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Analysis of Nigeria Power System Voltage Collapse Incidences From 2000 To 2017

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Abstract: *The growth of any country depends on how effective their power sector is. Voltage collapse eventually leads to system blackout and this is a major concern for every day power system operations. The Nigeria National Grid experience an average of (28) system collapse every year over the past 12 years. In this paper the incidences of power system voltage collapse have been studied, analyzed and discussed. The paper also looks at the causes of the voltage collapses in Nigeria power system and proffer some possible solutions.The method used in this research involves data collection and analysis. The data comprise of series of voltage collapses in the Nigeria power Network. The data were analyzed and simulated using MATLAB application software. Results from the study showed that the Nigeria power system experienced the highest number of total system collapse of about 53 in year 2003 and least voltage collapse of 9 in 2014. There are also fears that the cases of collapse which went down in 2015 could be rising at present. In the first six months of 2017, 12 Total collapses and two Partial collapses had been recorded on the grid.Nigeria power system needs total revamping so as to decrease the economic impact of the high incidence of system collapse in the country.*

Keywords: *Voltage instability, Grid, Voltage collapse, Nigeria National Grid*

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I. Introduction

Nigeria is the biggest country in Africa the continent with a total 356,667sq miles (923,768sq km), of which 351,649 sq. miles (910,771sq km or 98.6% of total area) is land. Nigeria operates a grid system known as the Nigeria National Grid. There are many benefits of this grid system. The National power system operates on a nominal frequency of $50Hz \pm 0.4\%$ [1].The function of a power system is to generate and transmit power to load centers at specified voltage and frequency levels. The generator in the system generates either 11kV or 16kV [2]. These voltages are stepped up to either 330kV or 132kV for the purpose of transmission. The high voltages levels are then stepped down to supply high load centers. The 330kV is then stepped down to 132kV and this is further stepped down to 33kV which is the primary distribution voltage [3]. The nominal voltage level is further stepped down to 11kV. As the system load changes, the resulting changes in real and reactive power demand cause variations in the network voltage and frequency levels. Voltage stability is a major concern in power system networks as the power system nowadays operates very close to its stability limit [4]. This is due to increasing load demand, industrialization, environmental and economic factor which affects the generating stations. This have affected some power system networks that are heavily loaded, weak and prone to voltage instability [4]. A power system is said to be in a state of instability when a disturbance causes a gradual and uncontrollable decline in voltage. Voltage instability is caused as a result of fault in the system (contingencies), lightning, imbalance between supply and demand side and faults from control devices [3]. Inability of power system network to meet the reactive power requirement leads to voltage collapse and eventually blackout. Fig. 1 has shown the one line diagram of the 330kV grid system in Nigeria.

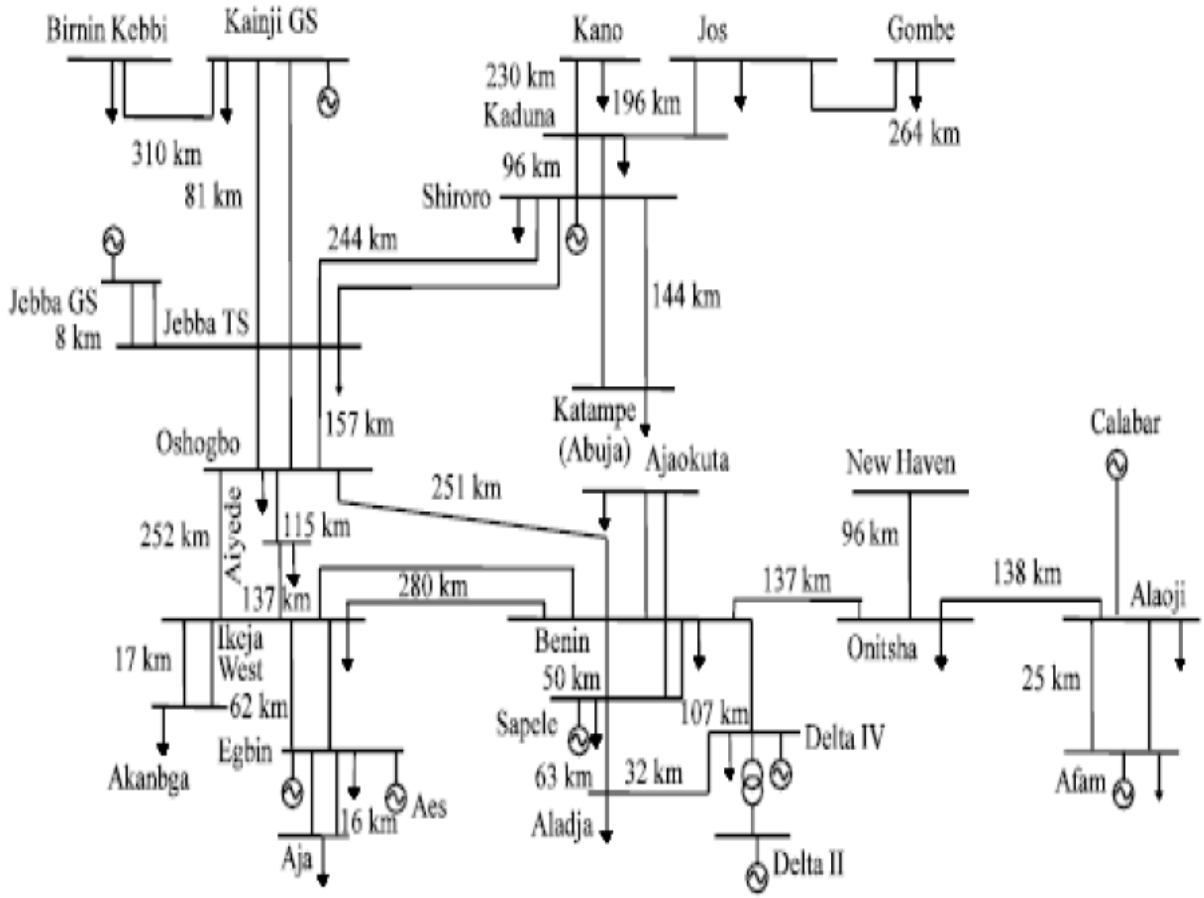

Fig 1: One-line diagram of Nigerian 330-kV transmission network [4]

In this research, data of Nigeria power system collapse from 2004 to 2017 are presented and analyzed. The frequency of the occurrence, causes and some suggestions were given on ways to reduce the incidence of voltage collapse on the power system.

II. Causes of Voltage Collapse In Nigerian Power System

Whenever there is occurrence of a voltage collapse, it brings about the tripping of transmission lines resulting to power blackout or brown out in some areas or all the areas of the network. The causes of system collapse may either be due to technical or non-technical fault [4, 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 lack of adequate investment [5]. A careful study of Nigeria power system network shown in Fig. 1 reveals that the Nigeria grid network comprises of only one ring network (i.e. Benin-ikeja-West-Aiyade-Oshogbo-Benin).Hence, exposing the grid to severe collapse because power has 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 lack of redundancy in transmission lines [6]. Transient stability problems deal with the effects of large, sudden system disturbances such as; Line faults, sudden switching of lines, sudden application or removal of loads and loss of a major generating unit [3]. In other to avoid these collapse, there is a need to carry out through maintenance at least once every fourty-one days along the transmission line in Nigeria [5, 7]. Table 1 shows the Power Generating Stations in Nigeria as at 2016.

Table 1: Power Generating Stations in Nigeria as at 2016[7]

Name	License Type	Site Location	Capacity (MW)
AES Nigeria Barge Limited	Generation on-Grid		270
Afam power Plc	Generation on-Grid	Afam, Rivers State	987.2
African Oxygen & industry Gases Limited	Generation Off-Grid	Ikorodu, Lagos State	19

Agbara Shoreline power Limited	Generation On-Grid	Angara , Ogun	100
Akute Power Limited	Generation Off-Grid	Lagos water cooperation	13
Alaoji Generation Co.Ltd(NIPP)	Generation On-Grid	Alaoji Abia State	1074
Anita Energy Ltd	Generation On-Grid	Agbara Lagos State	90
Azura Power west Africa limited	Generation On-Grid	Ihovbor Benin, Edo State	450
Benin Generation Company Limited	Generation On-Grid	Ihovbor, Edo State	450
Calabar Generation Company	Generation On-Grid	Calabar Cross River State	561
Century Power Generation Limited	Generation On-grid	Okija Anambra State	495
CET Power Projects (Ewekoro)	Generation Off-Grid	Wapco Ewekoro, Ogun State	6
CET Power Project Limited	Generation off-Grid	Tinapa, Cross River State	20
CET Power Project Ltd	Generation Off-Grid	Nigerian breweries Limited, Iganmu, lagos	5
CET Power Project (Sagamu)	Generation Off-Grid	WAPCO Sagamu,Ogun State	7
Countour Global Solution(Nig) Ltd	Generation Off-Grid	NBC Bottling plant,Ikeja	10
Countour Global Solution(Nig) Ltd	Generation Off-Grid	NBC Bottling plant,Ikeja	4
Countour Global Solution(Nig) Ltd		NBC Bottling plant,Ikeja	7
Coronation Power and Gas	Generation Off-Grid	Sango Otta	20
Delta Electric Power Limited	Generation On-Grid	Oghareki, Etiope West LGA	116
DIL Power Limited	Generation Off-Grid	Cement Factory, Ogun State	114
DIL Power Plc	Generation On-Grid	Obajana, Kogi State	135
Egbema Generation Company Limited	Generation On-Grid	Egbema, Imo State	338
Egbin Power Plc	Generation On-Grid	Egbin, Lagos State	1320
Eleme Petrochemical Company Limited	Generation On-Grid	Eleme Complex, PH River	135
Energy Company Of Nigeria(NEGRIS)	Generation On-Grid	Ikorodu,Lagos State	140
Energy Company of Nigeria limited	Generation Off-Grid	Nestle Agbara Ogun State	3
Energy's Nigeria Limited	Generation On-Grid	Ado-Ekiti,Ekiti State	10
Ethiope Energy Limited	Generation On-Grid	Ogorode, Sapele, Delta State	2800
Ewekoro Power Ltd	Generation Off-Grid	Ewekoro ogun State	12.5
Farm Electric Supply Ltd	Generation On-Grid	Ota Ogun State	150
First Independent Power Co. Ltd	Generation On-Grid	Omoku, River State	150
First Independent Power Co. Ltd	Generation On-Grid	Trans-Amadi,River State	136
First Independent Power Co. Ltd	Generation On-Grid	Eleme,River State	95
Fortune Electric Power Co.Ltd	Generation On-Grid	Odukpani, Cross River State	500
Gbarain Generation Company Ltd	Generation On-Grid	Gbarain,Bayelsa State	225
Geometric Power Limited	Generation On-Grid	Aba,Abia State	140
Geregu Generation Company Ltd	Generation On-Grid	Geregu II,Kogi State	434
Geregu Power Plc (BPE)	Generation On-Grid	Geregu,Kogi State	414
Hudson Power Limited	Generation On-Grid	Warawa Ogun State	150
Ibafo Power Station Limited	Generation On-Grid	Ibafo,Ogun State	200
ICS Power ltd	Generation On-Grid	Alaoji,Abia State	624
Ibom Power Ltd	Generation On-Grid	Ikot Abasi,Akwa Ibom State	190
Ikorodu Industrial Power Ltd	Distribution For Ewekoro Cement	Ikorodu Lagos State	
Ikorodu Industrial Power Ltd	Embedded Generation	Ikorodu Lagos State	39
Ilupeju Power Limited	Generation Off-Grid	Academy Press,Ilupeju	2
Income Electrix Limited	Generation Off-Grid	NPA,PH,River State	6
Island Power Limited	Embedded Generation	Marina,Lagos State	10
Isolo Power Generation Limited	Generatiion On-Grid	Isolo,Lagos State	20
JBS Wind Power Limited	Generation On-Grid	Maranban pushit,Mangu,plateau State	100
Kaduna Power Supply Company Limited	Embedded Generation	Kudenda ind.Area,Kaduna	84
Kainji Hydro Electric PLc(kainji Station)	Generation On-Grid	Kainji Niger State	760
Kainji Hydro Electric Plc(Jebba Station)	Generation On-Grid	Jebba,Niger State	570
Knox J&L Energy Solutions Limited	Generation On-Grid	Ajaokuta Kogi State	1000
Lotus & Bresson Nigeria Limited	Generatiion On-Grid	Magboro,Ogun State	60

Mabon Ltd		Dadinkowa,Gombe State	39
MBH Power Limited	Generation On_Grid	Ikorodu,Lagos State	300
Minaj Holdings Ltd	Generation On-Grid	Agu-Amorji Nike,Enugu East LGA, Enugu State	115
Nigeria Agip oil co.Ltd	Generation On-Grid	Okpai,Delta State	480
Nigeria Electric supply Corperation (Nigeria)Limited (NESCO)	Generation On-Grid	Buruku,Plateau State	30
Notore Power PLC	Generation On-Grid	Onne,River State	50
Ogorode Generation Co.Ltd (NIPP)	Generation On-Grid	Ogorode,Delta State	450
Olorunshogo Generation Co. Ltd (NIPP)	Generation On-Grid	Olorunshogo,Ogun State	750
Olorunsogo Power Plc (BPE)	Generation On-Grid	Olorunsogo,Ogun State	335
Omoku Generation Company Limited	Generation On-Grid	Omoku,River State	250
Omotosho Generation Company Limited	Generation On-Grid	Omotosho II, Ondo State	500
Paras Energy and Natural Resources Development Limited	Generation On-Grid	Ogijo,Ogun State	96
PZ Power Company Limited	Generation Off-Grid	PZ Cussons Aba actuary,Abia State	4
Sapele Power Plc	Generation On-Grid	Sapele,Delta State	1020
Shell Petroleum Dev.Co.Ltd	Generation On-Grid	Afam VI	642
Shiroro Hydro Electricity Plc	Generation On-Grid	Shiroro,Niger State	600
Supertek Nig.Ltd	Generation On-Grid	Akwete,Abia State	1000
Tower Power Abeokuta Limited	Generation Off-Grid	Abeokuta,Ogun State	20
Ughelli power Plc	Generation On-Grid	Ughelli,Delta State	942
Unipower Agbara Limited	Generation off-Grid	Agbara,Ogun State	6
Zuma Energy Nigeria Ltd (Gas plant)	Generation On-Grid	Ohaji Egbema,Owerri,Imo	400
Zuma Energy Nigeria Ltd (Coal Plant)	Generation On-Grid	Itobe,Kogi State	1200
Westcom Technologies & Energy service Ltd	Generation On-Grid	Sagamu,Ogun State	1000
Wedotebary Nigeria limited	Generation off-Grid	Kuru,Jos	5

III. Problems of The Nigerian Power Sector

Electric industry is the largest utility and complex industry in the whole word. Consequently, it is prone to different challenges. These challenges differ from country to country based on how technological informed and how effective their government is [8]. Nigeria power sector is still suffering with a lot of challenges which sometimes seem unexplainable [8]. These challenges range from technical, financial to government inability to handle to develop the power sector. Onahaebi [9], presented some causes and effects of power outages in the Nigeria transmission network from 2004 and 2015.The problems were grouped into transmission lines constraints, shunt reactor problems overloading of transformers and vandalization of the lines [9]. A summary of the causes and effects of transmission network faults is shown in Table 2.

Table 2: Summary of Transmission Network Faults, Causes and Effects [10]

Line	Fault	Causes	Effects On The Network
Ikorodu-Ayede-Oshogbo 132kV	Frequent conductor/jumper cut along entire length	Circuit was constructed in 1964 and is aging	Frequent and prolonged outages on the circuit.
Akangb-Ojo 132kV	Frequent earth fault	Reduction of overhead clearance refused burning due to proliferation of houses and stations. Industrial pollution of lines and insulators due to heavy refuse dumps and heavy industrial built up reported since 1983	Frequent forced outages on the circuits
Gombe-Maiduguri 132kV Circuit	Large voltage drops of 20-40kV between Gombe and Maiduguri	Line is single circuit and is too long (310km) conductor size is also small 150mm2	Gombe 132kV bus has to run as high as 140-145 kV to enable acceptable voltage levels at Maiduguri Gombe 132kV has to be run split.
New-Haven-Oturkpo-Yander	About 20kV voltage drop between New Haven and Yandev	Single line configuration using 150mm2 and line is 330km long	New Haven 132kV bus voltage had to run high voltage
Benin-Onitsha-Alaoji 330kV	Constant tripping of Benin-Onitsha-Alaoji Line	Limited by single line contingency voltage control problems	Frequent shutdown of Afam Power station due to transmission line faults thus stressing the Afam P.S. units. Restoration of Electricity supply

			prolonged due to voltage control problems. About 11 states capitals and environs experienced prolonged blackouts.
Aba-Itu 132kV line	Frequency of tripping of line	Breakdown of only 1 circuit breaker on the line with no provision for by-pass facilities and is limited by single line contingency	Prolonged blackout of Itu, Eket and Calabar complex serving the majority of cross River and Akwa Ibom State.
Delta-Benin 132kV DC	Several spans of collapsed towers	Poor Maintenance and Aging	No output for Delta O.S generation through the inter-bus transformer to Benin Transmission Station on 132Kv
Delta/Sapele/Aladja	Poor configuration leading to poor maintenance and operation of Aladja Steel switch gear by PHCN	The arrangement is defective since power flows from Sapele/Delta Steel Power Station through Aladja Delta Steel Company	Fault tracing/clearing is very precise and energy metering is difficult
Reactors: Onitsha 9 Rs-30 MX	Reactor out of circuit	Low resistance causes the reactor to be out of Circuit	High voltages experienced at Onitsha and New Haven substations respectively. When Afam Power Station generation is separated, it took long time to synchronize the station to the grid because of high voltage difference, resulting in many areas thrown into darkness

IV. Methodology

The method used in this research involves data collection and analysis. The data comprise of series of voltage collapses in the Nigeria power Network. The data were analyzed and simulated using MATLAB application software. The variations and frequency of occurrence was shown comprising of both the partial and total system collapse. The graphical representation and voltage collapse incidences frequencies were obtained. Total system collapse against the number of year was simulated in MATLAB application software. Table 3 shows the statistical data for both partial and total collapse on the Nigeria National Grid.

Table 3: Statistical data of both partial and total Collapse On the Nigerian National grid from 2000 to 2017 [7].

Year	Partial System Collapse	Total Collapse	Total System Collapse
2000	6	5	11
2001	5	14	19
2002	32	9	41
2003	39	14	53
2004	30	22	52
2005	15	21	36
2006	10	20	30
2007	9	18	27
2008	15	25	40
2009	20	19	39
2010	20	22	42
2011	6	13	19
2012	8	16	24
2013	2	22	24
2014	7	2	9
2015	2	10	12
2016	6	4	10
2017	2	12	14

V. Presentation And Analysis of Results

The data collected as represented in Table 3, a graph of a total number of system collapses against the year is plotted using MATLAB application software as shown in Fig. 2 to compare the frequency of the collapse in the years. System collapse was on the increase between the year 2001 and 2013 resulting in insecurity and unreliability of the entire power system network. This was caused majorly by different line tripping due to many reasons. In the year 2000, 11 systems collapses were recorded; all of these were caused by faults from the transmission section of the power system. From the simulation, the highest number of system collapse was recorded in 2003 with a total number of 53[12].

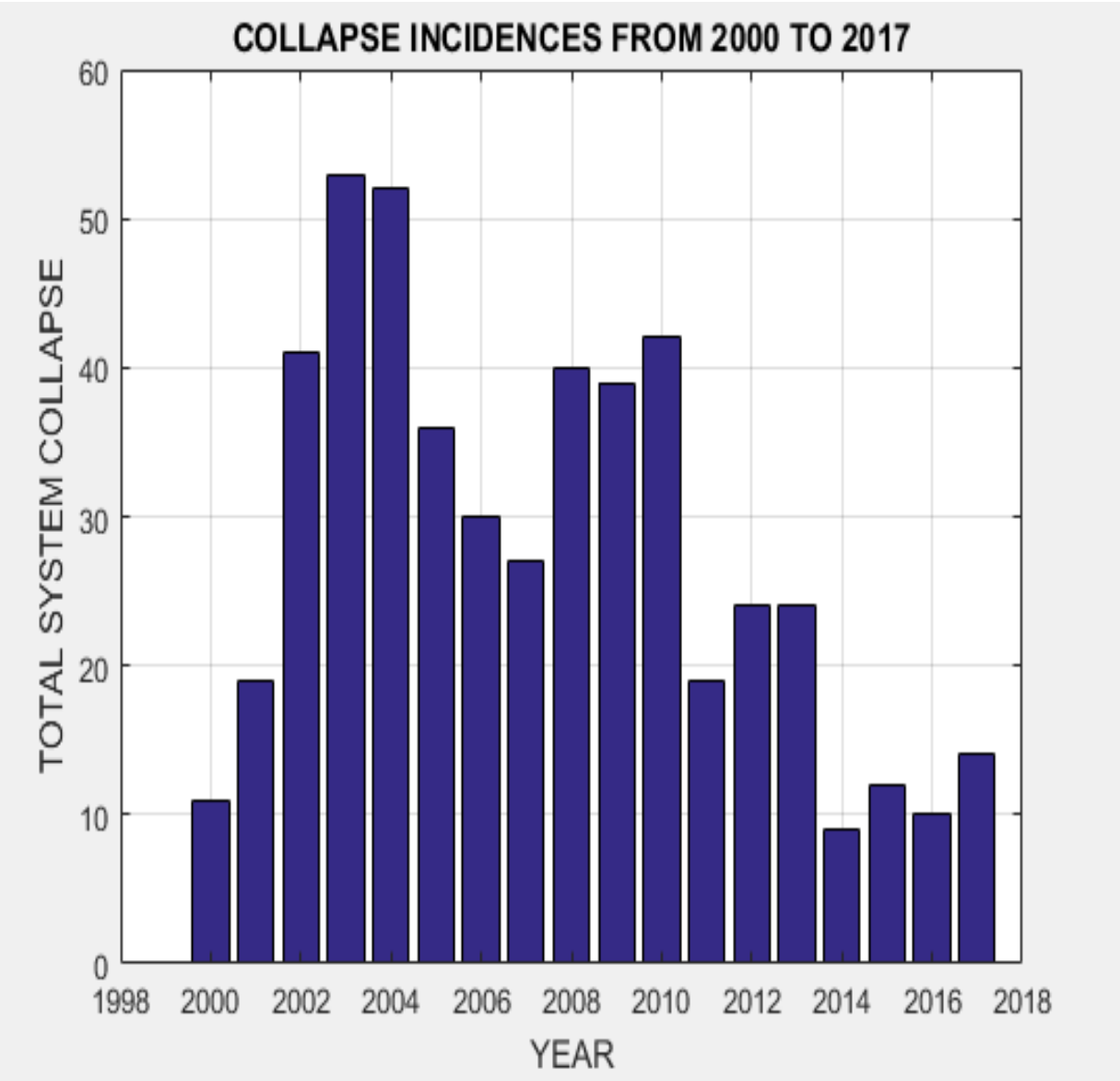

Fig. 2 A bar chat of Total system collapse against the number of Years

The inconveniences and economic loss that the power system collapses inflict on both domestic and industrial customers are high and unbearable. The resultant power outages cost the nation huge amount of money of about $1billion per year which is 2.5% of the GDP [13, 14]. This frequent collapse of the power system has caused many industries to close down during this period because of the high cost of running diesel generators. Small businesses and heavy machinery manufacturers are severely affected by the abysmal performance of the power industry. In addition, the entire population is also affected socially, psychologically and physically due to inadequate and unstable power supply. The Nigeria Electric system experienced the least number of system collapse (partial system collapse) in the year 2014 within the period of the study.

VI. Conclusion

Power system should have the ability to maintain stability during and after faults. The number of voltage collapse is perturbing and has led to system blackouts and shutting of so many generating companies. This has led to decrease in economic sustainability. There is need for contingency analysis evaluation which permits systems to be operated defensively. Modern computers are equipped with contingency analysis programs that model possible system troubles before they arise. System monitoring is another security measure that provides the operators of power system with pertinent up-to-date information on the conditions of the power system. Nigeria power system needs total overhauling so as to reduce the economic impact of the high incidence of system collapse in the country. Also the case of adequate security of power system substations equipment against vandals should be treated with utmost concern.

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