The International Journal Of Engineering And Science (IJES)
|| Volume || 4 || Issue || 7 || Pages || PP.09-16 || July - 2015 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

An Assessment of Voltage Instability in the Nigerian Power System Network

[1,] Abel EhimenAiroboman, [1,] Ignatius KemaOkakwu,
[2,] Peter AigboviosaAmaize, [3,]EmmanuelSeunOluwasogo.
PhD ScholarsDepartment of Electrical/Electronics Engineering, University of Benin, Nigeria
Department of Electrical and InformationEngineering, Covenant University, Ota, Nigeria
Department of Electrical and Computer Engineering, Kwara State University, Malete, Nigeria

ABSTRACT

This paper assesses the trends in voltage instability in the Nigerian Power System Network (PSN). Data of voltage instability were collected for the year (1995-2013) and was analyzed sequentially using simple statistics and the result interpreted graphically. The result shows an average collapse of 5.1% recorded during this period. 50.8%of the voltage collapses are as a result of total grid collapse while 48.4% collapses are as a result of partial grid collapse while 0.9% collapses caused by foreign objects. The paper therefore emphasizes how poor government policies had led to poor power generation hence leading to voltage instability in the Nigeria power system network.

KEYWORDS:*Government Policy,Power Generation, Power System Network, Voltage Collapse.*

Date of Submission: 20-June-2015 Date of Accepted: 10-July-2015

I. INTRODUCTION

In recent years, voltage stability problem have been encountered by many power utilities in Nigeria. Hence, the appropriate authority are forced to operate the system under increasing stressed condition [1].Systems collapse is the loss of synchronization of the component of the grid system that is the units on bar in the different generating power stations, and one of the major problem of these collapses has been attributed to political factor(s) [2]. Due to the importance of the sector, the government of Nigeria in 2007 declared a state of emergency in the power sector thus eliminating bureaucracy in generation, transmission and distribution sector [3].Fig 1 has shown the one line diagram of the grid system in Nigeria.

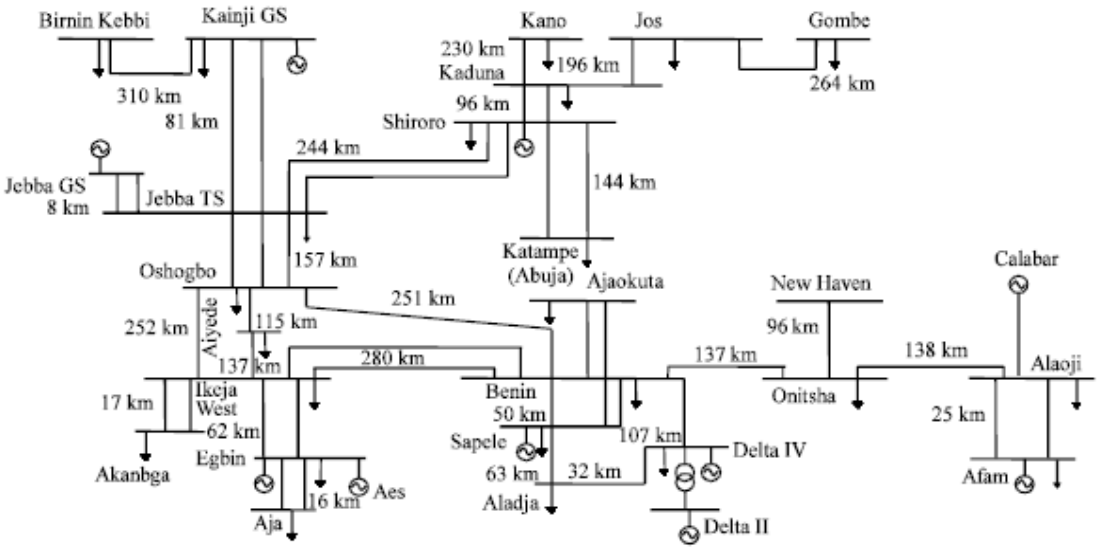

Fig 1: One-line diagram of Nigerian 330-kV transmission network [4]

In other to avoid these collapses, there is a need to carry out thorough maintenance at least once every forty-one days along the transmission line in Nigeria [5]. Whenever there is the occurrence of a voltage collapse, it brings about the tripping of a transmission line(s) resulting to power blackout in some areas or all the areas of the network. The causes of system collapse may either be a technical or non-technical fault [5] .Generally, system collapse may arise due to any of the following reasons; radial grid System, weak system inertia, faulty protection system, defective governor, vandalization, natural accident, poor maintenance, human error, corruption, neglect of government by politicizing the sector and paying of lip service to the it.A careful study of the Nigerian Power System Network from fig 1. shows that theNigerian grid network comprise of only one ring network i.e. Benin-IkejaWest-Aiyede-Oshogbo-Benin hence, exposing the grid to severe collapses because power have to flow in one direction only in a large portion of the grid thus exposing the grid to a great instability during fault conditions because of the lack of redundant transmission lines. Transient stability problems deal with the effects of large, sudden system disturbances such as: Line faults, Sudden switching of lines or the sudden application or removal of loads and Loss of a major generating unit [6].This work analyses the effects of voltage collapse and how it has been affecting the grid over the years and also proffer solution and suitable recommendations on how this problem can be curbed

II. OVERVIEW OF THE NIGERIAN GENERATION AND TRANSMISSION SYSTEM

The total Installed capacity of the currently generating plants is 7,876MW but the presently installed available capacity is less than 4,000MW. Seven of the fourteen generating stations are over 20 years old and average daily power generation is less than 4,000MW which is quite below the currently installed infrastructure [7]. On the other hand, the transmission network in Nigeria is characterized by several outages leading to the disruption in lives and property of the citizenry. This level of disruption is a function of the people dependence on electricity which can be very high for a developed country and not as much for a developing country like Nigeria [8]. For instance, if we divide the generating capacity in Nigeria (4,000MW) by the number of population in Nigeria (160Million) then, it implies that an individual in Nigeria can only get (25W) of power supplied to him/her daily and even as poor as this may be, the reliability of this power to be available when needed is less than one.

The transmission system in Nigeria does not cover every part of the country. It currently has the capacity to transmit a maximum of about 4,000MW and it is technically weak thus very sensitive to major disturbances.The Federal Government of Nigeria has been able to complete the privatization process whereby the Federal Government retains the ownership of the transmission assets with the generation and distribution sectors fully privatised. The Nigerian Power Sector Privatization is reputed to be one of the boldest privatization initiativesin the global power sector over the last decade, with transaction cost of about $3.0bn [9] but to no avail no conscious achievement has been noted in the sector rather voltage collapse, poor wheel power, poor generation, power generated no close to its corresponding load demand has been the order of the day.

Voltage collapse is a situation whereby a power Island has become detached from the rest of the grid system, and thus experienced a collapse of the associated power stations leading to either a partial or total collapse.Fig 2 has shown the section of the Nigerian grid system affected by voltage collapse.

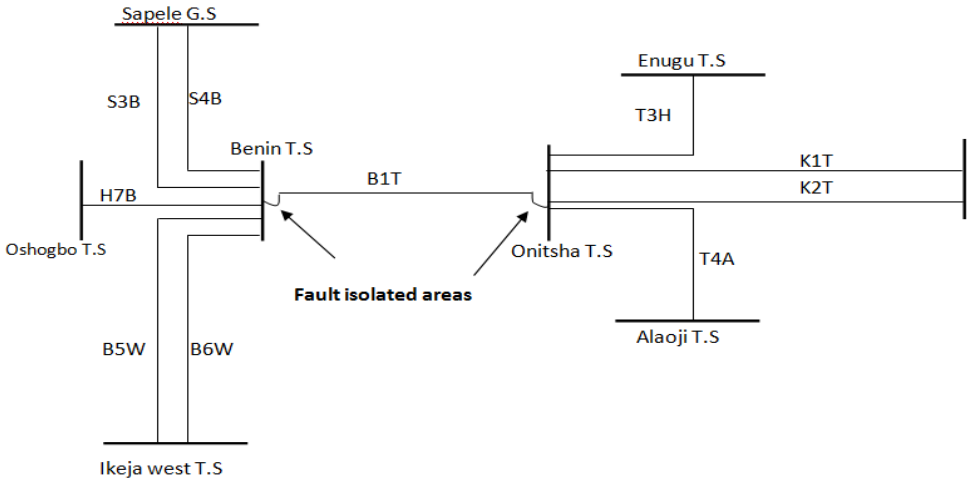

Fig 2: Shows fault isolated area in the grid that caused total collapse on 25/08/2007 at 13:34 hrs.[10]

III. RESEARCH METHODOLOGY.

Table 1 shows the various collapses, the nature of the collapses as well as the frequency that a particular collapse occurs in the NNG.Similarly, Table 2 shows the existing power generation capacity in Nigeria with respect to the type of plant, their location, the type of energy used to fire the plants, the age of the plants, installed capacity, installed units and available units respectively. The tables were analyzed sequentially using percentages while the graphical representation was obtained using the Microsoft Office Excel. The formula below has been used to calculate for the averages and percentages in all cases where applicable:

$$Ave = \frac{\sum_{i=1}^{n} xi}{n} \quad (1)$$

$$\%Collapse = \frac{No.of collapse in a year}{overall no of collapse} \quad (2)$$

$$Average\ \%\ Collapse = \frac{Average No.of collapse in a year}{overall no of collapse} \quad (3)$$

Table 1. Grid Disturbance (1995-2013)[10] [11][12]

	TOTAL	DISTURBANCES CAUSED BY GENERATION FAULTS		DISTURBANCES CAUSED BY TRANSIETTTTTTNT		PARTIAL GRID COLLAPSE (DISTURBANCE)			TOTAL GRID COLLAPSE DISTURB			DISTURBANCE WITH INDETERMINATE CAUSES			
Year	No of	ACTUAL NO	OF % TOTAL	ACTUAL NO.	OF % TOTAL	GEN. CAUSED	TRANSIENT CAUSED		GEN	TRANSIENT		TOTAL	PARTIAL		OF % TOTAL
JAN	DISTU	NO	TOTAL	NO	TOTAL	CAUSED	CAUS	TOTA	CAUSED	CAUSED	TOTA	CO	CO	TOTA	TOTAL
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. Generating Plant and their Capacity [9]

S/N	PLANT	PLANT TYPE	LOCATION STATE	AGE (YEARS)	INSTALLED UNITS	INSTALLED CAPACITY (MW)	UNITS AVAILABL E
1	Egbin	Thermal	Lagos	29	6	1320	4
2	Egbin AES	Thermal	Lagos	13	9	270	9
3	Sapele	Thermal	Delta	35	10	1020	1
4	Okpai	Thermal	Cross River	9	3	480	2
5	Afam	Thermal	Rivers	32	20	702	3
6	Delta	Thermal	Delta	24	18	840	12
7	Omoku	Thermal	Rivers	9	6	150	4
8	Ajaokuta	Thermal	Kogi	8	2	110	2
9	Geregu	Thermal	Kogi	8	3	414	3
10	Omotosho	Thermal	Ondo	New	8	335	2
11	Olorunsogo/ Papalanto	Thermal	Ogun	New	8	335	2
	SUB-TOTAL (THERMAL)				**93**	**5979**	**44**
12	Kainji	Hydro	Niger	47	8	760	6
13	Jebba	Hydro	Niger	31	6	540	6
14	Shiroro	Hydro	Niger	29	4	600	2
	SUB-TOTAL (HYDRO)				**18**	**1900**	**14**
	GRAND TOTAL				**111**	**7876**	**58**
SUMMARY		**% Thermal**			**84**	**76**	**76**
		% Hydro			**16**	**24**	**24**

IV. RESULTS AND DISCUSSION

From Table 1, it is evident that between 1995-1999 (The last five years of the military regime) the average number of collapses was approximately 16 but when this value is compared to the average collapses in the next five years 2000-2004 (The first five years of the fourthrepublic of the civilian regime), an approximate average value of 35 collapses which isover a 100% increase was recorded.

In the year 1992, the Nigerian National Grid under the military decree recorded a zero collapse [10]and this was when there was adequate staff training and effective SCADA(i.e. Supervisory Control and Data Acquisition) system in place and this was because the SCADA enables the system operator monitor happenings at all grid stations for instant linkup between the control centre and all stations. As of date, all the SCADA systems built between 1960s-1980s which function till the mid-1990s are allnow virtually broken down or not even there anymore. [13]Hence; one can conclude that politicizing of the sector has not help the sector since the civilian administration came into office.

The result further shows that apart from the fact that our generating plants are ageing only four out of the fourteen power generating stations are operating at full capacity.

The effect of poor policy and mismanagement of funds can be said to be one of the reason for poor generation of power in the country where billions of naira have been spent in the sector to improve power generation but to no avail the situation keep getting worse from one civilian regime to the other and the overall resultant effect is that load imposed on the grid is always greater than the combined capacity of all interconnecting generating stationthereby causing system frequency to fall hence, voltage collapse. The appropriate authority thus resolve to load shedding and in doing this they resolve to giving government facilities priority and it is this same government that have not been able to improve on the system.

Theresultalso shows that an average of 27 voltage collapses was recorded during this period of the nineteen years. Table 3shows that 267 collapses during this period are partial collapse while255 are total collapse leaving the remaining 5 voltage collapses as a result of foreign object.

Table 3.Summarized Table of Partial, Total and Collapse with Indeterminate Causes

Collapse Type	**Frequency of Occurrence**
Partial Collapse	267
Total Collapse	255
Collapse with Indeterminate Causes	5

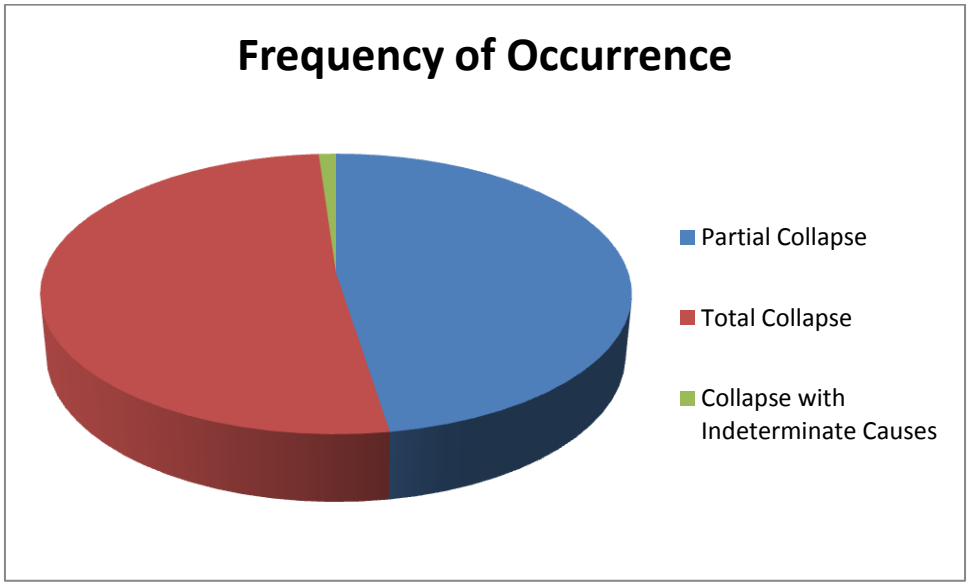

Fig 3: Summarized Chat of Partial, Total and Collapse with Indeterminate Causes

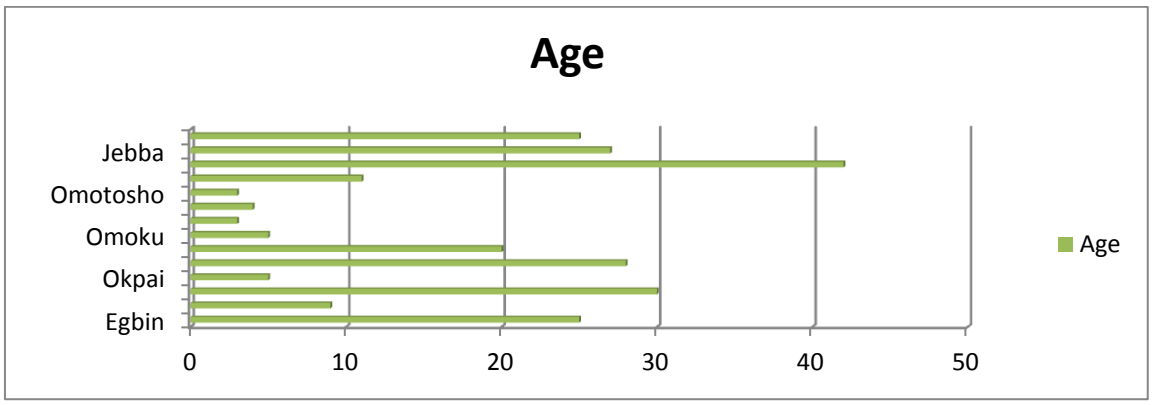

Fig 4:Generating Plants in Nigeria and their Ages

Table 4**:** Generating Plant with 100% Availability Factor

Plant Operating at Full Capacity	**Installed Units**	**Available Units**	**Availability Factor**
Egbin AES	9	9	1
Ajaokuta	2	2	1
Geregu	3	3	1
Jebba	6	6	1

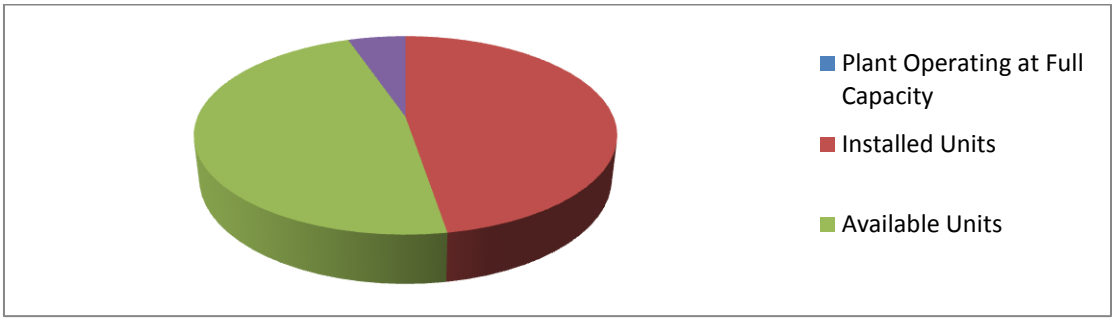

Fig 5:Plants with 100% Availability Factor in Nigeria

Table 5**:**Plant Installed Capacity and Their Availability Factor

Type	**Thermal Plants**	**Hydro Plants**
Installed Capacity	93	18
Available capacity	44	14
Availability Factor	0.47	0.77

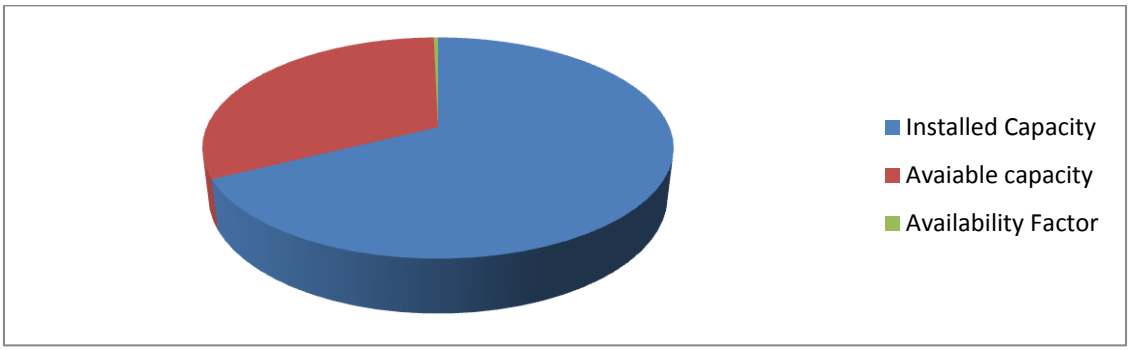

Fig 6: Installed Capacity of Hydro and Thermal Plants in Nigeria and Their Availability Factor

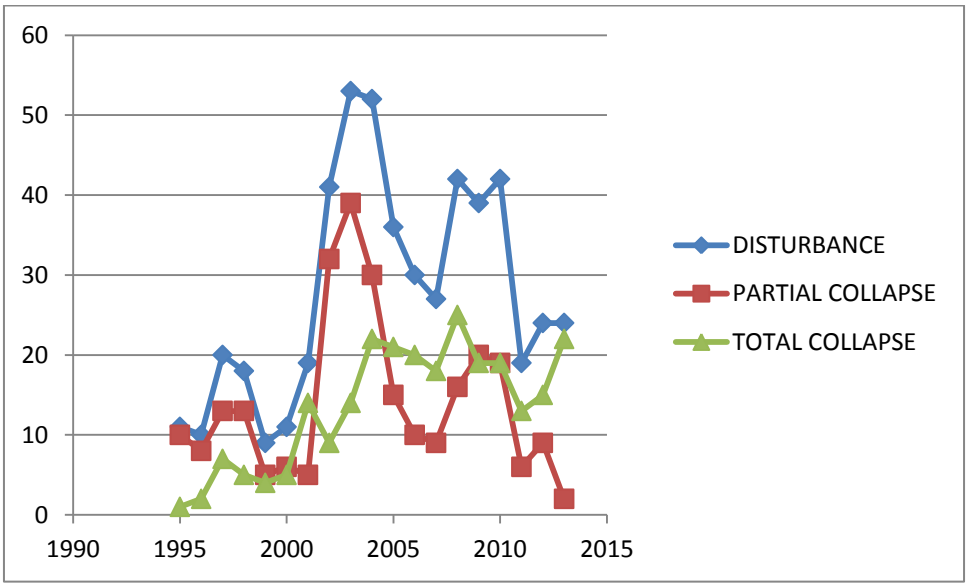

Fig 7: Graphical Representation of Voltage Collapse (1995-2015)

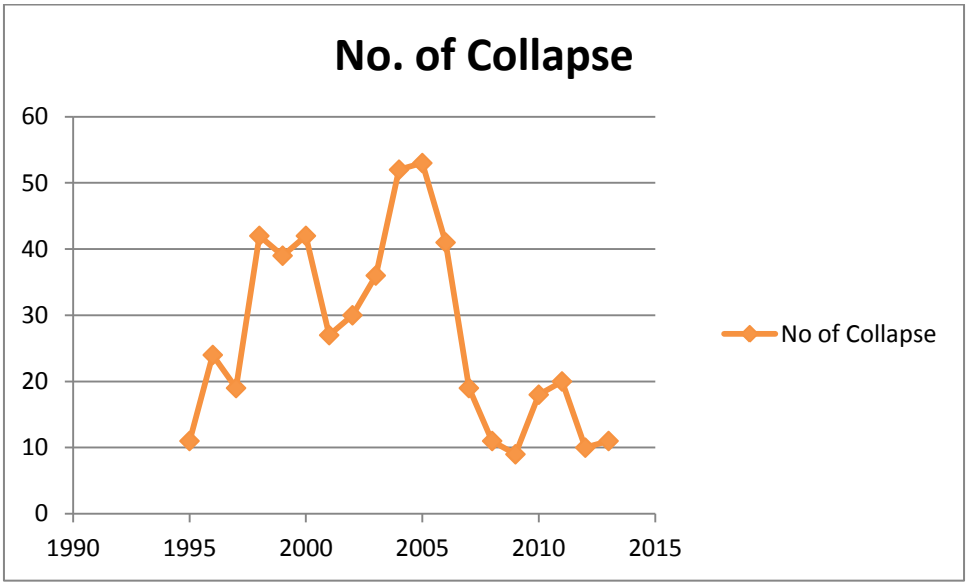

Fig 8: Showing Voltage Collapse Versus No of Years for the year under review

V. CONCLUSION AND RECOMMENDATIONS.

This work has analyzed the effect of voltage collapse with respect to the Nigerian National Grid Part one of the research gives a brief introduction of the topic while part two discusses the overview of the power system network with respect to generation, transmission and distribution. Part three captures the data used for the study as well as the research methodology while part four of the research discusses the result obtained from the data and part five concludes the work and also gives possible recommendations.

Finding a lasting solution to voltage collapse problem therefore requires both concentrated effort on the part of those saddled with the responsibility of governance and professional in the industry to fashion ways to curbing collapse the following are some possible recommendations made

[1] The state of emergency in the power sector as earlier discussed was validated; FromTable 1 we will discover that in that year the no of collapse reduced for that year when compared to the previous year i.e. between (2002-2006) hence, if the government of the day can remove political factor from the sector and put in appropriate and sustainable policies then it will be a beginning to solving the problem at hand.

[2] Nigeria has a strong hydro potential as well as a rugged hydro base station this result is evident from Table 2 & 7 where we see the availability factor of the hydro plants to be over 70% an indication that if there is also a reliability centered maintenance policy put in by the appropriate authority, then the country may record a 100% availability factor from hydro potential.

[3] Only recently Shell Petroleum Company were able to boast of generating 624MW (15%) of the total power generated in Nigeria and this power is coming from Afam VI Power Station [14]. Hence if appropriate policies should be put in place by the appropriate authority to encourage private individuals, group, companies toinvest in the sector, then poor generation will be a thing of the past and hence voltage collapse from the generation end will reduce.

[4] Embedded generation should also be encouraged by the appropriate authority such that the power generated is much more closer to the point where it is needed for consumption by so doing small power plants can be placed in strategic areas. In this scenario, the cost of installation is cheaper when compared to bigger plants and also more power plants e.g (fifty 10MW plants) can be installed in a year simultaneously in fifty different locations in the country and this can be equivalent to a big power plant e.g (500MW) that normally takes longer time to purchase the equipment needed, toship the equipment to the point of utilization and also to install. The advantage of this scheme is that it will greatly reduce power system instability as the power generated need not to pass through the grid system or impose more burden on the transmission line.

[5] Efforts by the government have always been to generate power and this same effort have not been put into maintenance hence, attention should be given to maintenance of the network so that the collapses that could have arise as a result of poor maintenance can be checkmated.

VI. ACKNOWLEDGEMENTS

Showers of encomium to you Engr. Jonathan Ndiagwalukwe the former general manager system operation of the Transmission Company of Nigerian for the immensurable support you gave in the production of this work especially in data collection.

REFERENCES

Journal Papers:

[1] K. Paramjeet, K. Manojkumar, andPriyanka.Review and Analysis of VoltageColapse in Power System,*International Journal of Research Publications*,*18*(1), 2012, 1-4.

[2] 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.* EIECON2012, 128-131.

[3] A.Sambo, B. Garba, I. Zarma, and M. Gaji, Electricity Generation and the Present Challenges in the Nigerian Power Sector, *journal of Energy and Power Engineering, 6,* (7), 2012.

[4] 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, 51-64.

Thesis:

[5] 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.

Proceeding Paper:

[6] J. Ndiagwalukwe, Frequency Control and Grid Stability,*National Power Summit*, 2012

[7] H. Labo, Current Status and Future Outlook of the Transmission Network,*Investors Forum For The Privatization of PHCN Successor Companies* 2010.

[8] 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*, 2007.

[9] KPMG., A Guide to the Nigerian Power Sector, 2013.

[10] N.C.C Oshogbo, Generation and Transmission Grid Operations Annual Technical Report, 2010.

[11] The Punch Newspaper, June 1, 2014

[12] The Punch Newspaper, January 31, 2013

[13] http://www.thisdaylive.com/articles/why-we-ve-power-system-collapses-and-why-they- last-solong/157212/

[14] The Guardian Newspaper. Tuesday, March 10, 2015.

BIOGRAPHIES

A.E Airoboman graduated from Ambrose Alli University, Ekpoma (Nigeria) in 2008. He received M.Engdegree from the University of Benin in 2012 all in Electrical/Electronics Engineering. He is currently pursuing a PhD degree in the department of Electrical / Electronics Engineering, University of Benin, Nigeria. He is a Corporate member of The Nigerian Society of Engineer, An Associate member of the Institute of Strategic Management of Nigeria anda registered engineer with COREN**.** His area of interest is Power System Stability, Energy Management and RCM.

I.K. Okakwu graduated from Ambrose Alli University, Ekpoma (Nigeria) in 2008. He received M.sc degree from the University of Lagos in 2012 all in Electrical/Electronics Engineering. He is currently pursuing a PhD degree in Electrical / Electronics Engineering, University of Benin, Nigeria. He is a Corporate member of The Nigerian Society of Engineers and also a registered engineer with COREN. His area of interest include power systems stability and control, electrical machines, power systems reliability, economic dispatch, FACTS and its applications

P.A Amaize graduated from Ambrose Alli University, Ekpoma (Nigeria) in 2009. He received M.sc degree from the University of Benin in 2013 all in Electrical/Electronics Engineering. He is a lecturer and also a PhD student in the Department of Electrical and Information Engineering Covenant University, Ota, Nigeria. His research interest is on Renewable Energy, Power Quality and Control Systems.

E.S. Oluwasogo graduated from University of Ilorin, Nigeria, in 2008. He received the M.Sc degree from the University of Lagos, Nigeria, all in Electrical Engineering. He is a lecturer in the Department of Electrical & Computer Engineering at Kwara State University, Malete, Nigeria. His research interests include Control of Industrial drives, Distribute Systems Control, Optimization and Robust Control, Automation etc. He is a member of IEEE and a registered Engineer with COREN.