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Power Outages in the Nigeria Transmission Grid

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Abstract: This study presents, the analysis of power outages in transmission lines associated with the Nigerian grid. The study revealed that the Nigeria power transmission network is characterised by prolonged and frequent outages. It was observed that planned outages on the 132 kV recorded the highest value of only 7% while, the remaining 93% were due to either forced outages or emergency/urgent outages. This suggested that the reliability of the network is very low resulting in very low efficiency and disruption in the lives of the citizenry. Recommendations to reduce these outages are proffered in this study to ensure good power quality and security in the network.

Key words: Voltage, outage, buses, power world simulator, transmission, faults

INTRODUCTION

The electrical utility is probably the largest and most complex industry in the world. The electrical engineer, who researches in this industry will encounter challenging problems in designing future power systems to deliver increasing amounts of electrical energy in a safe, clean and economical manner (Glover and Sarma, 2002). The transmission network in Nigeria is characterised by several outages leading to disruption in the lives of the citizenry. According to Anil *et al.* (2007), the level of disruption is a function of the dependency of people on electricity, which can be very high for a developed country and not as much as developing countries. In Nigeria, the available energy generated is not enough to meet the demands of the users leading to constant load shedding and blackouts. Outages can be planned or forced. The National Control Centre (NCC), a unit of the Power Holding Company of Nigeria (PHCN), stipulated in its operational procedure No. 10 (OP 10) '(NCC and PHCN, 2006)' that power stations and transmission stations are required to forward their planned outages schedules for the following year to NCC, latest by end of the month of November. This enables the NCC to plan a master programme of planned outages properly co-ordinated to ensure maintenance of Grid integrity after a thorough study and analysis of the various outages. Forced outages can be associated with aging equipment/defects, lightning, wind, birds/animals, vandalization, accidents and poor job execution by contractors. However, forced outages can be minimised if the system is properly designed and maintained but this will not completely eliminate interruptions. In this study, the outage data gathered on the 132 and 330 kV networks in Nigeria are presented. Thus, the objective of this study therefore, is to examine the power outages in Nigeria and make recommendations to minimise its occurrences.

MATERIALS AND METHODS

The methodology adopted for this study is as follows:

- The overview of the 330 and 132 kV Nigeria transmission network
- Data collation on transmission power outages based on PHCN annual reports for 2003, 2004 and 2005 and logbooks
- Analysis of power outages in the networks
- Simulation of various aspects of faults on the test system using power world simulator to examine their effects on the grid

Test system for transmission outages: The power stations in Nigeria are mainly hydro and thermal plants. Power Holding Company of Nigeria (PHCN) generating plants sum up to 6200 MW as at December 2006 out of which 1920 MW is hydro and 4280 MW is thermal-mainly gas fired. Onohaebi (2006) provides a more general analysis of the generating stations in Nigeria in his Ph.D Thesis. The Nigerian Electricity Network comprises 11,000 km transmission lines (330 and 132 kV), 24000 km of sub-transmission line (33 kV), 19000 km of distribution line (11 kV) and 22,500 substations (Sadoh, 2005). It has only one major loop system involving-enin-Ikeja West-Ayede-Oshogbo and Benin. The absence of loops accounts mainly for the weak and unreliable power system in the country. The single line diagram of the existing 28 bus 330 kV Nigerian transmission network used as the test system is shown in Fig. 1 and the bus identification are as shown in Table 1.

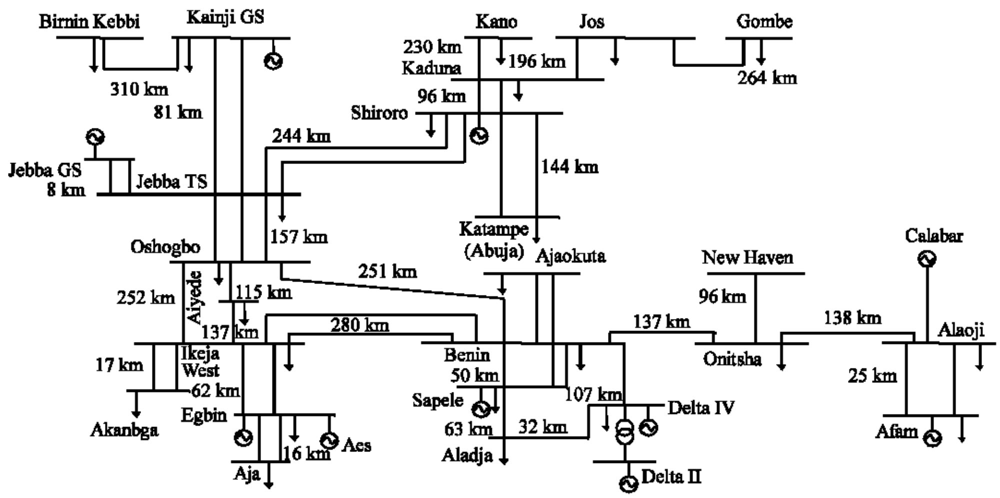

Fig. 1: The Nigerian 330 kV transmission grid used for the case study

Table 1: Bus identifications

Bus No.	BUS name	Bus No.	Bus name
1	Oshogbo	15	Aladja
2	Benin	16	Kano
3	Ikj-West	17	SAP P/S
4	Ayede	18	AJA
5	Jos	19	Ajaokuta
6	Onitsha	20	N Haven
7	Akangba	21	Alaoji
8	Gombe	22	AFAM GS
9	Abuja	23	Jebba
10	Egbin-PS	24	Jebba GS
11	DELTA PS	25	Kainji GS
12	AES	26	B Kebbi
13	Okpai	27	Shiroro
14	Calabar	28	Kaduna

RESULTS AND DISCUSSION

Analysis of power outages in Nigeria transmission networks: The Nigeria transmission network is characterised by frequent outages due to aging of equipment/lines leading to frequent conductor/jumper cuts, frequent earth faults resulting from reduction in overhead clearance and refuse burning, circuit breaker problems, etc. According to the (NEPA) Technical Committee Report (2004), the last transmission line in Nigeria was built in 1987 while none of the on-going ones have been completed. A summary of outages recorded for 2003, 2004 and 2005 is presented in Table 2. Figure 2 showed the diagrammatic representation of different types of outages in the Nigeria transmission network as reflected in Table 2. Figure 3 depicts the percentage contributions of the various forms of outages for 2003, 2004 and 2005 on the 330 and 132 kV networks. Figure 4 and 5 showed the monthly analysis in terms of value and percentage contributions of various types of outages on 330 and 132 kV networks for 2003- 2005.

Table 2: Summary of outages in Nigeria for 2003, 2004 and 2005 (PHCN, 2005; NCC, 2006)

Year	Network (kV)	Forced outage	Planned outage	Urgent outage	Emergency outage	Total
2003	330	252	90	69	48	459
2004	330	277	190	139	179	785
2005	330	225	181	59	64	529
2003	132	884	169	321	1361	2735
2004	132	759	130	240	752	1881
2005	132	731	200	296	2358	3585

A total of 3585 outages were recorded in 2005 in the 132 kV network, out of which 65.78% were emergency outages. The outages on 330 kV grid in 2005 was 529 with forced outages constituting 225 representing 42.53% compared to 2004 value 277 (35.1%) and 2003 of 252 (54.47).

Causes and effects of power outages in the Nigeria transmission network: The outages that occurred in transmission network for 2004 and 2005 are grouped into transmission lines constraints, shunt reactor problems, overloading of transformers and vandalisation of the lines (Onohaebi, 2007) (Table 3).

Over-loading of transformers: Many transformers in the system are experiencing over loading above 100%. Table 4 shows some transformers loaded above 100% in 2004 and 2005 in the transmission network. PHCN and NCC (2006) for transformer loadings. Many of the distribution transformers are also characterised by overloads which often lead to very low voltages and these voltages can be as low as 40 V in some areas as contained in Ali (2005). The distribution transformers are not well protected. It is a common practice in the Nigeria power system to see feeder pillars without properly rated fuses but iron bars inserted into their fuse compartments.

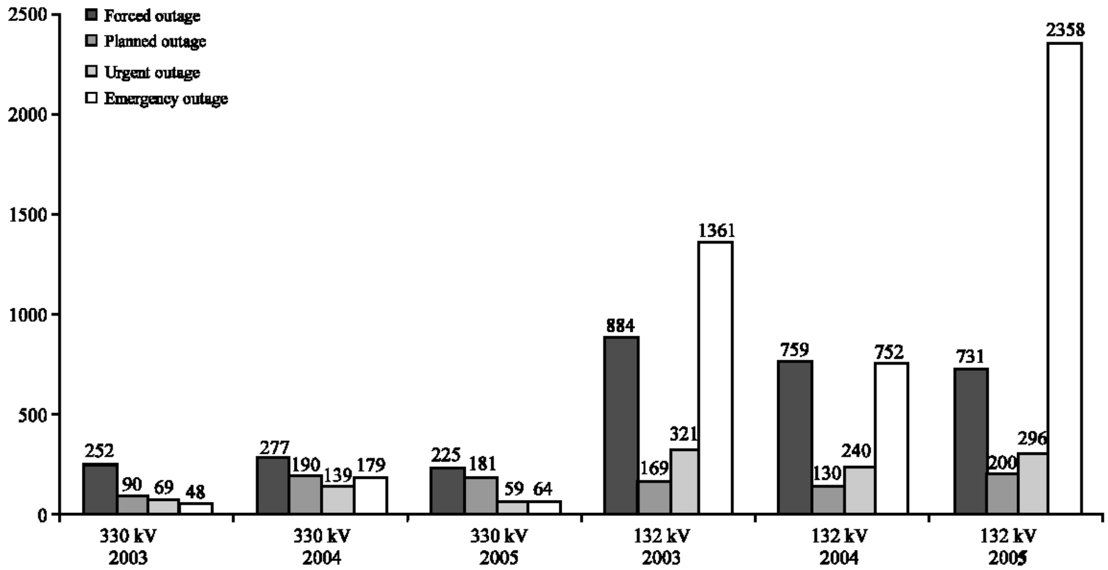

Fig. 2: Number of various types of outages on the 330 and 132 kV for 2003- 2005

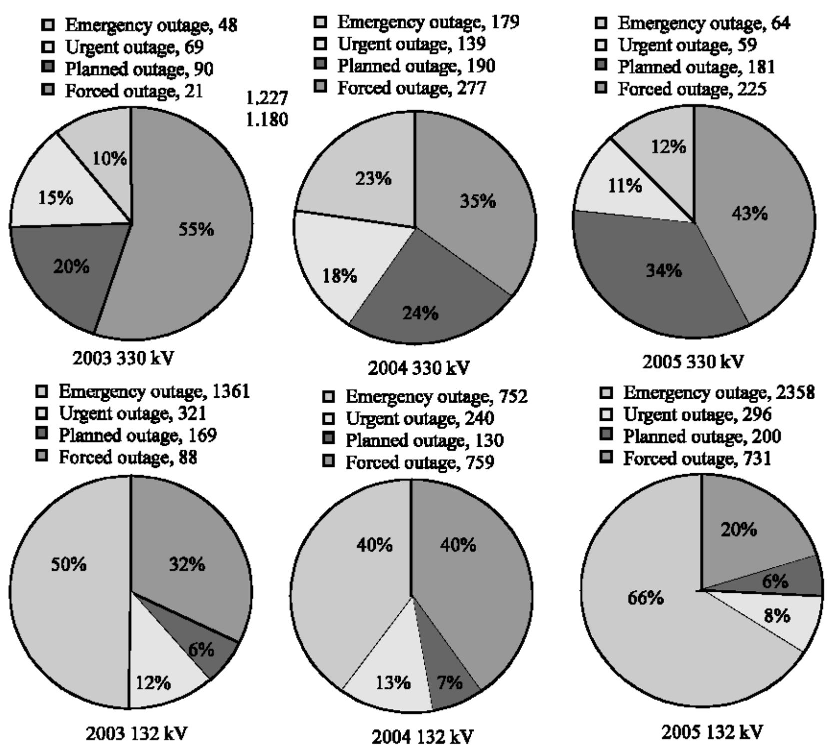

Fig. 3: Comparison of various types of outages in the 330 kV network for 2003- 2005

Political considerations allocate transformers to areas where they are less required to satisfy self ego, thus, preventing areas that are actually in dire need of them.

Vandalisation: Vandalisation of transmission lines by unscrupulous individuals for selfish gains is very rampant in the Nigerian power system. Ali (2005) gives a summary of the vandalised transmission lines in Nigeria in <8 months and the effects it had on the consumers as shown in Appendix 1.

Simulation of various aspects of faults on the test system: In order to examine the effects of faults on the network,

Table 3: Summary of faults, causes and effects on the network

Line	Faults	Causes	Effect on the network
Ikorodu-Ayede-Oshogbo 132 kV	Frequent conductor/jumper cut along entire length	Circuit was constructed in 1964 and is aging	Frequent and prolonged outages on the circuit
Akangba-Ojo 132 kV circuit	Frequent earth fault	Reduction of overhead clearance refuse burning due 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-Maiduguru 132 kV circuit	Large voltage drops of 20-40 kV between Gombe and Maiduguri	Line is single circuit and is too long (310 km) conductor size is also small 150 mm^2	Gombe 132 kV bus has to run as high as 140-145 kV to enable acceptable voltage levels at Maiduguri Gombe 132 kV has to be run split.
New-Haven-Oturkpo-Yander	About 20 kV voltage drop between New Haven and Yander	Single line configuration using 150mm^2 and line is 330 km long	New Haven 132 kV bus voltage had to run high voltage
Benin-Onitsha-Alaoji -330 kV	Constant tripping of Benin-Onitsha-Aladja Lines	Limited by single line contingency voltage control problems	Frequent shutdown of Afam Power Station due transmission line faults thus stressing the Afam P. S. units Restoration of Electricity supply prolonged due to voltage control problems. About 11 state capitals and environs experienced prolonged blackouts.
Aba-Itu 132 kV 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 132 kV DC	Several spans of collapsed towers	Poor maintenance and aging	No output for Delta O.S. generation through the interbus transformer to Benin TX station on 132 kV circuit
Delta/Sapele/Aladja 330 kV configuration	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 PS through Aladja Delta Steel Company	Fault tracing/clearing is very precise 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 P.S. generation is separated, it took long time to synchronise the station to the grid because of high voltage difference, resulting in many areas thrown into darkness
Oshogbo 4R1-75 MX	Reactor out of service	Faulty winding	Excessive high voltage at Oshogbo
Benin Kebbi 19R1-30 MX	Reactor out of service	Burnt underground cable	High voltages at Birnin Kebbi above limits

Table 4: Transformer loaded above 100% in 2004 and 2005

Location	Rating (MVA)	Trans. ratio (kVA)	Loading (%)
Abeokuta	30	132/33	111
Apapa Road	30	132/33	111
Apapa Road	30	132/33	111
Akoka	15	132/11	109
Ejigbo	30	132/33	109
Ejigbo	30	132/33	109
Jericho	15	132/33	108
Otta	60	132/33	104
Aja	150	132/33	104
Akwanga	30	132/33	107
Kankia	7.5	132/33	101
Gusau	15	132/33	101
Hadeja	15	132/33	101
Benin	30	132/33	101

the test system shown in Fig. 1 was redrawn in the Power World Simulator (PWS) (Power World Co-opration, 1996-2000) environment as shown in Fig. 6.

Load flow analysis was carried out to determine the bus voltages, as shown in Fig. 7 under normal operating condition. The scenarios considered in this analysis include unbalanced faults involving single phase to ground, line to line and double line to ground faults. These faults were simulated at buses 1-3. Bus 1 was selected because it is the major bus linking the southern and northern parts of the grid and also the location of the National Control Centre (NCC). Bus 2 represents the bus, which links the Eastern, Western and Northern parts of the network. Bus 3 is the highest loaded bus in the entire network and also tied to the highest generating stations located at Egbin and AES.

Singe line to ground fault: The bus voltages after the simulation of singe line to ground fault are shown Fig. 8

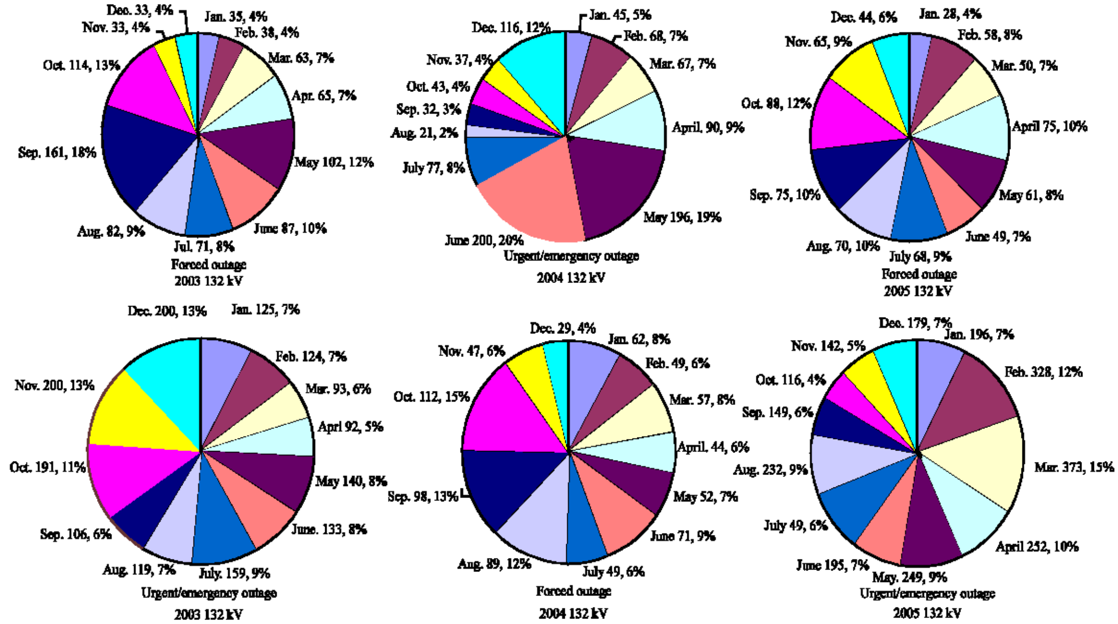

Fig. 4: Monthly outage analysis in values and percentages in the 132 kV network for 2003- 2005

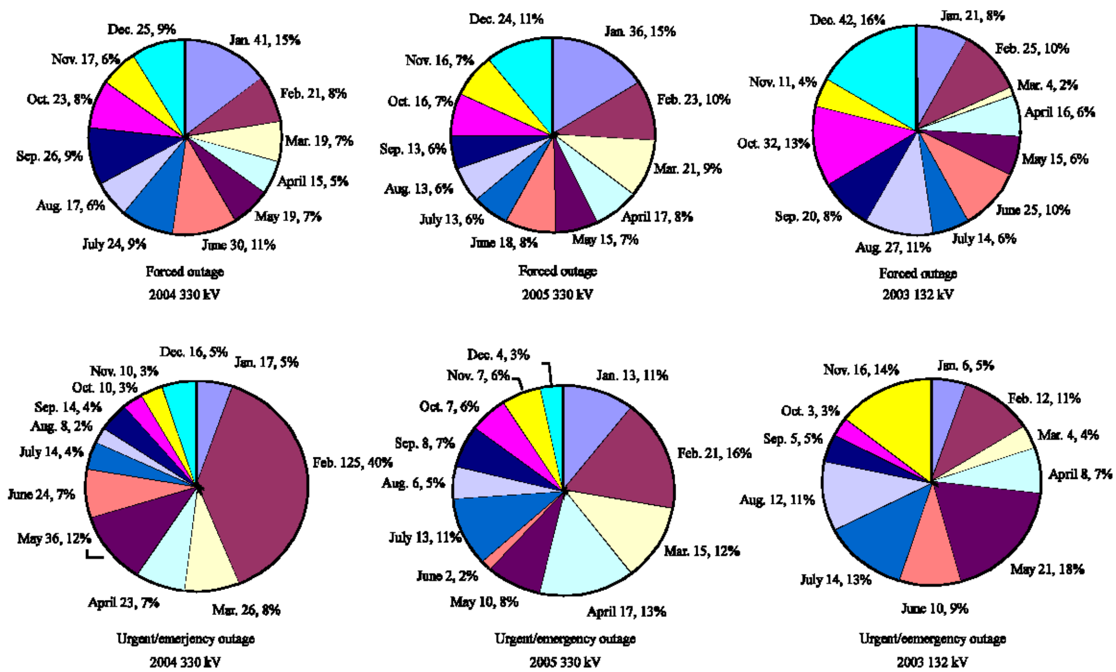

Fig. 5: Monthly outage analysis in values and percentages in the 330 kV network for 2003- 2005

for buses 1-3. The results showed low voltage values at bus 4, 9, 16, 23, 24, 26, 27 and 28 when bus 1 was affected. The highest voltage value of 2.52/units was recorded at bus 8, when bus 2 was subjected to the same fault.

Line to line fault: The bus voltages after the simulation are shown in Fig. 9 for buses 1, 2 and 3. This scenario showed that most of the bus voltages are within limits except buses 5, 8 and 16. The voltage profiles showed a great resemblance to the normal operating condition as shown in Fig. 7.

Double line to ground fault: The bus voltages after the simulation are shown in Fig. 8 for buses 1-3. The

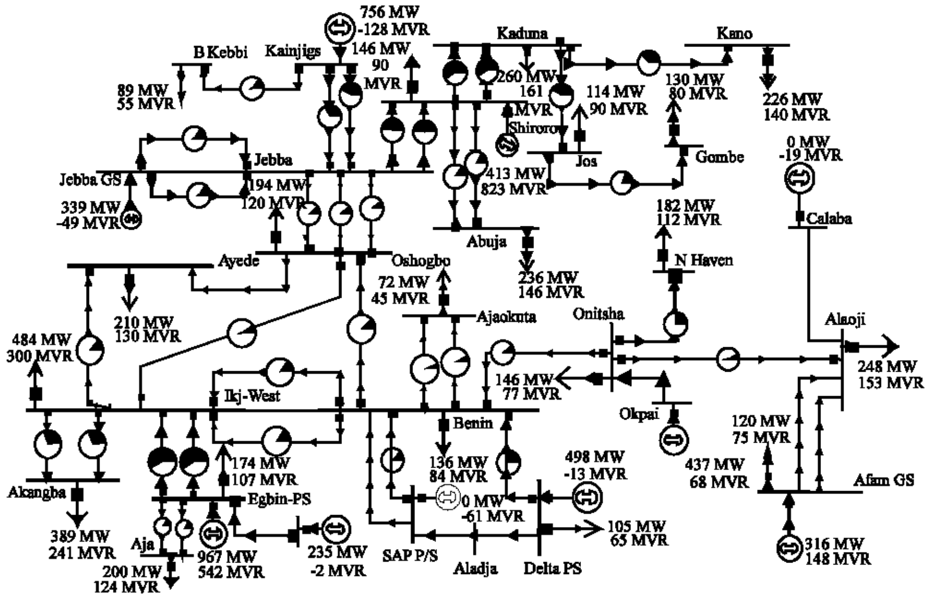

Fig. 6: The Nigeria 330 kV transmission network (simulated in the run mode)

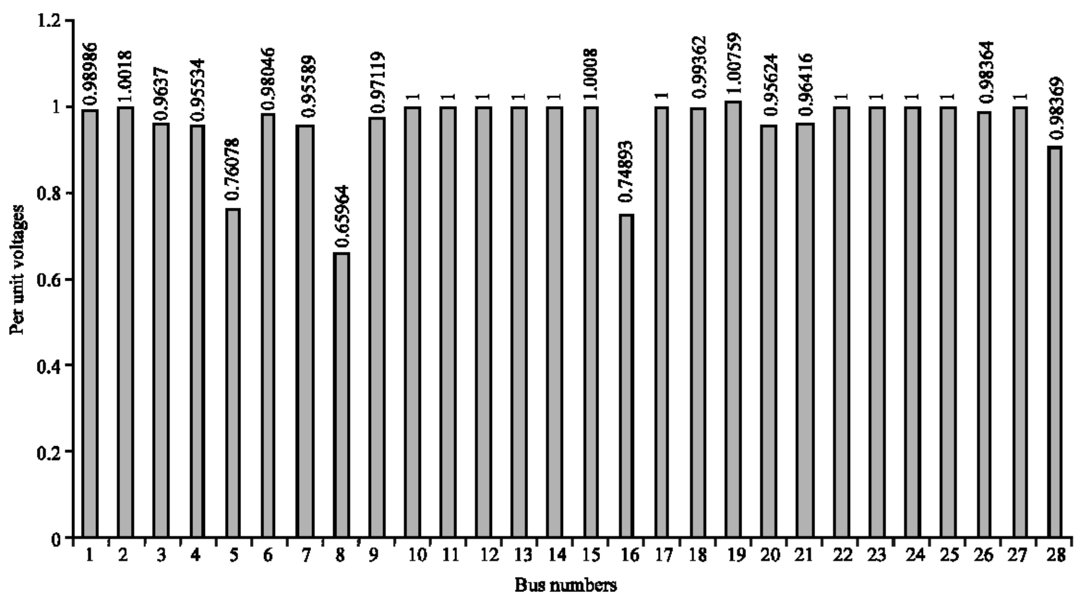

Fig. 7: Voltage profiles under normal conditions

voltages were very high in this scenario except for buses 5, 8, 16 and 28, which recorded very low values. There was no bus voltage in the network that was within the acceptable limits.

This study revealed the following:

- The existing transmission network is characterised by poor maintenance and is over aged leading to the collapse of several spans
- Prolonged and frequent outages are phenomena in the transmission networks. It was observed that planned outages on the 132 kV recorded the highest value of 7% while, the others are either due to forced outages or emergency/urgent outages as summarised in Table 2. This suggested that the reliability of the network is very low resulting in very low efficiency and disruption in the lives of the citizenry

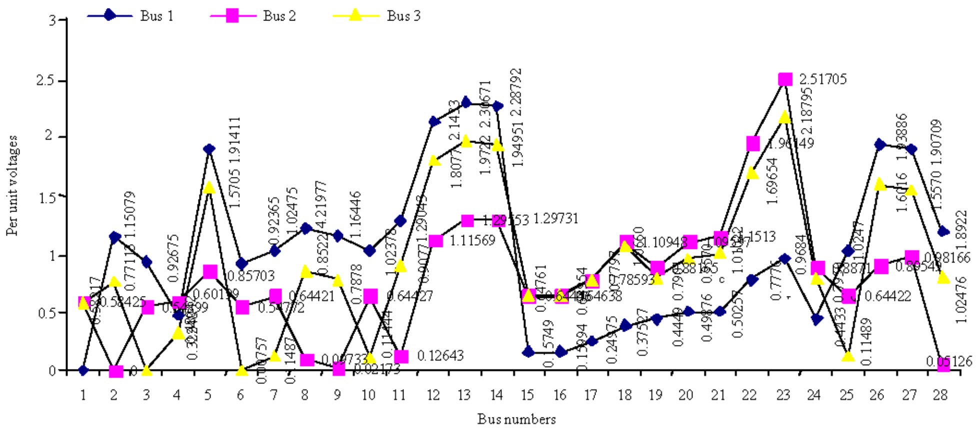

Fig. 8: Voltage profiles for single line to ground fault at buses 1- 3

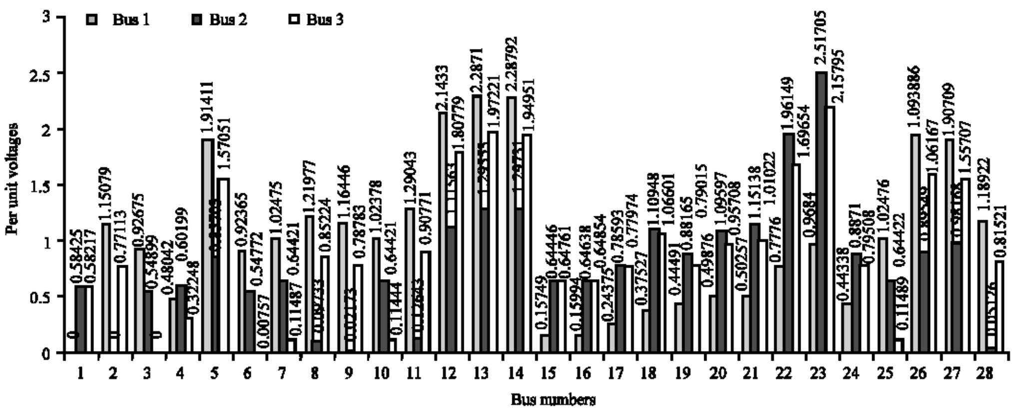

Fig. 9: Voltage profiles resulting from simulation of line to line fault at buses 1-3

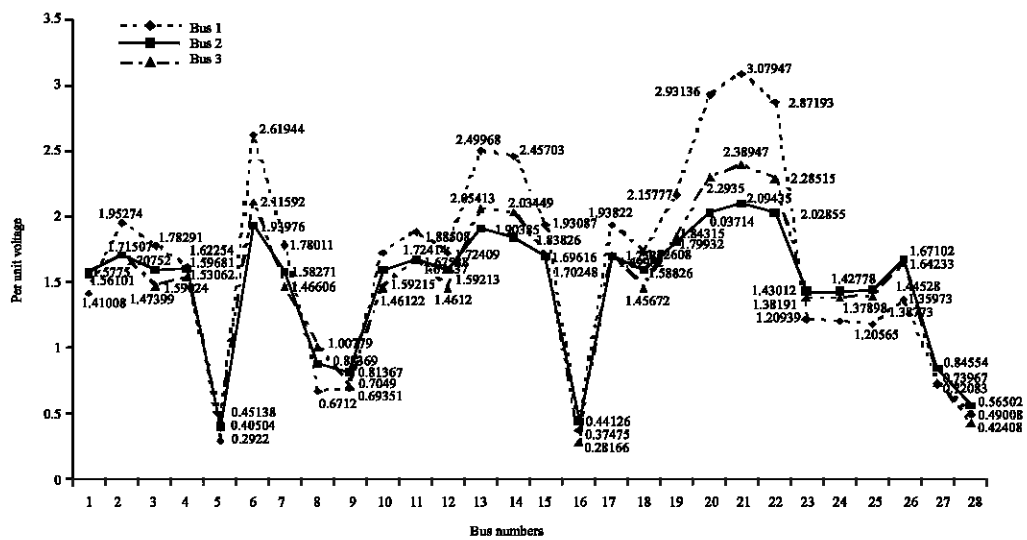

Fig. 10: Voltages profiles due to double line to ground faults

- Most of the transmission lines are very long and fragile leading to frequent conductor cuts. This gives rise to high voltage drops and power losses in the network. The voltages can be as low as 217 for a 330 kV line and 92 for 132 kV lines
- Single line contingency and small conductor sizing are major features in most lines in the network. Thus, high voltage drops are associated with such lines and they are also subjected to constant tripping and have to run at very high voltage up to 150 for 132 kV line to be able to operate at acceptable limits.
- High voltages are experienced in some very long lines where the reactors are out of circuits due to low resistance, winding faults and damaged cables
- Many of the transformers in the network are overloaded and this could have adverse effect on the power network
- The simulation of the various faults revealed that the single line to ground fault recorded very high voltage at some buses, while others were within acceptable limits. The double line to ground fault recorded astronomical high voltages, while, the line to line fault was similar to the normal condition

RECOMMENDATIONS

In order to reduce transmission outages in the Nigerian transmission network, the following should be given due consideration:

- A proper study should be carried out to identify all weak areas in the network with a view to strengthen the network
- Planned and routine maintenance should be carried out on the network to reduce the incident of collapsed spans
- Very long and fragile lines should be re-enforced to improve the voltage stability and efficiency in the network
- Additional circuits and loops should be introduced into the network to reduce the single line contingency constraints associated with most parts of the network
- Good protection system taking into consideration the short circuit current in the network should be put in place to assist in fault isolation and protection of the network
- More substations should be introduced into the network to assist in the reduction of long lines and improve the voltage profiles of the network
- Vigilant groups to be introduced to guide against vandalisation which constitute a major setback in the network
- Faults should be promptly rectified and all the lines should be energised to reduce the incidence of vandalisation
- Proper clearing should be carried out for transmission lines that have be over grown by trees and weeds to reduce the effect of constant tripping of the lines

CONCLUSION

The various causes and effects of power outages in the Nigeria transmission network have been examined in this study. Outages in the network are due to aging of equipment/defects, lightning, vandalisation, poor maintenance, etc. The fault analysis showed that the system needs to be properly protected to ensure safety and security of network.

ACKNOWLEDGEMENT

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Appendix 1: Summary of vandalized transmission lines between 17-11-02 and 05-07-03 Ali (2005)

Names of line	Date vandalized	Effect of vandalization
New Haven-Nkalagu 132 kV	17/1102 and 23/12/02	Ebonyi State and Northern Part of Cross River State lost supply for about one week.
New Haven-Oji River 132 kV	08/05/02 and 27/01/03	Reduction of security of power supply to Enugu and Onitsha complexes.
Minna-Suleja 132 kV line	Discovered 02/01/03	Reduction of protection against lightening.
Oshogbo-Erinle-Ibadan 132 kV line	12/01/03	The 132 kV link between Osogbo and Ibadan was severed.
Shagamu-Ijebu Ode 132 kV line	22/01/03	Supply to Ijebu Ode and environ was affected.
New Haven-Oturkpo-Yandev 132 kV line	17/02/03, 22:2 h	Benue State was thrown into darkness for 3 days.
Onitsha-New Haven 330 kV line	19/02/03, 19:22 h	Enugu, Ebonyi, Benue and parts of Kogi, Taraba and Cross River States thrown into blackout for 4 days.
New Haven-Nkalagu 132 kV lines 1and 2	Between 20/02/03 and 22/02/03	Ebonyi State and Northern part of Cross River State in blackout for 3 days.
Oji River-Nsuka 66 kV line	22/02/02, 13:42 h	Nsukka and environs thrown into darkness for 3 days.

Appendix 1: Continue

Names of line	Date vandalized	Effect of vandalization
Onitsha-Oji River 132 kV	20/02/03, 18:30 h	Loss of supply to Orji River Complex.
Alaoji-Owerri 132 kV line	06/03/03	Security of supply to Owerri and its environs reduced.
Benin-Ikeja West 330 kV line 2	08/03/03	Reduced security of supply and system stability in Benin and complexes.
Alaoji-Owerri 132 kV line	14/03/03, 21:48 h	Entire Imo State in blackout
Benin-Ikeja West 330 kV Line 2	15/03/03	Reduced Security of supply and system stability in Benin and complexes.
Benin-Ikeja West 330 kV Line 1	15/03/03, 22:46 h	Link between Lagos and Benin Complexes severed. Security of the National Grid jeopardized.
Benin-Okene-Ajaokuta 132 kV line	21/03/03, 23:06 h	Reduction of Security of power supply to Ukiplla, Okene, Ajaokuta and environs.
Alaoji-Owerri 132 kV line	Discovered 22/03/03	Worsened problem of power blackout in Imo State.
Alaoji-Owerri 132 kV line	Discovered 23/03/03	Worsened problem of power blackout in Imo State.
Ajaokuta-Itakpe-Okene-Ukiplla 132 kV line	26/03/03	Loss of supply to Ukpilla
Benin-Okene 132 kV line	09/04/03, 21:45 h	Reduction of security of supply to Okene and environs.
Otukpo-Yandev 132 kV line	06/05/03	Loss of supply to Makurdi, Yandev and environs.
Ajaokuta-Itakpe-Okene 132 kV line	08/05/03, 22:05 h	Loss of supply to Okene, Itakpe and environs.
Alaoji-Afam 132 kV line	28/05/03, 23:13 h	Reduced security of supply to Port Harcourt area
Alaoji-Owerri 132 kV line	09/06/03, 02:30 h	Reduced security of supply to Imo State. Total blackout to Imo state from 16/06/03-19/06/03
New Haven-Nkalagu 132 kV line 1	15/06/03, 23:53 h	Ebonyi State and Northern part of Cross River State in blackout.
Onitsha-New Haven 330 kV line	01/07/03, 22:50 h	Loss of power supply to Enugu, Ebonyi and Benue States as well as parts of Cross River, Kogi and Taraba States.
Onitsha-New Haven 330 kV line	Discovered 05/07/03	Worsened problem of power blackout in affected states.

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