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POWER GRID COLLAPSEIMPACTS ON CONSUMERS AND UTILITY COMPANIES IN NIGERIA

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Abstract

Electricity is germane to socio-economic development of any country in the world. Nigeria requires rigorous grid assessment because of incessant collapse caused by increased energy demand, over blotted population, obsolete lines, obsolete transformers, inadequate gas supply to certain generating stations and huge power demand-generation gap. The paper reviews the causes of grid collapse and its impacts on both consumers and utility companies. The method used in this paper was collection of secondary data on grid collapse from previous literatures, the use of simple mathematical percentage and bar charts to carry out analysis of partial and total grid collapse. Mathematical estimate of economic losses in one hour for domestic consumers was carried out in to estimate the capital cost being wasted at any point that grid collapse occurred which ought to be re-invested into the power sector. The amount estimated was #1,125,000,000($2,450, 000).This paper recommends that there should be power demand and generation gap through vigorous injection of renewable energy into the grid network, adequate power planning with respect to population increase, replacement of obsolete power components and adequate injection of gas into the gas power stations. Both total and partial grid collapse should be reduce in order to make electricity available to citizens and this will make payments of electricity bills regular for consumers while the utility companies will have access to funds in order to carry out maintenance activities on the networks.

KEYWORDS*: collapse, consumers, generation, grid, impacts, utilities*

1. Introduction

Nigeria is most populous and largest economy in Africa with a landmass of 923, 768 sqKm with numerous mineral resources deposit spread across the length and breadth of the country(Donatus, 2002; Adeoye, 2014). The country has thirty –six states and the federal capital territory is Abuja as shown in the administrative map of Nigeria n fig.1. The country has a population of over 170 million citizens with the government targeting 10,000MW generating capacity. However, the power generation is fluctuating from time to time based on gas pipeline vandalism and other environmental factors with low values of 1,508.6MW, 2,800 MW and high values of 4,387 MW and 5,000 MW (Adeoye & Adebayo, 2018). Electrical Power System is designed to function by generating and transmitting power to the load centres with specific frequency and voltage(Fasina et al., 2021; Adeoye & Oladimeji, 2018.; Samuel et al., 2017). The nominal frequency is 50Hz $^{\pm}$ 0.5% and under stress condition or fault occurrence, the power system is within the limits of 50Hz ± 2.5Hz. The nominal voltage of power system is 330kV, 132kV, 33kV, 11kV ±0.5%. It is obvious that under fault or stress condition, the voltage deviation outside the limits by ± 5%(Samuel et al., 2017). The system instability of power grid is based on increased load demand, increased population, industrialization, environmental and economic factors which adversely affect the design and construction of transmission lines and generating stations(Baby et al., 2013; Samuel et al., 2014). Disturbances in power system is one of major contributors to power system instability and subsequently grid collapse which leads to both technical and economic losses (Stojsavljevic et al, 2010). The power grid collapse is vulnerable to geomagnetic storms with the source from solar activity, electromagnetic pulses produced by altitude, cyber-attacks, and physical attack (Weiss & Weiss, 2019). Voltage collapse arises from the inability of heavily loaded power system network to withstand contingencies and finally result to voltage drop and subsequently grid collapse (Uche & Vitalis, 2018).In a situation where power is and or disconnected from the grid system, a partial or total system collapse is experienced(Adzua, 2021; Ehimen Airoboman, 2015).

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source: nationsonline.org/one world/map/Nigeria administrative map.htm (The Nations online project from nations online.org retrieved on 17th March 2023).

Fig. 1: Administrative Map of Nigeria

2. LITERATURE REVIEW

This section reviewed various papers as posited by authors on voltage stability assessment and voltage collapse based on methods and limitations, the perennial problems of persistent grid collapse, technical challenges, effects of grid collapse, and causes of grid collapse. (Olugbenga et al., 2013) *reviewed that Nigeria electricity reforms historical trend, the recent challenges in the electricity market, and the process of reformation, corruption, and building of market for electricity.*(Samuel et al., 2017) *noted utilized a new line stability index to predict voltage collapse in a power system network and the method was more accurate than previous approaches such as line stability index and fast voltage stability index.*(Benjamin & Epemu, 2021) *opined that the classification of system collapse on the grid with induced fault of 88%. Accuracy of the technique is in doubt. The author posited that transmission system should be expanded based on overstressing of the network.* (Ngoo et al., 2011) *used continuation power flow analysis, neuro-fuzzy model on IEEE 30 bus system to reduce power grid collapse. The author opined that the use of three-phase unbalanced continuation power flow algorithm for voltage stability assessment of distribution system with high distributed energy system on IEEE 13 node feeder* (Nirbhavane & Corson, 2021). *The authors used voltage limitation approach on different IEEE busses system to minimize the grid collapse* (Sadiq et al., 2015; Shen et al., 2019). (Laton et al., 2008) *presented that a potential algorithm for modified continuation power flow method in voltage stability assessment with the help of predictor, corrector, and tangent techniques. The adopted method had the ability to overcome challenges experienced by traditional power flow technique.*(Molekar & Pande, 2019) *used circuit theory approach for voltage stability assessment in a power system network on IEEE 14 bus network with slow operation or high computation time. When the network was re-configured to a 8bus system, power loss reduced and the computation time was reduced.*

2.1. REVIEW OF PERENNIAL CHALLENGES OF GRID COLLAPSE IN NIGERIA

The perennial challenges associated with persistent grid collapse in Nigeria are stated:

(i) Limited use of technology such as supervising control and Data Acquisition (SCADA) mechanism, a computer system for gathering and analyzing real-time data at National Control Center, Osogbo was not working for some times (Awosope, 2014; Onuoha, 2012).

(ii) Poorly Capitalised Distribution Companies with little or no investment on their networks that is grossly deficient to utilize available generation and this leads to load rejection and excessive pressure on the grid (Oubrahim, 2018).

(iii) Unattractive domestic gas marketing and inadequacy in its supply are part of the challenges for the controlling agencies and has made it difficult for the government to meet the power demand of the electricity consumers in the country which in most cases lead to power imbalance(Ehimen Airoboman, 2015).

(iv) Multi-Year Tariff Order (MYTO) tariff policy in 2015 posited that electricity distribution tariffs for the period of 2015 to 2024 with effective date from 1st Feb 2016. This tariff system is a model that is defined to provide the needed profit to the distribution companies. However, consumers of electricity are not properly metered by the distribution companies. National Electricity Regulatory Commission (NERC) carried out biennial minor reviews of tariffs and macroeconomic variables outside the control of electricity distribution companies in line with the methodology of MYTO. The variables outside the control of electricity distribution companies are inflation rate, foreign exchange rates, gas prices, and available generation capacity. The continuous increase in demand, industrialization, environmental and economic factors have made it difficult for power generation to match the demand and both the generation and transmission stations were not adequately built to specification and design. This has made the power network to be heavily loaded, prone to instability and weakness (Anosike et al., 2017; Ohajianya et al., 2014).

There are other contributors to persistent grid collapse in Nigeria as under-listed:

(1) The disconnection of power plants from the power grid at any point in time will lead to decrease in electricity generation in the country.

(2) Insurgency has brought sabotage to infrastructural development and due to increasing population of the citizens, energy demand is on the rise while gas supply shortage also contribute immensely to this problem due to incessant gas pipelines vandalism.

(3) The multiple tripping of circuit breakers is a major contributor to the persistent grid collapse.

(4) Gross mismanagement and misappropriation of funds set aside for upgrade of facilities in the power

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sector. The Central Bank of Nigeria gave out some money to distribution companies as bailout funds. However, most of the discos mismanaged the bailout funds. (Katende et al., 2014;Samuel et al., 2014b; Samuel et al., 2017).

2.2. REVIEW OF TECHNICAL CHALLENGES LEADING TO PERSISTENT GRID COLLAPSE

The technical challenges that leads to persistent grid collapse are the continuous utilization of old and obsolete power system equipment and this is due to their lifespan. Most of the equipment have been in operation for more than fifty years and they cannot satisfy the requirements of modern power system. Secondly, most of the protection system are very weak and faulty which affects the efficiency of the protective scheme while the use of backup protection with reinforced protection of zones will help the grid network. The indiscriminate tripping of lines due to weak grid network. The generation shortage due to increased population and increased demand in energy are serious contributors to grid collapse. The wheeling power is very weak and poor maintenance culture also contributes immensely to incessant power grid collapse. The categorical technical challenges that lead to power grid collapse are:

(1) Increased renewable energy sources (RES) connection to the grid: About 62 % of energy in the grid system is being expected to be RES in the next thirty years. The connection of RES is complex and weather dependent which will result into less efficiency, more losses, and grid network imbalance.

(2) Electricity transmission losses in Europe, India, and Haiti are 5%, 19%, and 50% respectively. The longer the length of a distribution line, the more the heat generated which produce energy losses.

(3) Huge power blackouts will have consequential damage on electronic device and loss of data.

(4) Electric vehicles charging and supercharger may be introduced to aid continuous power supplies for movement of cars, lorries, and trains rather than wasting a whole day queueing for fuel.

(5) Grid modernization through injection of REs and electric vehicles (EVs)

(6) Threats of cyber-attacks sequel to digitalization of energy sector which has exposed consumers to hackers leading to incessant blackouts.

(7) Continuous terrorist attacks on power lines, food supplies, farms, oil pipelines, and the consumers.

The possible solutions to the listed technical challenges are under-listed:

(1) Accurate weather prediction will assist grid balancing through computational intelligence. Standard energy storage to store unused energy for a future utilization is crucial to effective, adequate, and constant power supply.

(2) Energy requires to be decentralized by setting up smaller generating stations that can supply local consumers rather than the usual large plants.

(3) REs and backup supply will help in the area of continuous power supply for sensitive equipment.

(4) Smart grid application to the grid will assist to solve problems by online connection of solar panels, batteries, and EVs.

(5) Local energy production will reduce the energy utilization and distribution through power grid, transmission losses is reduced, and less burdened on power lines.

(6) Distributed database will minimize effects on cyber-attacks on the power generating stations.

(7) Microgrids should be set up in order to reduce the effects terrorist attacks on power grid which will be obvious and grievous on larger power plants(Ehimen Airoboman, 2015; Olugbenga et al., 2013).

2.3. GRID COLLAPSE IMPACTS ON CONSUMERS AND UTILITY COMPANIES

This section deals with the impacts of grid collapse on consumers and utility Companies.

1. Slow development of the country is a product of incessant grid collapse in Nigeria, this is detrimental to technological innovation, and the level of fabricating machines for the artisans is on the downward trend.
2. The rate of unemployment is alarming such that young school leavers and graduates are not gainfully employed due to constant grid collapse which adversely affects constant power supply. Erratic power supply and grid collapse have adverse effects on small and medium-scale enterprises.
3. There is poor business environment in the country due to power grid collapse. In view of the fact that electricity drives any economy, the grid collapse usually endanger conducive business environment due loss of energy thereby creating a state of downtime for artisans in their place of work.
4. The present state of security in the country is highly challenged due to porous boarder system, illegal immigrants, poor business environment and power outages in the country. The security apparatus to combat for present security challenges is through electronic security. However, grid collapse in this country will always cause a setback by the way of distorting the usage of security cameras at strategic locations.
5. The food security challenges in Nigeria are characterized by climate change and insecurity. The average citizen cannot afford a three-squared meal because peasant farming is still in vogue in this part of the world. Nigeria should take a step further by embracing mechanized farming. Food processing

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and preservation is achievable through constant power supply. However, regular grid collapse is a menace to food production due to mechanised farming system is not achievable without regular power supply(Adeoye, 2021; Ohajianya et al., 2014).

3. MATERIALS AND METHODS:

The methods used in this paper is through review of existing publications as related to power grid collapse, power stability, and use of collected secondary data in literatures, the use of simple mathematical tool of percentage and bar charts on the data, the use of internet facilities, also, the application of measure of central tendency like mean, median and mode was applied to the statistically assess the secondary data of grid collapse Mathematical equations are set up as shown in equation (1-4) in respect of the collected data on partial and total grid collapse. The economic losses due to power grid collapse in the country was estimated by the Mathematical equations (5-6)asset up with special consideration for the approximate population of the country, the population of Nigerians with access to electricity, and the supposed power consumption during power grid collapse.

Let grid collapse be G_C
Fault occurrence be F_{OCC}
Low gas be L_G
Frequency be F
Total collapse be T_C
Partial collapse be P_C
Overload be OVLD
Total grid collapse contributors be T_{GCC}
Percentage of grid collapse be $\%G_C$
Percentage of total grid collapse be $\%T_{GC}$
Percentage of partial grid collapse be $\%P_{GC}$
Frequency of grid type and causes be F_{GTC}
Frequency of total grid collapse be F_{TGC}
Frequency of partial grid collapse be F_{PGC}
Total of causes of grid collapse be T_{CGC}
Total occurrence of total collapse be T_{OTC}
Total occurrence of partial collapse be T_{OPC}

$$G_C = \frac{F_{OCC}+L_G+F}{T_{GCC}} \quad (1)$$

$$\%G_C = \frac{F_{GTC}}{T_{CGC}} \quad (2)$$

$$\%T_{GC} = \frac{T_{TGC}}{T_{CGC}} \quad (3)$$

$$\%P_{GC} = \frac{F_{PGC}}{T_{OPC}} \quad (4)$$

The population of Nigerians $= P_T$
The population of Nigerians with access to electricity $= 0.4P_T$
Power consumption per hour$= P_c$
When the country is fully electrified$= P_T \times P_c$ (5)
The obvious power accessibility $= 0.4P_T \times P_c$ (6)

TABLE 1: CURRENT EXCHANGE WITH RESPECTIVE HOUSEHOLD AND BUSINESS ELECTRICITY RATES

Currency	Household(KWh)	Business (KWh)
Nigerian Naira	22.55	36.15
American	0.049	0.078
Dollar		

Source: globalpetrolprices.com uploaded in March 2023 and retrieved in April 2023

TABLE 2: CLASSIFICATION OF SYSTEM COLLAPSE FROM 2008-2010

Disturbance	2008	2008 (%)	2009	2009 (%)	2010	2010 (%)
Faults	36	85.71	33	82.5	18	78.26
Low gas	2	4.76	5	12.5	0	0
Overload	1	2.38	2	5	3	13.04
Frequency	2	4.76	0	0	2	8.7
No reason	1	2.88	0	0	0	0
Total	42	100	40	100	23	100

Source:(Samuel et al., 2014b; Samuel et al., 2017)**s**

TABLE 3: TOTAL AND PARTIAL GRID COLLAPSE IN NIGERIA FROM 2010-2020

Year	Total collapse	Total collapse (%)	Partial collapse	Partial collapse (%)
2010	22	15	20	33.3
2011	13	8.8	6	10
2012	16	10.9	8	13.3
2013	22	15	2	3.3
2014	9	6.1	4	6.7
2015	6	4.1	4	6.7
2016	22	15	6	10
2017	15	10.2	9	15
2018	12	8.2	1	1.7
2019	9	6.1	0	0
2020	1	0.7	0	0
-	147	100	60	100

Source: (Samuel et al., 2014b; Samuel et al., 2017)

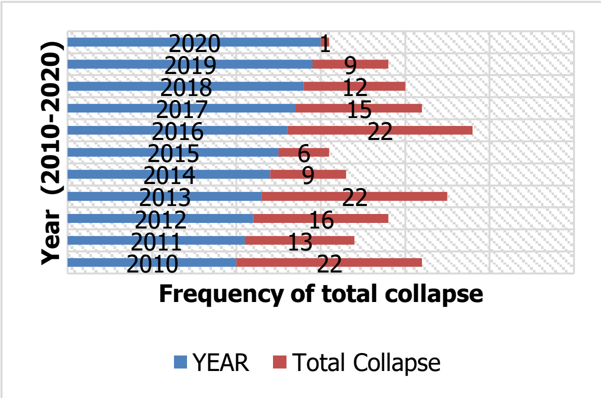

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Fig. 1: Plot of frequency of total grid collapse from 2010-2020 in Nigeria

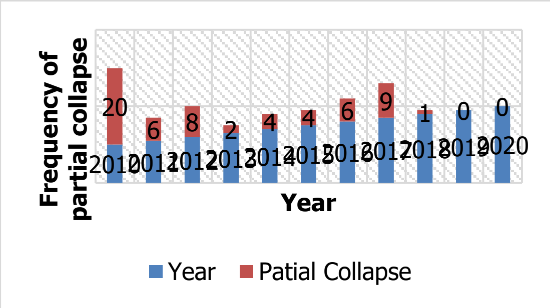

Fig.2: Plot of partial grid collapse from 2010-2020 in Nigeria

4. RESULTS AND DISCUSSION:

Table 1 shows the electricity rates with respective currencies in both Nigerian Naira and American dollar. The mean, median, and mode for 2008 was more prominent on fault that occurred in the system for thirty-six times. In 2008, the major contributor was fault to the grid collapse. In 2009, the mean, median, and mode was also more prominent on faults while in 2010, the mean, median and mode was also highly prominent on fault as shown in Table 2. In Table 3, when the mean, median, and mode were applied to partial and total grid collapse, the mean was more prominent in 2014 with nine occurrences; the median was in same year with same frequency while the mode occurred twenty-two times in 2010, 2013, and 2016. In Table 3, the percentage analysis of partial and total grid collapse showed that the highest total collapse occurred in 2010 and 2016 for twenty-two times with 14.97%. The least total grid collapse occurred in 2020 for just once at 0.68 %. The least occurrence is sequel to reduced minimal movement of people from one place to another due to COVID-19 pandemic. For partial grid collapse, the maximum event was in 2010 with twenty times at 33.33% while the least occurred in 2019 and 2020 with no occurrence at 0%. Fig. 1 and Fig. 2 show the plots of total grid collapse and partial grid collapse in Nigeria from 2010-2020. The plots displayed the frequencies of both total and partial collapse. From Fig.1, the plot displayed that twenty times of total grid collapse in 2016 while the highest partial collapse was in 2010 with twenty times. All these have significant effect on the security of the citizens, economy downturn due to adverse effect on domestic, commercial, and industrial consumers. In the same vein, the adverse effect on the utility companies is enormous because the citizens will not be ready to pay energy bills and the amount of money that ought to be re-invested into the energy business will be affected. Therefore, revenue generation will be reduced and staff payment will be affected, maintenance activities will also have negatively affected in the area of replacing obsolete and damaged equipment. Table 1 shows the electricity prices for household and business consumers with the prices stated in Nigerian and United States currencies. The estimated economic loss for fully electrified country is #4, 500,000, 000 and $9,800, 000 for Nigeria and United States currencies respectively. The actual economic loss in both Nigeria and United States currencies are #1,125,000,000 and $2,450,000 respectively.

5. CONCLUSION

The incessant grid collapse in Nigeria will definitely affect socio-economic development adversely. The paper has examined the most conspicuous causes of collapse of the grid to be partial collapse in eleven years with its severity in 2010. The occurrence of total collapse shows that 2010, 2013, and 2016 recorded the highest with twenty-two times. The paper also discussed the causes of grid collapse from 2008-2010. This establishes that faults are the major contributor to collapse of grid system with its severity in 2008 with 36 events, 33 events in 2009, and 18 events in 2010. All these pointed to the fact that while the electricity consumers are affected, industrialization, commercial activities are also badly affected. The estimated economic loss for fully electrified country is #4, 500,000, 000 and $9,800, 000 for Nigeria and United States currencies respectively. The actual economic loss in both Nigeria and United States currencies are #1,125,000,000 and $2,450,000 respectively. It is obvious that the utility companies are not left out of the negative impact on dwindling revenue generation due to unwillingness of electricity consumers to pay energy bills. The image of the utility companies may also be adversely affected.

6. RECOMMENDATION

The following recommendation will help in overcoming regular grid collapse.

1. Bridging of power generation and demand gap through injection of renewable energy.
2. Effective monitoring of the frequency of the generators within the standard.
3. Vigorous investment of oil firms into the energy sector.
4. All obsolete transformers and lines should be replaced without any delay.
5. Gas supply to gas situation should be adequate.
6. Internal and external faults should be cleared immediately and alternative power grid may be constructed, however, the cost of construction may be on the high side.

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