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Evaluation of Large System Disturbance in the Nigeria Electric Power System

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Abstract: *The repeated case of power system collapse in the Nigerian National Grid isof a great concern and need to be investigated. This research paper discusses the effect of voltage collapse and the methods of power generation with respect to the Nigerian National Grid. Other major causes of voltage instability were also examined. Politics has been known to be one of the major factors responsible for epileptic power supply in the country as a result of corruption within the power sector. Single Line Diagram (SLD) showing all the generating stations and transmission network and the distances covered is also presented. Results recorded an average of twenty five disturbances over a period of twenty three years under investigation (January, 1995- July, 2017). 2003is the year with the highest number of faults recorded over the period of twenty three years, representing 8.95% of the total faults. Similarly, the year 1999 recorded the least number of faults representing 1.52% over the same period. The partial grid collapse and total grid collapse disturbances represent49% and 51% respectively. Only four power stations out of the fourteen are identified to be operating on full installed capacity. The thermal plants represents 76% while 24% for hydro power plants across the country. Collated results are tabulated, exhaustively discussed and analysed using tables, charts and graphs. Appropriate recommendations are also presented such that if implemented will proffer lasting solutions to the challenges confronting the power sector in Nigeria.*

Keywords*: Large system disturbances, Political factor, Voltage collapse, Voltage instability, National grid,*

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I. Introduction

Uninterrupted power supply is inevitable in Nigeria even for a full day as a result of incessant cases of voltage collapse over the years which has called for attention. The Nigerian power system has recorded two hundred and fifty five voltage collapses in the last ten years. However, the key purpose of a power system network is to generate and transmit power to load locations at precise voltage and frequency within acceptable variation base levels. The nominal frequency of50Hz with ±0.5% variation is acceptable and ±2.5% variation when subjected to stress. Similarly, the nominal voltage shall be 330kV, 132kV, 33kV and 11kV with ±0.5% variation limits. System voltages are required to fluctuate only within the acceptable limit of ±5% when subjected to stress as long as transient and sub-transient disturbances are neglected [1]. The difference in the voltage and frequency levels arises because of change in reactive and real power. The power system is usually incorporated with controllers that control these variations within acceptable limits. Voltage stability has been a major problem to power system engineers in ensuring smooth working and control of power system architecture [2]. This problem is usually because of increase in load demand, industrialization, environmental and economic factors. The environmental factors such as mountains, valleys, and water bodies hinder the construction of new generation stations and transmission lines. This further leads to weakness of the power system network resulting to voltage instability [2, 34]. The ability of a power system network to retain steady voltage at all points after been subjected to stress is called voltage stability [5,6]. An efficient and reliable power system is supposed to return to its state of equilibrium as soon as the disturbance is cleared.

Voltage instability in a power system is said to occur when a disturbance causes a gradual and uncontrollable drop in voltage. The major causes of voltage instability are contingencies. The frequently occurred contingencies arise from voltage or line outage and changes in load. Considerably, the variance in supply and demand of reactive power does not result to voltage instability. Voltage collapse can be explained as an inability of a heavily loaded power system network to withstand contingencies and finally result to voltage drop and eventually collapse. This ultimately affects the security of the power system in ensuring delivery of uninterrupted power supply to users. Systems collapse on the other hand is the loss of synchronization of the component(s) of the grid system. One of the major problems of these collapses has been credited to political factor(s) [7]. In the year 2007, the Nigerian government privatized the generation and distribution system and retains ownership of transmission system [8]. The single line diagram (SLD) of the Nigerian network is shown in Figure1.

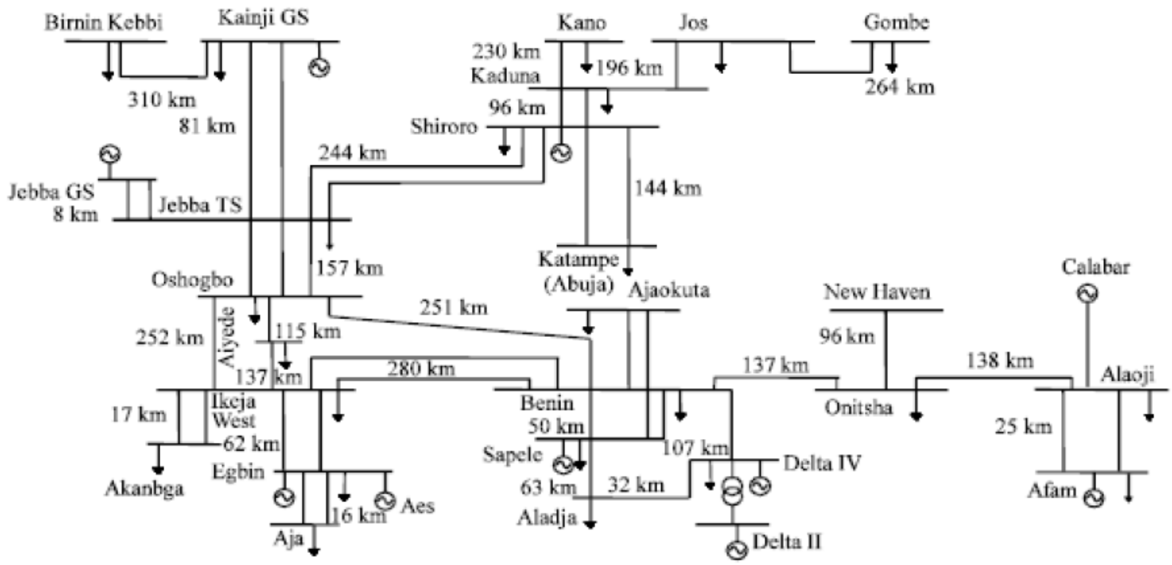

Figure 1: Single line diagram (SLD) of the Nigerian 24 Bus 330kV Network [9]

It is necessary to carry out thorough maintenance at least once in every fourty-one days along the Nigeria transmission lines so as to avoid those collapses [10]. There are usually cases of tripping of transmission lines leading to partial or total power outages of the network. Technical and non-technical faults remain the major causes of system collapse [9]. System collapse may occur as a result of radial grid system, weak system inertia, faulty protection system, defective governor, vandalization, natural accident, poor maintenance, human error, government negligence and politicization of the power sector. Figure 1 depicts clearly that the Nigerian grid network consists of only one ring network –the Benin-Ikeja west-Aiyede-Oshogbo-Benin. The Nigerian power system lack sufficient ring networks thereby exposing the grid to serious collapses due to excessive current flow during fault conditions as a result of insufficient transmission lines. Problems of transient stability concern with the effects of large and sudden system disturbances such as; sudden switching of lines, line faults, collapse of a major generating unit and application or removal of loads [11].This research paper focuses on the effects of voltage collapse on the grid over the years and suitable recommendations on how this problem can be curtailed.

II. Summary of the Nigerian National Grid System

The full installed capacity of the National Grid is 7,876MW at present but the available capacity is less than 4,000MW. About Seven generating stations are over 20 years out of the fourteen generating station and the average generation is less than 4,000MW per day which is much smaller compared to the present installed capacity [12]. The Nigerian transmission network is characterized by poor voltage profile in many parts of the network with insufficient power system infrastructure, radial and weak grid network especially in the northern part of Nigeria [1], resulting to numerous outages and causing disruption in the lives and property of the people. This disruption is as a result of high demand of electricity by consumers which is fairly much for Nigerian as a developing nation [13]. For example, every individual is entitle to be supplied only 23.5W of power considering the available generating capacity of approximately 4,000MW for an estimated Nigerian population of 170 million people. This is extremely poor, yet the reliability of available power is still less than one percent [14].

It's however unfortunate that the Nigerian transmission lines do not cover the entire parts of this country. It has the capacity to transmit about 4,000MW maximum presently and is technically fragile with frequent cases of system collapse and high transmission losses, making the system vulnerable to major disturbances [1]. The Nigerian Power Sector Privatization was commended to be one of the bravest privatization initiatives in the history of the Nigeria's power sector over the last decade, which cost about $3.0bn [15].However, no substantial achievement has been made in the sector rather than frequent cases of voltage collapse, poor generation, and poor wheel power. The power generated is still much far from the daily load demand.

The Nigerian National Grid recorded no collapse during the military regime in the year 1992 [16]. Staff were properly trained and the use of Supervisory Control and Data Acquisition (SCADA) systems for effective monitoring and control of the power system network were the reasons for this giant success. These SCADA systems were built between 1960s-1980s which function till the mid-1990s before they all became obsolete and could not function properly. One could infer that the advent of civilian administration did not favour the power sector till today.

The National transmission network covers 5000km which is made up of 330kV and 132kV lines. The 330kV lines link thirty three substations through 330/132kV step down transformer with a total capacity of 4,800 MVA and 6,000 MVA at 80% and 100% utilization factor respectively. Similarly, a step down transformer of 32/33kV ratings supply ninety one substations by 132kV lines with combined capacity of 5,850 MVA and 7,800 MVA at 75% and 100% utilization factor respectively [I7].

Voltage collapse is said to occur when a power island is disconnected from the rest of the grid system and thus leading to either a partial or total collapse. The segment of the national grid system affected by one of the major voltage collapses of 25th August, 2007 is shown in Figure 2.

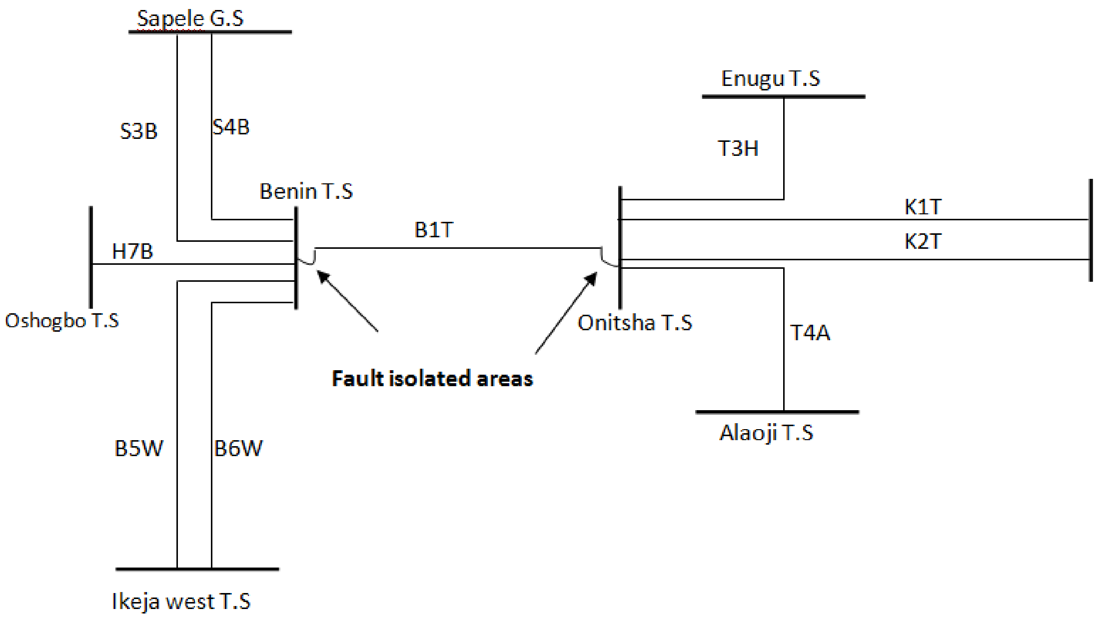

Figure 2: Total voltage collapse on 25/08/2007 [16]

III. Methodology

The National Control Centre (NCC) Oshogbo was contacted for possible interaction with their team of electrical engineers as regard records of system collapse in the Nigerian power system. Other sources of data include published journals, conference papers and online newspaper publications. Available data were collated as primary source of data for presentation and analysis. The records of various collapses, the frequency and the nature of collapses that have occurred in the Nigerian National grid were also collated. In the same way, the existing generating capacity of power plants in Nigeria with respect to the kind of plant, the nature of fuel used by the plants, their location, age of plants, installed and available capacity, installed units and available units were also determined and tabulated. Tables were analysed sequentially using simple percentages as represented in Tables 1 to 5. Microsoft Office Excel has been used to generate charts and graphs from obtained results and evaluation as shown in Figures 3 to 12.

III. Presentation of Results

Table 1: The Nigerian Grid Disturbance [14]

Year	Disturbances	Disturbances Caused by Generation Faults		Disturbances Caused by Transient Faults		Partial Grid Collapse Disturbances			Total Grid Collapse Disturbances			Disturbances with Indeterminate causes			
		Actual No.	% Total	Actual No.	% Total	Gen. Caused	Transient caused	Total	Gen. Caused	Transient	Total	Total. C	Partial.C	Total	% Total
2017	14	-	-	-	-	-	-	2	-	-	12	0	0	0	0.00%
2016	28	-	-	-	-	-	-	6	-		22	0	0	0	0.00%
2015	10	-	-	-	-	-	-	6	-	-	4	0	0	0	0.00%
2014	13	-	-	-	-	-	-	4	-	-	9	0	0	0	0.00%
2013	24	-	-	-	-	-	-	2	-	-	22	0	0	0	0.00%
2012	24	-	-	-	-	-	-	9	-	-	15	0	0	0	0.00%
2011	19	-	-	-	-	-	-	6	-	-	13	0	0	0	0.00%
2010	42	9	21.23%	29	69.05%	2	17	19	7	12	19	4	0	4	9.52%
2009	39	8	20.51%	31	79.49%	3	17	20	5	14	19	0	0	0	0.00%
2008	42	11	26.92%	30	71.42%	4	12	16	6	19	25	0	0	1	2.38%
2007	27	3	11.11%	24	88.09%	1	8	9	2	16	18	0	0	0	0.00%
2006	30	8	26.67%	22	73.33%	2	8	10	6	14	20	0	0	0	0.00%
2005	36	15	41.67%	21	58.33%	4	11	15	11	10	21	0	0	0	0.00%
2004	52	20	38.46%	32	61.54%	7	23	30	13	9	22	0	0	0	0.00%
2003	53	14	26.42%	39	73.58%	9	30	39	5	9	14	0	0	0	0.00%
2002	41	19	46.34%	22	53.66%	18	14	32	1	8	9	0	0	0	0.00%
2001	19	9	47.37%	10	52.36%	1	4	5	8	6	14	0	0	0	0.00%
2000	11	2	18.18%	9	81.82%	0	6	6	2	3	5	0	0	0	0.00%
1999	9	2	22.22%	7	77.78%	1	4	5	1	3	4	0	0	0	0.00%
1998	18	2	11.11%	16	88.89%	2	11	13	0	5	5	0	0	0	0.00%
1997	20	0	0.00%	20	100.00%	0	13	13	0	7	7	0	0	0	0.00%
1996	10	3	30.00%	7	70.00%	3	5	8	0	2	2	0	0	0	0.00%
1995	11	0	0.00%	11	100.00%	0	10	10	0	1	1	0	0	0	0.00%

Table 2: Summarized Table of partial and total collapses

Type of Collapse	Frequency of Occurrence
Partial grid collapse disturbance	285
Total grid collapse disturbance	302

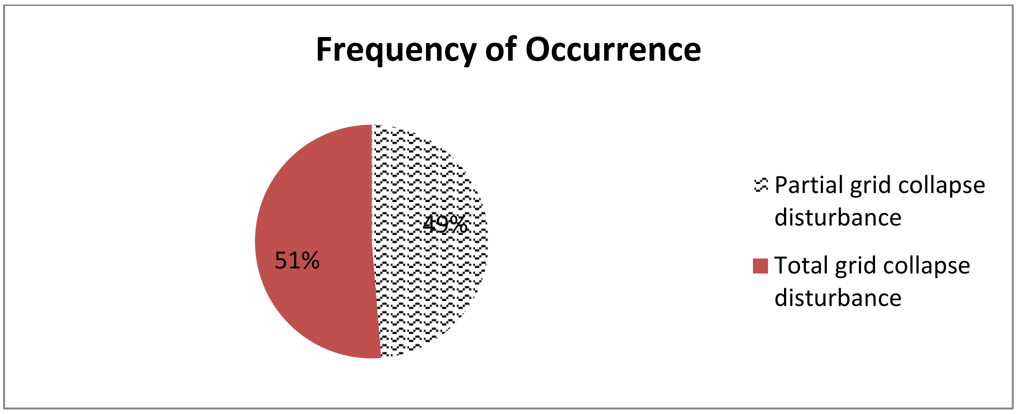

Figure 3: Pie chart showing partial and total grid collapse

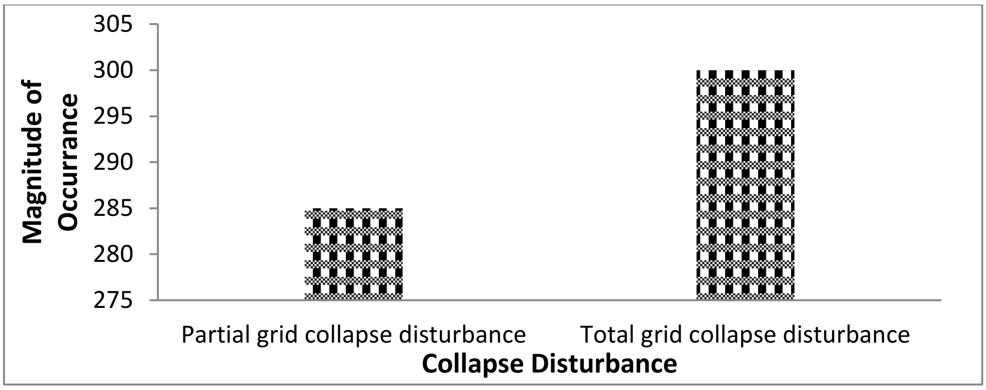

Figure 4: Bar chart showing partial and total grid collapse

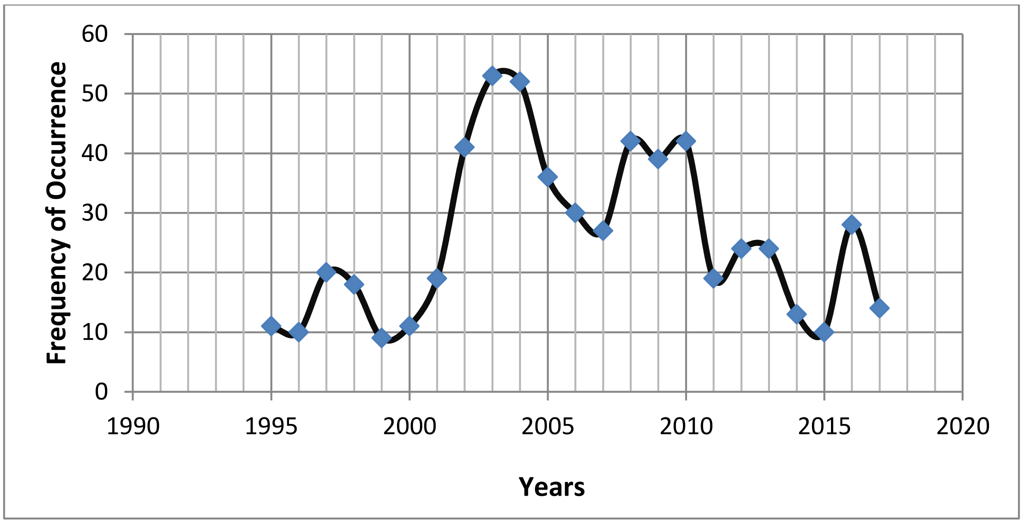

Figure 5: Graphical representation of total disturbance (1995-2017)

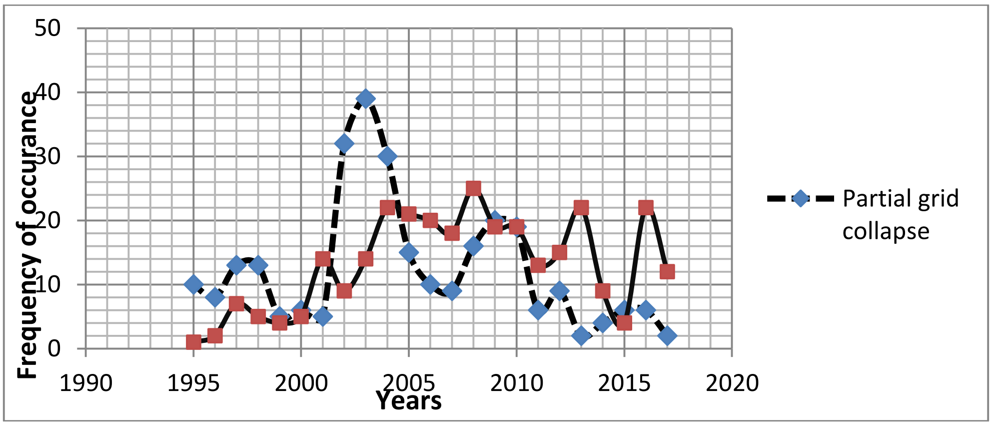

Figure 6: Graphical representation of partial and total grid collapse (1995-2017)

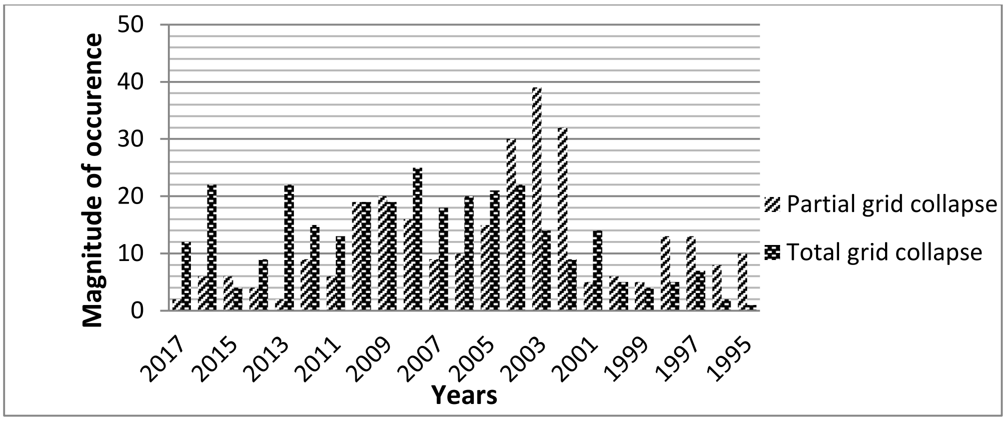

Figure 7: Bar chart representation of partial and total grid collapse (1995-2017)

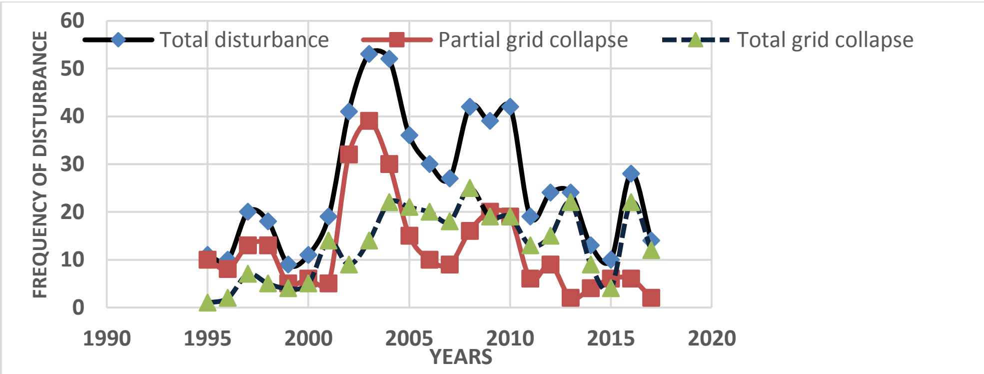

Figure 8: Combined graphical representation of voltage collapses (1995-2017)

Table 3: Plants and their generating capacity [14]

S/n	Plant	Plant type	Location State	Age (years)	Installed Units	Installed Capacity (MW)	Units Available
1	Egbin	Thermal	Lagos	31	6	1320	4
2	Egbin AES	Thermal	Lagos	15	9	270	9
3	Sapele	Thermal	Delta	37	10	1020	1
4	Okpai	Thermal	Cross river	11	3	480	2
5	Afam	Thermal	Rivers	34	20	702	3
6	Delta	Thermal	Delta	26	18	840	12
7	Omoku	Thermal	Rivers	11	6	150	4
8	Ajaokuta	Thermal	Kogi	10	2	110	2
9	Geregu	Thermal	Kogi	10	3	414	3
10	Omotosha	Thermal	Ondo	3	8	335	2
11	Olorunsog/ Papalanto	Thermal	Ogun	3	8	335	2
	SUB-TOTAL (THERMAL)				**93**	**5979**	44
12	Kainji	Hydro	Niger	49	8	760	6
13	Jebba	Hydro	Niger	33	6	540	6
14	Shiroro	Hydro	Niger	31	4	600	2
	SUB-TOTAL (HYDRO)				**18**	**1900**	14
	Grand Total				**111**	**7876**	58
SUMMARY		**% Thermal**			**84**	**76**	**76**
		% Hydro			**16**	**24**	**24**

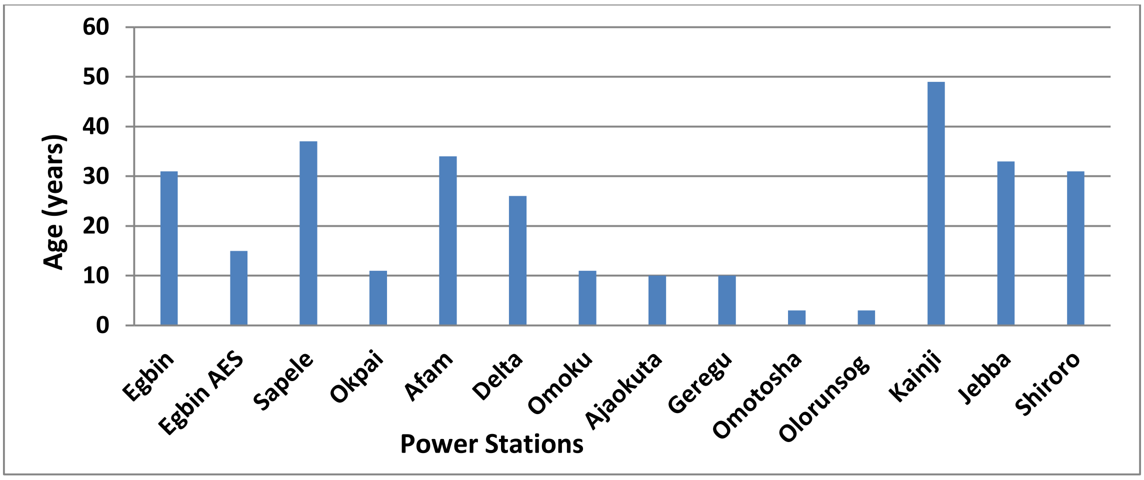

Figure 9: Bar chart showing Nigerian generating stations and their ages

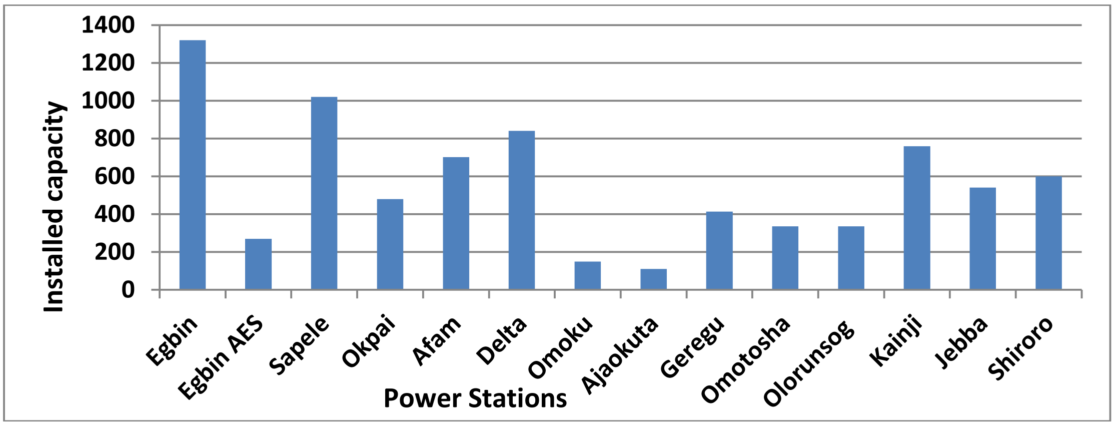

Figure 10: Bar chart showing Nigeria generating stations and their installed capacity

Table 4: Generating plants with full available factor

Plants Operating at Full capacity	Installed units	Available units	Available factors
Agbin AES	9	9	1
Ajaokuta	2	2	1
Geregu	3	3	1
Jebba	6	6	1

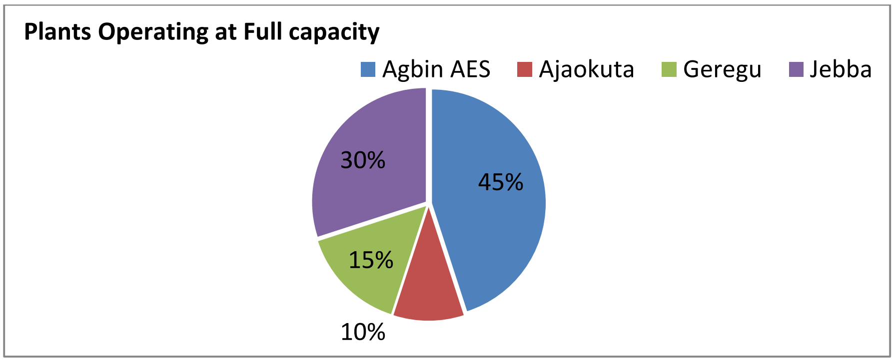

Figure 11: Pie chart showing plants with full available factor in Nigeria

It is seen that Agbin is the most available of all the operating plants.

Table 5: Plant installed capacity and their available factor

Type of plant	Thermal Plants	Hydro plants
Installed capacity (units)	93	18
Available capacity (units)	44	14
Available factor	0.47	0.77

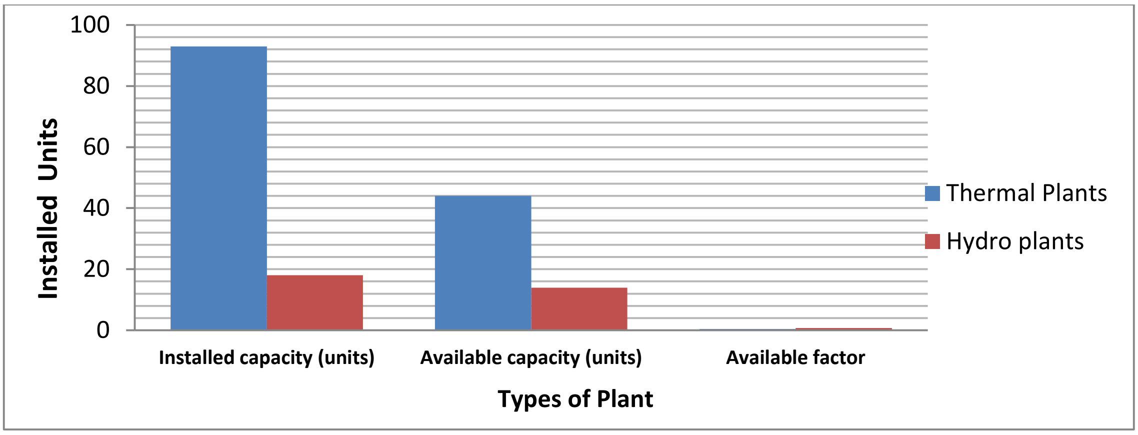

Figure 12: Bar chart of thermal and hydro Installed units and their available factorin Nigeria

V. Discussions of Findings and Analysis

The average percentage of collapse in a given year can be deduced as thus;

$$\text{Av \%} = \frac{\text{Number of collapse in a year}}{\text{Total number of collape}} \times 100 \quad (1)$$

Also, the average number of collapse for a given period of time under investigation can be given as;

$$\text{Av} = \frac{\text{Total number of collapse for a given period of time}}{\text{Total number of years under investigation}} \quad (2)$$

Findings reveal that Nigeria had recorded a total of five hundred and ninety two collapses, making an average of twenty five disturbances over a period of twenty three years under investigation (January, 1995- July, 2017). The average number of collapses within this period (1995 – 1999) was approximately fourteen. The average number of collapses rose tothirty five which is about 150% increase within (2000 – 2004).

Table 1 reveals that, fifty three disturbances were recorded in the year 2003 been the highest number of disturbances recorded over the period under investigation (twenty three years), representing 8.95% of the total disturbances. Similarly, nine faults were also recorded been the least number of faults in the year 1999 representing 1.52% over the same twenty three years. This implies that 2003 was the worst year with the highest number of voltage collapse incidences. Meanwhile, the end of the military regime in 1999 had the best record of voltage stability recording the least number of voltage collapse cases. 2010 was the only year that had cases of voltage collapses due to indeterminate causes representing 9.52% in that year. There were fewer cases of total voltage collapses within (1995 – 2004) compared to partial voltage collapses and eventually rose from 2005 – 2017 as shown in Figure 6.

Table 2 and the figure 3 results also show that out of numerous collapses, 49% represents partial grid collapse whereas 51% were total grid collapse. The installed units of the power stations operating at full capacity include; Egbin AES, Jebba, Geregu and Ajaokuta representing45%, 30%, 15% and 10% respectively as shown in Figure 11.

There are fourteen generating station in all. Results show that out of fourteen generating stations, only four are operating in full capacity. Table 3 shows that eleven out of fourteen power plants are thermally operated while the remaining three are hydro power generating stations. The thermal plants have a total installed capacity of 5,979MW while the hydro plants with 1,900MW in total, representing 76% and 24% respectively across the country. The oldest generating station in the country is Kainji hydro station in Niger state which is fourty nine years at present followed by Sapele thermal station located in Delta state, aged thirty seven years. Egbin thermal station located in Lagos state remains the highest generating station with installed capacity of 1,320MW. Ajaokuta thermal plant in Kogi state has the least generating capacity in the country with installed capacity of 110MW.

Mismanagement of funds and poor government policies has being one of the reasons for poor power generation, transmission and distribution in the country ranging from one civilian government to another. However, billions of naira has been spent in the sector to improve power generation but no substantial results have been recorded. The daily load increase on the grid is always higher than the combined generating capacity of all the interconnected generating stations leading to drop in system frequency, hence voltage collapse. The concerned authorities resort to load shedding, giving priority to government facilities and commercial centres, leaving the masses poor in total blackout for many hours or even days depending on the severity of the problem.

V1. Conclusion

This research paper discussed and analysed the effect of voltage collapse with respect to Nigerian National Grid system. Major causes of voltage instability are contingencies. The overview of the Nigerian national Grid comprising the installed and available capacity of all the generating station within the country was presented. Voltage and generator outages, faults due to increase in load demand and external factors have significant effect in voltage instability. Single Line Diagram of Nigerian power system showing all the generating stations, transmission network and distances covered were perused. From the available data collated, Egbin has the highest installed capacity while Ajaokuta has the least. In order to operate the system optimally, it is highly recommended that maintenance be carried out once in every minimum interval of fourty one days along transmission lines. This enhances identification of potential disturbances which could be matched up with appropriate preventive measures. This reduces the bottle neck of high transmission losses and weak transmission network which may result in a vulnerable situation of network disturbances and accidental collapse. Finding reveals that much have-not been achieved despite privatization of the power sector for almost a decade now in Nigeria. Minimal cases of system collapse were however recorded during the military regime until the emergence of civilian government in the fourth republic. Collated results were tabulated and exhaustively discussed and analysed using tables, charts and graphs. The implementation of the recommendations as presented in this work will proffer solution to the lingering challenges within the power sector.

VI1. Recommendations

- Embedded generation should be encouraged through every renewable means possible so as to bring electricity closer to the users and save cost of long distance transmissions usually associated with power losses and high risk of disturbance leading to system collapse.
- Favourable government policies can encourage private partnership in the area of power generation, especially the oil producing companies so as to boast supply and compensate losses.
- Government should ensure that politics don't take centre stage in the power sector by ensuring that power projects are given to competent contractors and supervised to the end as well by competent personnel to ensure completion and compliance with specifications.
- The government should also go into more Public Private Partnership (PPP) to ensure routine maintenance of the Nigerian National Grid to increase efficiency, reliability and reduce incidences of disturbances that could result to system breakdown.

References

[1]. Nigeria Electricity Regulatory Commission (NERC) "The Grid Code for Nigeria Electricity Transmission System," Version 1, pp. 66 –74, 1st August 2007.
[2]. L. D Arya, "Voltage Stability Evaluation using Line Voltage Stability Index," IE(I) Journal-El Vol 87, December 2006, pp. 1-7.
[3]. S. Almeida, N. Machado and R. Pestana, "Voltage Collapse: Real Time and Preventive Analysis in the Portuguese Transmission System," *2007 IEEE Lausanne Power Tech*, Lausanne, 2007, pp. 1817-1822.
[4]. M. Hasani and M. Parniani, "Method of Combined Static and Dynamic Analysis of Voltage Collapse in Voltage Stability Assessment," *2005 IEEE/PES Transmission & Distribution Conference & Exposition: Asia and Pacific*, Dalian, 2005, pp. 1-6
[5]. Kundur, Prabha, Neal J. Balu, and Mark G. Lauby. "Power system stability and control," The EPRI power system engineering series, New York: McGraw-hill, 1994, pp.816-920
[6]. Taylor, Carson W., N. Balu, and D. Maratukulam. "Power system voltage stability, ser. EPRI power system engineering series," 1994, pp. 10-16
[7]. S. Isaac, K. James, and I. Frank, "Voltage Collapse and the Nigerian National Grid", EIE's 2nd Intl' Conference, Comp., Energy, Net, Robotics and Telecom. EIECON, 2012, pp. 128-131.
[8]. Sambo, Abuabkar Sani, Bashir Garba, Ismaila Haliru Zarma, and Mohammed Musa Gaji. "Electricity generation and the present challenges in the Nigerian power sector," Journal of Energy and Power Engineering 6, no. 7 2012, pp. 1050.
[9]. A. Airoboman, I. Okakwu, A. Alayande and O. Seun, **"**On the Assessment of Power System Stability Using Matlab/Simulink Model", International Journal of Energy and Power Engineering,4, (2), 2015, pp. 51-64.
[10]. A.E Airoboman,"Power System Dynamic State Stability Analysis," A case study of Benin- Onitsha-Alaoji 330kV Transmission Line, master's thesis. University of Benin, Nigeria,2012, pp. 1-6.
[11]. Ndiagwalukwe, J. U. "Frequency Control and Grid Stability," National Power Summit, Abuja Nigeria, December 2012, pp. 2-10.
[12]. Labo, H. S. "Current status and future outlook of the transmission network" TCN, Abuja, 2010, pp. 10-15.
[13]. P. Anil, H. Mark, and T. Graunt, "Estimation of Outages in Overhead Distribution Systems of South Africa and of Manhattan, Kansas, USA," 7th International Conference on Power System Operation and Planning, Cape Town, South Africa, Jan; 2007, pp. 10-16.
[14]. A. Ehimen, I. Kema, P. Aigboviosa and E. Seun. "An assessment of Voltage Instability in the Nigerian Power System Network". The International Journal of Engineering and Science 4(7), 2015, pp. 9-16.
[15]. KPMG., A Guide to the Nigerian Power Sector, 2013, p.9.
[16]. N.C.C Oshogbo, Generation and Transmission Grid Operations Annual Technical Report, 2010, pp.66-76
[17]. I. Samuel, J. katende, S. Adebayo and A. Awelewa "review of System Collapse Incidences on the 330kV Nigerian National Grid" International Journal of Engineering Science Invention, 31(3), April, 2014, pp. 55-59.

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