corrective action.

Nigeria Integrated Network and the Proposed Smart Grid

Existing Grid	**Proposed Smart Grid**
Cost of operation is high as much cost is spent on trucks, high demand on call centers operations	Reduced operational costs due to fewer truck rolls, and less demand on call center operations, engineering, and outage response resources
Employee safety is high as load shedding are done manually	Improved employee safety as employees are subjected to hazardous conditions less frequently
Interruption of electricity supply reduces energy consumption and revenue	Increased revenues as electricity sales are interrupted less frequently and for shorter durations
Level of services is bad due to power outage and poor power quality	Improved level of service with fewer inconveniences caused by outages and poor power quality
The conventional grid of Nigeria is congested and it is characterized by power outage and low quality of power delivered.	A smart grid reduces the cost of grid congestion and power outage since renewable can be to supplement the power generated.
Peak demand require spinning reserve and expensive electricity supply to satisfy peak demand	Peak demands are reduced by using smart appliances and equipment to reduce the need of spinning reserve. It is achieved by using demand response programs.

Revenues collected by PHCN are reduced to illegal connections use of inaccurate traditional meters	Increased revenues as theft of service is reduced, from improved metering accuracy of smart meters over traditional ones, and from shorter power outages
Interaction between utilities and consumers is difficult since no good communication network	Opportunity to interact with the electricity markets through home area network and smart meter connectivity
Consumption of electricity, transmission and distribution losses is high about 10%	Reduced consumption of electricity through conservation, demand response, and reduced transmission and distribution (T&D) losses from 10% to 2%
Productivity of employee is reduced due to lack of necessary information for operation and maintenance processes.	Improved employee productivity through the use of smart grid information that improves Operation and maintenance processes. Improved load forecasting enabling more accurate predictions on when new capital investments are needed.
Require the use of inefficient generation to meet peak demand	Reduced use of inefficient generation to meet system peaks demand as it is achieved by using demand response program. Efficiency of generation is improved due to flatter load curves
Conventional grid is a one way communication network, communication between the utilities and consumer is slow or delayed	Smart uses two way communications network there is always feedback between the utilities and consumer using internet or any other means available.
Integration of renewable energy is difficult so the energy generated uses non renewable which affect the eco system.	Increased capability to integrate intermittent renewable resources through conservation demand response. Reduction in emissions as a result of more efficient operation, reduced system losses, and energy conservation
In case of wide spread blackout a substantial losses in economic activity because distributed energy resources is not used	Reduction in injuries and deaths of employees due to reduction in time spent in hazardous situations and the availability of more intelligent systems that support worker safety

V. Making the Nigeria 330kV Network Smart

Certain factors are considered in making the Nigeria 330KV network smart. These include real-time pricing, smart sensors and controls and communication infrastructures.

Real-Time Pricing

Increase in gas prices rise significantly, consumers get very clear "price signals" posted on signs outside the filling station. In response, they may look for alternatives, such as conservation, ethanol-based gasoline and fuel-efficient vehicles. But residential electric customers are not billed on a real-time basis. Consumers receive monthly bill that charges the same amount whether the electricity was used at expensive (peak) times or low-cost times. Until electric customers get price signals, they will not be motivated to pursue Distributed Energy Resources.

Tariff features are usually allowed and approved by Power Holding Company of Nigeria (PHCN) so those entities must re-calculate rate designs with price as a function of time. Then technologies need to get the price signals to consumers, so they can make a decision. Providing those signals requires smart meters, information gateways, and technologies that allow transmission and distribution operators to send pricing information. The real-time pricing information will tell suppliers, marketers, Distributed Energy Resources vendors and consumers when it makes sense to buy more Distributed Energy Resources. That investment will in turn spur the development of next-generation Distributed Energy Resources devices, making them even more cost effective.

Smart Sensors and Controls

Integrating Distributed Energy Resources into the system requires advances in the research and commercialization of smart sensors, protective relays and control devices. Lower cost sensors and controls will reduce Distributed Energy Resources installation costs, ensure stable operation of interconnected Distributed Energy Resources units and safeguard line crews and the public during maintenance and restoration. These devices will be needed even more as autonomous operations increase. On the customer side of the meter, there is need for energy-management systems to monitor and control DER operations and demand response requests from the utility.

Communications Infrastructure

There is need for a standard, integrated communications platform to enable all power system components to intercommunicate. Smart sensors and controls must communicate, but today's grid lacks communications integration and standardization. In most cases, communication does not yet reach to the consumer level. For system operators to integrate new generation sources, communication systems must be able to handle energy price signals and commands.

Controls and Tools for Operation and planning

The modern grid will incorporate generation sources that are smaller, decentralized and often intermittent. But today's operating models cannot reliably operate this new configuration. We require several new tools and technologies:

- New operating models and algorithms to address the transient and steady-state behavior of the modern grid, and the integration of large amounts of Distributed Energy Resources.
- Improved operator visualization techniques and new training methodologies to enable system operators (both distribution and transmission) to work together to manage systems in both routine and emergency operations.
- Advanced simulation tools that can provide a more complete understanding of grid behavior, especially where a large number of diverse Distributed Energy Resources units are deployed. These tools are also needed to assist system planners in designing reliable power systems in this new environment.
- Methods for resolving the unique maintenance and operational challenges created by Distributed Energy Resources, demand response, and other new generation sources.
- Advanced system-planning tools that assess the benefits (and consider the uniqueness) of Distributed Energy Resources to locate optimal sites for power stations.

Interconnection Codes and Standards

Interconnection and operation codes and standards need to be more quickly adopted across the industry to support Distributed Energy Resources implementation. Efforts are underway to develop fair and uniform interconnection standards at the federal level and in individual state

The development of these standards will enable Distributed Energy Resources to be easily integrated with the modern grid—called "plug and play"—to connect any power generation into the grid and communicate fully.

Metrics

Key metrics need to be developed and promulgated to provide the transparency needed to most effectively support the safe operation of the modern grid. Some areas where metrics might be established include:

- Distributed Energy Resources percentage of system-wide capacity, energy, and ancillary services
- Improvements in system and customer reliability
- Improvements in power quality
- Improvements in transmission congestion
- Energy prices, with and without congestion
- Capital investments and deferred investments
- Reduction in emissions and other environmental impacts
- Reduction in system losses

The new generating sources of Distributed Energy Resources must be able to do the following:

- Auto start, load, and shut down in response to price signals and commands from system operators.
- Represent a significant amount of capacity, energy and voltage support on an aggregated, system-wide basis
- Integrate safely and reliably with legacy distribution topologies

VI. Conclusion

It has been shown that for the Nigeria 330KV integrated power network to be made smart, modern trend in information and communication technology should be introduced into the power network. This will make the network to be operated very close to their thermal limit and power losses (both technical and non-technical) will be reduced at both generation, transmission and distribution stages in the power network. Supervisory Control and Data Acquisition (SCADA) should be introduced for the purpose of obtaining real time monitoring of happenings in the network, so as to ensure that appropriate solution are taken at the right time. This will also ensure that assets/power equipments are effectively utilized and the time value of money for anything spent on the industry is maximally and optimally used. it is therefore recommended that Smart grid technology be incorporated in the Nigeria power network.

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