Evaluation of Electrical Power Outages A Restructuring Approach In Nigeria

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EVALUATION OF ELECTRICAL POWER OUTAGES: A RESTRUCTURING APPROACH IN NIGERIA

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ABSTRACT

It is crucial to notice that everyone is dependent on reliable and quality power supply. Modern economies are becoming increasingly dependent on reliable and secure electricity services. The paper examined the causes of power outages in Nigeria and the attributes of restructuring approach that have exhibited good reliability by creating a predictable environment that will help country attract outside investment in energy infrastructure. Integration, deployment of technologies that has the potential to substantially improve generation, transmission and distribution system flexibility.

Keywords: Power Outages, Electrical Energy, Evaluation, Restructuring, Reliability, Nigeria

1. INTRODUCTION

A structural shortage of electricity supply in Nigeria remain one of the country most critical challenges. [10] Energy plays a vital role in the economic, social and political development of our nation. In adequate supply of energy restricts socio-economic activities, limits economic growth and adversely effects on the quality of life. Despite Nigeria being energy resource abundant, there are still constant power outages. Industries and individuals cannot rely on electricity from the national grid for high productivity.[1] Thousands of geographically dispersed and connected electricity, oil, and natural gas assets. Which the sector provides for and relies on the Nation's transportation, water, information technology (IT), communications, finance, government, and other critical infrastructures

(CIs). That all sectors reciprocally depend on energy especially electricity. As reliance on electricity continues to grow, a significant disruption to the electric grid may put lives, the economy, and the environment in danger.[5]

Despite fundamental changes, development of regulatory arrangements, reliability standards and system operating practices relating to transmission system security generally have not kept pace with the new real-time system operating challenges resulting from electricity market reform.[4] According to (Oseni, 2012, p.1) said electricity provision in Africa has been marred by low generation poor supply and frequent power outages.[10]

Nigeria most populous country in Africa with over 180 million people according to the latest United Nations, estimates equivalent to 2.5% of the world population. On a fundamental level, and simply put there is no enough electricity generated to support this entire population.[14] Electricity development in Nigeria can be traced back to the end of the 19th Century, when the first generating power plant was installed in Marina, Lagos, in 1898, fifteen years after its introduction in England. Its total capacity was 60kW. After the amalgamation of the Northern and Southern protectorates in 1914 to form modern Nigeria, other towns in the country started to develop electric power supply system on the individual scale.1 1946. In this year, the Public Works Department ceased to have control over the operation of the electricity generating plants and distribution system in the country. In the same vein, the Nigerian Government Electricity Undertaking (NGEU) was immediately established (as an arm of the Public Works Department) to take over the assets and liabilities of electricity supply in Lagos. Four years later, in 1950, a central body was established to take over all the various electricity supply outlets within the country. This body is referred to and addressed as the Electricity Corporation of Nigeria (ECN).Meanwhile, the Native Authorities (NAs) continued to manage their respective systems while Niger Dams Authority (NDA) was also inaugurated for the benefit of generating electricity through hydro power systems. As a result of this, the Colonial Government established the Electricity Corporation of Nigeria (ECN) under the ordinance no.15 of 1950.The new body, i.e. ECN, officially took over all electricity supply activities in Nigeria in April 1951 by integrating all the Government owned as well as native-owned generating plants and systems. This creditably improved the electric power supply in the country through grid connection of generation, transmission and distribution of electricity. Meanwhile, the sale of electrical energy was also done in such a way that the return on its investment had a common purse. This was later referred to as the vertically integrated utility (VIU). With the increase in demand for electricity, some projects were carried out in Ijora, Oji River, Kano and Ibadan power stations to improve availability and quality of power delivery. Thus, the Ijora power station was commissioned in Feburary 1956 and it served satellite towns like Ikorodu, Shagamu, Ijebu-ode and other towns in the Ibadan-Ijebu provinces which provided the socio-economic transformation of these western states ahead of other parts of the country.

In 1962, an Act of Parliament established Niger Dams Authority (NDA) which was responsible for dam construction after discovering the innumerable benefits that would accrue from the Dam. This led to the construction of Kainji Dam in 1962 and was completed in 1968. The vast nature of the country grid power transmission system started operation in 1966 with the collaborative effort of the defunct ECN and NDA, which linked Lagos with Kainji. Kainji-Kaduna link wasextended to Zaria and Kano. In the southern part, Oshogbo-Benin- Ughelli and Benin-Onitsha-Afam (Alaoji) links were constructed. Inspite of the great size of the country, the national grid now links the thirty-six state capitals and the Federal Capital Teritory Abuja. On 1st of April 1972, ECN and NDA merged to form a unified body known as National Electric Power Authority (NEPA) with the actual merging taking place on the 6th of January 1973 when the first manager was appointed. The network continued to grow under NEPA and between 1978 and1983, the Federal Government had sponsored two panels of enquiry to fashion out models for restructuring NEPA into an independent unit or toward privatizing it out of monolithic nature. This led to the establishment of the electrification boards whose work is to take power supply to the rural areas and new cities.[1]

NEPA's severe technological deficiencies are prevalent throughout the power system, both upstream and down. For example, with modern technology about 40% of the energy consumed in thermal plants can be converted to electrical energy. In the absence of this technology, as currently the case in Nigeria, this figure can be as low as 12% . Of the power that is produced, there is further loss through transmission. One estimate claims that between 30 and 35% of power generated in Nigerian power stations is lost in this way. By comparison, power losses across lines in the United States usually come to less than a percent, even across greater distances. It is impossible to determine exactly how much of this inefficiency is due to illegal users' tapping the lines, but it seems likely that underinvestment in technology is the greater problem.[13]

Availability of energy in Nigeria

It is generally recognized that Nigeria is richly endowed with both renewable energy resources (e.g).solar, hydro, wind, biomass and wood fuel) and non-renewable energy resources (e.g. crude oil, natural gas, lignite and coal). However, in spite of this abundance, the country is still unable to generate enough electricity to meet its domestic demand.

The grid is powered by hydropower and thermal, which itself is composed of fossil fuels (as shown in table 1 below). Within each of these sources there are structural problems that detract from the overall efficiency of the energy producing capacity of each type of infrastructure.

Nigeria's electricity sources

Source	% contribution
Gas	39.8
Hydropower	35.6
Oil	24.8
Coal	0.4

Source: World Bank (2001a).

Table1: Nigeria electricity source

The current infrastructure of the hydro plants is in dire need of rehabilitation and the actual energy output of the plants is far below their projected capacity. The trends of climate change have led to a continual loss of water. Since the power output of hydro plants is dependent upon the flow of the river, with less water, there is less potential energy to harness, making hydropower a less desirable energy source.

Nigeria has a large source of liquid natural gas (LNG), 163 trillion standard cubic feet. The Nigerian energy sector has begun the development of the necessary infrastructure to utilize LNG to contribute to the national grid capacity. This process involves building pipelines to transport the LNG to the power plant as well as building the power plants themselves to convert LNG to electricity.[19]

Country Comparison with Selected African Countries

The electricity consumption, transmission and distribution loss data in table 2 below, highlight two dimensional challenges confronting the electricity power sector in Nigeria. The first is the low level of energy consumption, evident in low level of electricity consumption per capita when compared with some other African countries. This can be said to be an indicator of energy and income poverty in the country.
The high level of loss in transmission and distribution of generated electricity power has rendered Nigeria as being the largest importer of generators in the world (Iwayemi, 2011).

Country	1971	1980	1990	2000	2009
Angola	25.07	25.04	25.09	14.6	10.09
Sudan	24.65	14.08	15.38	15.53	28.11
Libya	21.65	24.875	31.2	23.18	14
Kenya	15.38	14.6	15.02	21.16	15.53
Senegal	15.18	14.94	17.46	37.34	16.97
Tunisia	13.28	12.21	10.34	10.54	13.03
Nigeria	13.25	29.07	38.42	38.15	5.87
Algeria	10.72	10.91	14.36	16.15	20.57
Morocco	10.61	9.76	8.53	8.4	11.71
Egypt, Arab Rep.	9.78	12.65	9.96	13.76	10.52
South Africa	7.07	7.63	6.03	8.2	9.84
Ethiopia	6.91	7.84	9.98	9.98	9.52
Ghana	6.11	5.19	3.15	18.87	23.31
Cameroon	5.21	7.36	13.05	21.87	9.41
Gabon	1.75	0.75	10.74	17.79	18.18

Table 2: Transmission and Distribution loss

From the table 2, Nigeria is ranked higher than its West African neighbors such as: Gabon, Cameroon, and Ghana who are ranked lowest. The high level of transmission and distributional losses has led to electricity blackouts and pervasive reliance on self-generated electricity. This development has occurred despite abundant energy resources in Nigeria. The electricity market, dominated on the supply side by the state-owned PHCN, has been incapable of providing minimum acceptable international standards of electricity service reliability, accessibility, and availability for the past three decades (Adenikinju, 2005). The double-digit transmission and distribution losses are extremely large by international standards and are among the highest in the world. The system losses are five to six times higher than those in well-run power systems. The high level of power losses and the significant illegal access to the public power supply are indicative of the crisis in the industry. Though the peak electricity demand has been less than half of the installed capacity in the past decade, load shedding occurs regularly. This poor service delivery has rendered public supply a standby source as many consumers who cannot afford irregular and poor quality service, substitute public supply for more expensive electricity supply source to minimize the negative consequences of power supply interruptions on their production activities and profitability. An estimated 20% of the investment into industrial projects is allocated to alternative sources of electricity supply (Nnaji C et al,2010).[8]

2. BACKGROUND TO THE STUDY

The current status of electricity generated in Nigeria with regard to its population is grossly inadequate. This challenge has been in existence since 1970s when the Udoji's Federal Government awards improved the economic life of the workers. According to, this made the workers to increase their electricity consumption by purchasing several sophisticated and automating machines that consumed quite a lot of energy. The power utility company, on the other hand, was not prepared for this increase in consumption. This challenge has consistently left a deficit in consumption and generated electricity ever since that period in the Nigeria's electricity consumption history. Thus, this has led to consistent imbalance in the demand and the supply of electricity.1 Assessment detailed power outage can only be carried out successfully if a sufficient level of information is provided in a timely manner.[14] Market restructuring and concerns about electricity prices and supplies are still important issues in parts of the country. But at several key points during the unfolding crisis, features of the restructuring plan limited the responsiveness of the supply and demand sides of the electricity market.[12]

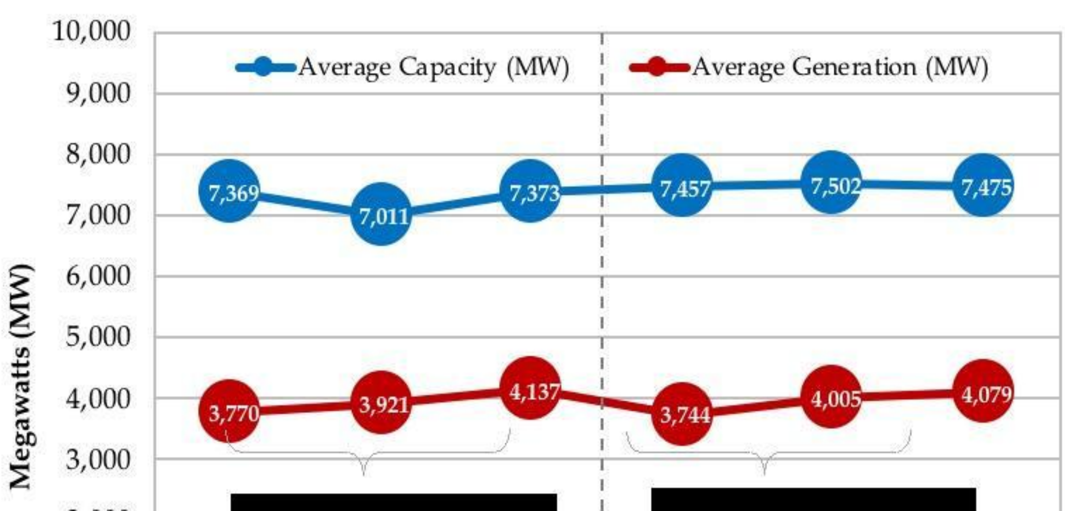
2.1 Security Assessment

Security assessment is defined as the real time analysis procedures by which the security of the system is measured (assessed). Security assessment procedures are classified into steady state and dynamic depending on whether the transients following the disturbance are neglected or not. Most of transmission line and transformer outages cause a rather fast rerouting of power flow in such a way that the transients following the disturbance are not of great consequence. The same is true for generating unit outages when the unit is small compared to the system or operating at low power points prior to the event. These cases represent the majority of outage events. Cases of major generation unit outages or major tie lines may cause transients with major effects on security. In this case, the transients must be studied and their effect on security must be assessed.

This process is called dynamic security assessment. In general, considering the power system as a nonlinear dynamic system, we can say that the steady state security assessment should evaluate if after a contingency (or a number of contingencies) occurs there will be a new equilibrium state for the post-contingency system and how secure this state is. The dynamic security assessment will, in addition to that, also show if there will in fact be a transient trajectory in the state space from the original pre-contingency equilibrium point to the post-contingency equilibrium point (thus, if the system will actually reach that equilibrium point) and what will be the security level of the system during this transition. It is therefore possible, for some severe disturbances, that even if a post-contingency equilibrium point exists the system may not be able to reach it, because there is no transient path from the one equilibrium to the other one. Or the final equilibrium state may be reached and may be a secure state, however, some of the transient states the system went through during the transition may have not be acceptably secure. This can only be investigated using transient analysis. However, in this report we are interested only in steady state or static security assessment. The purpose of this part of the project is simply to use security assessment techniques for contingency screening and ranking (not analysis) in order to reduce the size of the space of system states, to the few ones that worth to be further analyzed from the system reliability point of view. Dynamic security assessment is therefore beyond the scope of this report. Steady state security assessment, i.e., assessment of the effects of equipment outages on system security, requires the analysis of the post-contingency steady state conditions. In other words, steady state security assessment involves the analysis of the steady state post-contingency conditions for any foreseeable and probable outage. Since the number of such contingencies may be extremely large for practical systems, the basic problems in static security assessment are: (a) identification of contingencies which may cause system problems or adversely affect security (contingency selection) and (b) techniques for contingency simulation to assess the effects of the contingency.[15]

3. FINDINGS AND DICUSSION

The electricity industry highest peak daily generation of 5,047MW was recorded on the 14th February 2017. During the first quarter of 2018, available generation capacity rose by 3% to 7,477MW. This increase in available capacity is attributed to increase in the number of available generation units after maintenance and overhaul processing. On average, while 77 plant generation units were available in the last quarter of 2017, the generation units available during the first quarter of 2018 increased by one (1) unit to 78 units. However, due to some factors highlighted below, the increase in the available capacity did not translate into increase in output as total electricity generated during the first quarter of 2018 decreased by 2% from 8,705,606MWh recorded in the preceding quarter. Figure 1 presents the daily average generation (in MW) and available capacity (in MW) in the last quarter (October – December) of 2017 and the first quarter (January – March) of 2018. The Figure shows that just 53% of the available capacity was utilized in 2018, a decrease of 1.4% from the capacity utilization during the preceding year. This implies that approximately 47% of the available capacity was stranded due to a combination of factors including inadequate gas supply, limitation in transmission and distribution networks, and water management.[9]



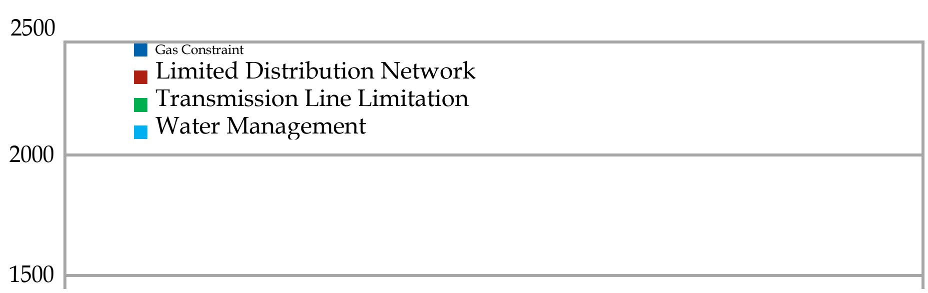
Ave. Utilized Capacity
2017Q4: 54.4%

Ave. Utilized Capacity
2018Q1: 53.0%

Figure 1: Average Daily Generation and Available Capacity

Gas shortage was exacerbated by a fire incident on the Escravos Lagos Pipeline of the Nigerian Gas Processing and Transportation Company (NGC) Limited which affected six thermal power plants, including Egbin, Omotosho and Olorunsogo plants, among others. Also, during the quarter, some GENCOs including Geregu experienced high quantity of condensate in the pipeline, limiting the quantity of usable gas supplied to them. ASCO was out of operation for most of the period under review on various issues including low gas pressure, leakages in the furnace, and operational maintenance. Azura plant was under construction and only underwent commissioning testing during the period. The loss of Escravos Gas pipeline due to fire incident on January 2, 2018 which resulted in the loss of energy output from Egbin and Olorunsogo NIPP among others resulted in total system collapse.

Noticeably, the decline in electricity generation due to gas constraint was very significant when compared to the constraints attributed to poor transmission and distribution networks. These later factors respectively accounted for 84.3MW and 452.3MW of stranded capacity while water management accounted for 134MW.[9]



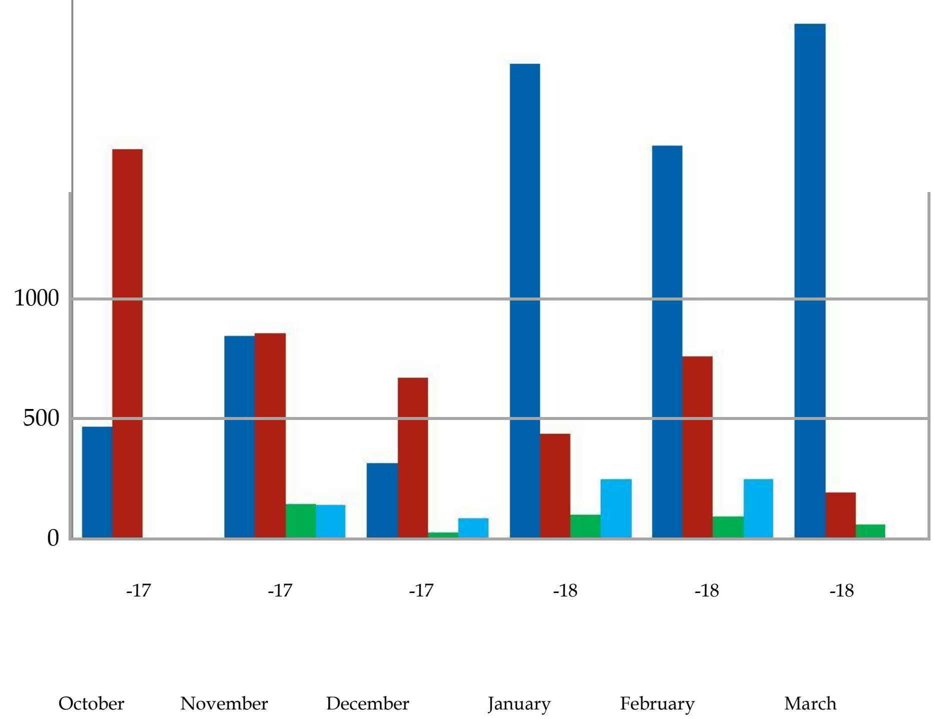


Figure 2: Average Daily Stranded Generation Capacity by Type of Constraints

3.1 Sources of Generation

Figure below presents the share of electricity generated by sources of fuel utilize. As expected, gas fired thermal plants dominated the electricity generation mix accounting for 81% of the energy generated in the first quarter. This implies that approximately 4kWh of every 5kWh of electricity generated in Nigeria in the first quarter of 2018 came from gas. The share of hydro-generation decreased from 23% to 19% between the two quarters. The recorded decline in electricity generated from hydropower plants is attributed to seasonal factor and turbine pit flooding incident in Shiroro dam. The Nigerian electricity regulatory commission is concerned that the apparent over-dependence on gas fired thermal plants may pose supply risk for the Nigerian electricity industry as vandalism of gas pipelines could result in total shutdown of the grid.[9]

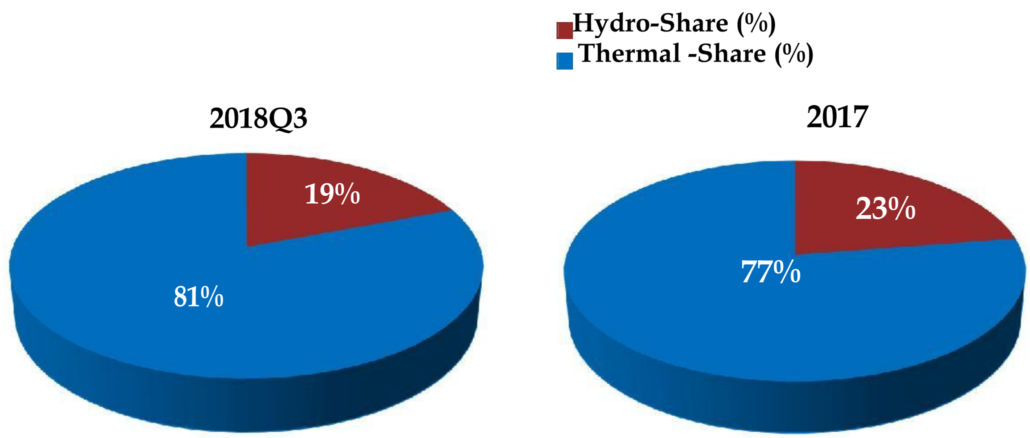


Figure 3: Quarterly Share (%) of Electricity Generated by Fuel Sources

To improve the fuel mix in the NESI, the Nigerian electricity regulatory commission in collaboration with other key players in Industry, is working to unfold regulatory and policy interventions to support the actualisation of energy mix through coal–to–power generation and on-grid renewables.

3.2 Grid Performance

The performance of the Nigerian Electricity Supply Industry, Commission focuses on four Key Performance Indicators (KPIs) that relate to power transmission. These include the transmission loss factor, system collapse, the grid frequency and the voltage fluctuation.

The Transmission Loss Factor (TLF) – the percentage difference between the total energy sent out by power stations and energy delivered to all DisCos by TCN relative to the total energy sent out – worsened.

Moreover, the average transmission loss factor for the quarter was 0.76% higher than the 8.05% industry (MYTO) acceptable loss factor, indicating a decline in the performance of the transmission network from the preceding quarter where the average TLF was 7.96%. The increase in the average TLF in 2018Q3 may be attributable to reduced efficiency in transmission network and/or energy theft among large industrial energy users who are connected to 132kV lines.

The industry recorded a significant decline in the stability of the grid network during the year of 2018

	2017Q4	2018Q3
Number of Partial Collapse	3	0
Number of Total Collapse	1	6
Average	4	6

Table 3: System Collapse in 2017 and 2018Q3

Despite the decline in the grid stability, the Nigerian electricity regulatory Commission remains committed to ensuring stable electricity supply. As such, to ensure tighter enforcement and adherence to the provisions of the grid code, free governor control at grid-connected power plants and increased investment in transmission network. e.g spinning reserved.

3.3 Grid Frequency and Voltage

Based on the provisions of the Grid Code, the system frequency, under normal circumstances, is expected to be between a lower limit of 49.75Hz and an upper limit of 50.25Hz. The Grid Code however provides for grid frequency to operate between 48.75Hz – 49.75Hz (lower stress boundary) and 50.25Hz – 51.25Hz (upper stress boundary) when the grid is stressed. The system low frequency was below the lower statutory limit most of the time during the quarter. Similarly, the system high frequency was considerably and consistently above the upper statutory limits with an average of 0.34Hz. At the end of the 13th week, however, the actual system (low and the high) frequencies were converging towards the statutory levels indicating improvement in grid stability.

There must be regulatory interventions to ensure that the system frequency is kept within the statutory limits in order to ensure stable and safe electricity supply. Additional Generators to be on free governor and frequency control mode in line with the provisions of the subsisting rules in the industry. And also ensure that the Transmission Company Nigeria (TCN) makes sufficient investment to strengthen the networks and procure required ancillary services to support electricity supply. Currently, by evaluating the adequacy of ancillary services already procured by TCN for sufficiency and to make appropriate provision for ancillary services when reviewing TCN tariff.

Similar to the frequency pattern, the industry Grid Code allows for voltage fluctuation between a lower boundary of 313.5kV and an upper boundary of 346.5kV. Although there were relative improvements recently, the system voltage was steadily outside the normal statutory boundaries throughout the period under review. Frequency fluctuation and other harmonic distortion will result in poor power quality that could damage sensitive industrial machineries and equipment that are connected at high voltage level. [9]

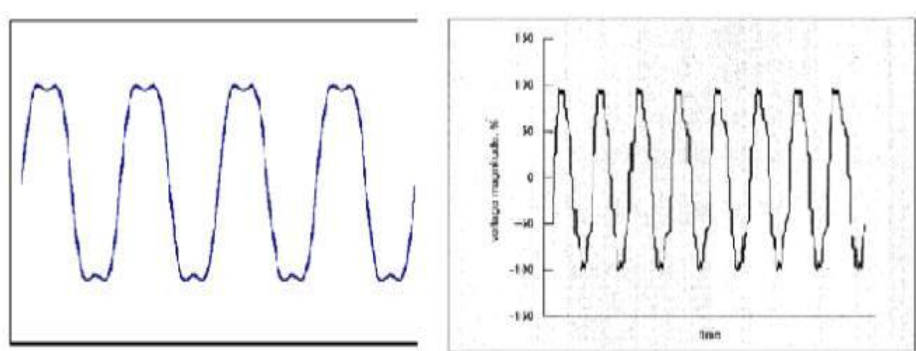


Figure 3: Distorted Voltage Waveforms

3.4 Energy Received Analysis

The amount of energy received by the distribution companies (DisCos) at their trading points decreased. Specifically, the energy received during the first quarter stood at 6,815GWh, a decrease of 3.4% from the 7,051GWh recorded in the fourth quarter of 2017. This decrease is reflective of the decline in energy generations and the increase in the transmission losses in the first quarter of 2018 relative to the preceding quarter. Table 2 shown the amount of energy received and billed by DisCos for the year of 2017 and the third quarter of 2018. The billing efficiency rose significantly from 73% in year of 2017 to 80% in the third of 2018. Of the 6,815GWh total energy received by DisCos in the third

quarter, 5,433GWh was billed to the end users.

	Total Energy Received (GWh)		Total Energy Billed (GWh)		Billing Efficiency (%)	
DisCos	**2017Q4**	**2018Q1**	**2017Q4**	**2018Q1**	**2017Q4**	**2018Q3**
Abuja	914	928	717	748	78	81
Benin	666	627	506	522	76	83
Eko	833	809	687	718	83	89
Enugu	623	591	397	431	64	73
Ibadan	952	894	643	715	68	80
Ikeja	791	855	673	756	85	88
Jos	394	347	251	247	64	71
Kaduna	533	524	315	374	59	71
Kano	504	466	389	389	77	84
Port Harcourt	586	526	396	368	68	70
Yola	255	248	161	164	63	66
All DisCos	**7,051**	**6,815**	**5,135**	**5,433**	**73**	**80**
DisCos Average	**641**	**620**	**467**	**494**	**71**	**78**

DisCos are the electricity distribution companies

Table 4: Energy Received and Billed by DisCos in 2017 & 2018Q3

The level of billing efficiency during these quarters shows that for every 10kWh of energy received by a DisCo from the Transmission Service Provider (TSP), approximately 2.2kWh is lost due to technical constraint and energy theft. In other words, for every ₦10 worth of electricity received by DisCos, ₦2.20 is lost due to poor distribution infrastructure and energy theft.

Regarding their individual performance, Table 2 shows that Eko DisCo had the highest billing efficiency of 89% in the third quarter, while Yola DisCo recorded the lowest billing efficiency of 66%. On the basis of relative improvement from the preceding quarter, Ibadan and Kaduna DisCos recorded the highest improvement of 12% in their billing efficiency. The remaining DisCos also recorded relative improvement in their billing efficiency.

To curb the losses attributed to DisCos' technical constraint (poor network), the Nigerian electricity regulatory commission is developing a framework where actual investments by the DisCos would be thoroughly verified, evaluated and compared with the proposed investments which they had been allowed a return. A mechanism will also be developed to, in the subsequent tariff review, claw back any return received on previously proposed investments that were not eventually executed by DisCos. This action is expected to improve DisCos' commitment to their network upgrade and reduce technical loss. To stop the commercial loss, the Commission has already directed the DisCos to do asset mapping and tagging customer enumeration in order to identify illegal connection and bring them onto their billing platform.[9]

4. RECOMMENDATION AND CONLUSION

Electricity market reform has fundamentally changed the environment for maintaining reliable and secure power supplies. Growing inter-regional trade has placed new demands on power systems, creating a more integrated and dynamic network environment with new real-time challenges for reliable and secure generation, transmission and distribution operation.[4] Technical planning of national grid interconnection should be properly carried out, pooling of large power generation stations, preparedness of spinning reserve and use of most economic energy resources.[18]

Harnessing sources of renewable energy such as Solar power, Biomass power the electricity generated from biomass and is obtained from wood, crops, harvest residues, urban refuse and industrial wastes known as biomass. It is one of the important sources of renewable energy and serves as an essential part of waste management process. Biomass (plant materials and animal wastes) can be burned to produce steam from water. The steam drives a steam turbine that, in turn, drives the electrical generator that produces electricity. Biofuels such as bioethanol (produced by fermenting plant materials), biodiesel (made from plant oils combined with alcohol to form ester) and biogas (produced by allowing organic matter to decay) can also be burned to generate electricity. The fuels are also readily transported, making it possible for the power plants to be located where the cost of electricity transmission can be minimized.[9]

Apart from gas and hydro power plants which the country currently rely on for electricity supply, the wind energy is also source of renewable energy. These wind projects can be preferably carried out in selected parts of the country where stronger wind movements occur, compared to other parts of the country. Particularly in seabed, hilly areas and seashores, wind is easily available and hence it is less expensive source of energy. By utilizing the momentum and transferring it to rotor blades, energy can be produced from wind. This paper strongly recommend system maintenance, which should include inspection, the inspection should be on schedule or off scheduled. Well-managed maintenance practices culture should result in fewer forced outages. The infrastructure for good maintenance should provide requisite technical training to personnel. For most of the ageing equipment such as power transformers, cables, lighting arresters, etc. diagnostic age analysis is necessary to undertake special or emergency repairs, replacement, modernization, Plan, design, and maintain the system to operate reliably.20 Effective control network (HV/LV system) (both on automatic and also manual) should be developed .The gradual phasing out of manual closing of circuit breakers should begin forthwith.[21] In conclusion, the problems that have emerged are now much better understood and solutions to many of them are at hand.[12] This study proof the concept of evaluation to mitigate power outages risk resulting from proposed changes in energy industry and this will eventually bring about the socio-economic and technological transformation of Nigeria.

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