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A Study and Evaluation of Power Outages on 132 Kv Transmission Network In Nigeria for Grid Security

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----------ABSTRACT----------
The 132 KV High Voltage (HV) transmission lines in Nigeria cover a total distance of 7780km and have 132 / 33 / 11 kV substations with an installed transformation capacity of 11,660 MVA. These lines convey power not only to Nigeria but also to Niger and Benin Republicsrespectively. Unfortunately, these lines are fragile (technically weak) and could wheel out a maximum of 8238 MW of power. Besides, they are mainly radial by construction, thus making voltage control even more challenging. It is very important that the outages on these HV lines are kept to a minimum to ensure sustainable economic activities in Nigeria and in those other countries. This work studies and evaluates the outages on 132 kV transmission system from 2008 to 2017. The data were analysed using descriptive statistics. The results show that a total of 11,062 outages occurred in the years under study. Out of this number, 9823 (88.8%) was as a result of forced outages while the remaining 1239 (11.2%) accounted for planned outages. The highest number of outages (1116) was recorded in 2016 while the least (689) occurred in 2010. Effective measures have been suggested to reduce the intensity and frequency of occurrence of forced outages on the transmission network.
Keywords: *Forced outage, planned outage, transmission line, grid, disturbances.*

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I. INTRODUCTION

The power value chain of a country such as Nigeria comprises: generation, transmission and distribution sub – systems. Electricity generated by the power plants is transported through the High Voltage (HV) transmission lines to the low voltage distribution network where it is made available to the various classes of consumers. The transmission network comprising the 330kV and 132kV HV lines is a link between generation and distribution segments of the grid.

In practical terms, the transmission lines and power transformers are the major equipment employed by the utility body to facilitate power supply to its numerous customers.

To ensure sustainable power supply, the generation, transmission and distribution components must be well coordinated and managed such that:

- Adequate electric power is generated at a particular time.
- The power generated must be efficiently and effectively evacuated or wheeled out to the relevant parts of the country / regions and beyond (in the case of cross – border electricity transaction).
- The transmitted power must be efficiently and conveniently distributed to the terminal consumers.

According to NSE (2017), ERGP (2017) and Amoda (2016), the 132kV transmission network covers 7780km and 132 / 33 / 11kV substations with installed transformation capacity of 11,660 MVA. Unfortunately, these lines are mainly radial, very long, with few mesh networks. As a result, voltage control (Caven, 1998; Okoye, 2018) and security of power supply become difficult to achieve. In fact, the existing 132 kV lines have the capacity to transmit only about 8238 MW. Comparatively, the U.S. electric grid (Hicks, 2012), boasts of 200,000 miles of HV transmission lines far much less vulnerable and fragile than what we have here in Nigeria. Since Nigeria's transmission system is fragile (technically weak), it is quite often prone to major disturbances. (Ogbuefi et al, 2018; Idoniboyeobu et al, 2017; Onah, 2019).

According to the TCN (2016), TCNN (2017). Out of 24 total disturbances experienced in Nigeria's electric grid in 2017, four (16.7%) were caused by generation faults while 20 (83.3%) was caused by transmission faults. In 2016 there were a total of 27 disturbances with eight (29.6%) and 19 (70.4%) caused by generation and transmission faults respectively (TCN, 2017; TCN, 2016). Ultimately, these disturbance result in loss of loads and thus power outages.

Over the years, forced outages have been a common feature on the 132kV transmission line which incidentally also transports power to Benin and NigerRepublics respectively. Due to the role of the 132 kV

network in evacuating (transporting) power for utilization within and outside Nigeria, it is important to explore ways of enhancing its performance in order to make power supply more secure.

II. METHODOLOGY

A number of visits were made to National Control Centre (NCC) and the Transmission Company of Nigeria (TCN) both at Osogbo, Nigeria to source for the relevant technical data.

Similarly, additional information were sort from some organisations and relevant literature. The data so collected were collated, classified and necessary computations made to make them suitable for the design and purpose of work at hand.

Descriptive statistics (tables, frequency counts, charts, graphical illustrations) were used to analyse the data in order to elicit salient features needed to draw conclusions from the study. The data over the 10 – year period are shown in Table 1.0.

Table 1.0: Outages on 132kV transmission line from 2008 to 2017

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Total
No of forced outages	865	917	689	1085	1021	951	1070	1048	1116	1061	9823
No of planned outages	93	52	73	128	59	103	113	167	227	224	1239

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III. RESULTS AND DISCUSSION

Table 2.0 reveals the number of outages on the 132kV transmission line covering ten years (2008 - 2017)

Table 2.0: Outages on 132kV transmission line: 2008 to 2017

Year	No of forced outages	Percentage of forced outages	No of planned outages	Percentage of planned outages	Total outages
2008	865	90.3	93	9.7	958
2009	917	94.6	52	5.4	969
2010	689	90.6	73	9.6	762
2011	1085	89.4	128	10.6	1213
2012	1021	94.5	59	5.5	1080
2013	951	90.2	103	9.8	1054
2014	1070	90.4	113	9.6	1183
2015	1048	86.3	167	13.7	1215
2016	1116	83.1	227	16.9	1343
2017	1061	82.6	224	17.4	1285
Total	9823	88.8	1239	11.2	11062

Source: Transmission Company of Nigeria (Various Annual Technical Reports)

In the period under study, there were a total of 11,062 outages, comprising 9823 forced outages and 1239 planned outages. In relative terms, 88.8 percent of the outages that occurred on the 132kV transmission line in the period was forced while 11.2 percent was planned. In other words, the 88.8 percent of the outages that occurred was not expected or anticipated. This has a very serious implication on the ability of the utility company to supply adequate and reliable power to the Nigeria.

Besides, with an outage, there is no electricity supply to consumers. Consequently, economic activities are greatly impaired. What follows next is a fall in Gross Domestic Product (GDP) of a nation (Akinloye et al, 2016; Onohaebi, 2019).

For instance, in a study carried out by Ogbuefi et al (2018) on voltage collapseincidences in Nigeria from 2000 to 2017, it was revealed that power outages cost the nation a whooping one billion USD per year which is 2.5% of the GDP.

It was discovered that forced outages may arise from (among other causes);

- Faulty protection or control equipment, resulting in tripping of transmission lines.
- Vandalisation of transmission lines and other equipment.
- Heavy loaded transmission lines (lines loaded above capacity)
- Problems related to gas supply.
- Plant / System faults.
- Overloading of transformers.
- Obsolete and aging equipment.

- Line is single circuit and too long. At times, conductor size is small (150mm^2). For instance, Gombe – Maiduguri 132kV transmission circuit which is 310km.
- Shunt reactor problems.
- Improper relay coordination.

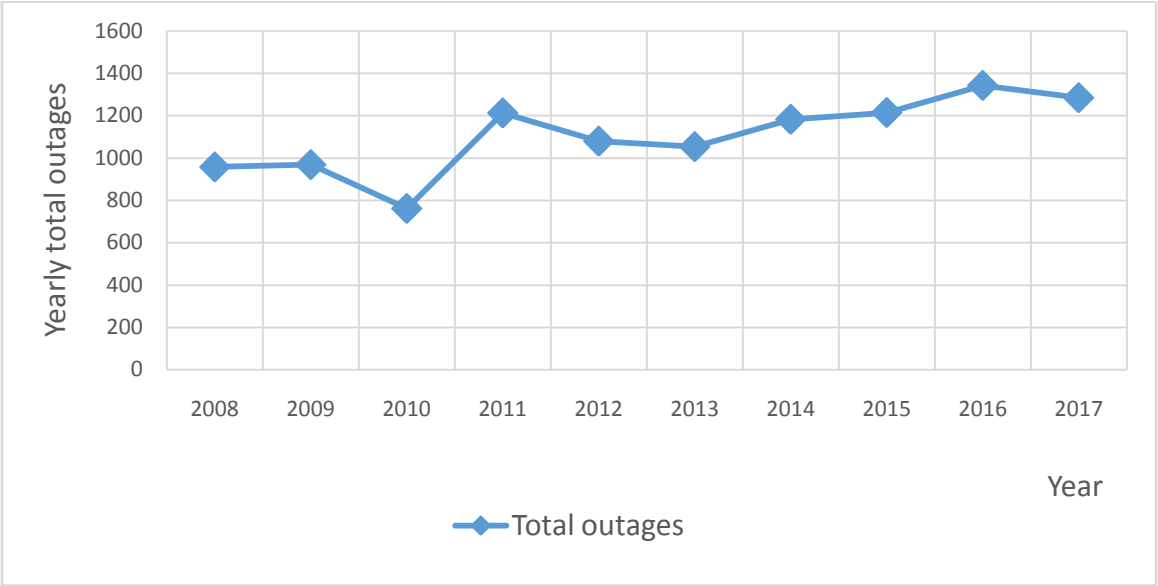

Fig. 1.0: Trend of total outages on Nigeria's 132 kV transmission line (2008 - 2018)

Fig 1.0 shows a sharp drop in outages in 2010 which rather than being maintained or improved on rose steeply again in 2011. Since then, the situation virtually remained the same all through the remaining years. The consequence is poor voltage profiling / control, and power unreliability.

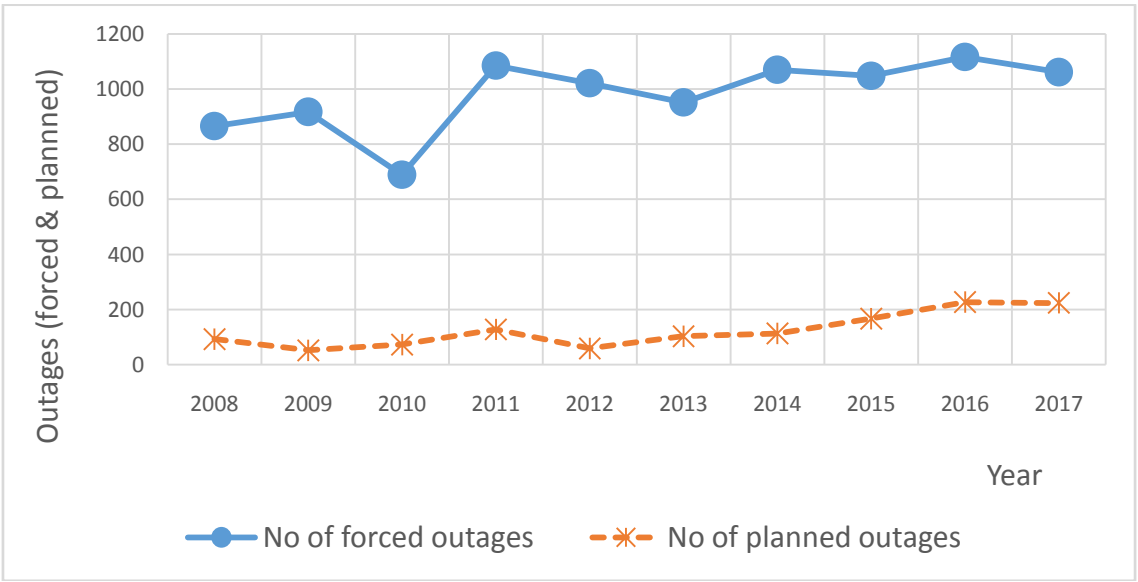

Fig. 2.0: Graphical display of forced and planned outages (2008 - 2018)

In Fig. 2.0, the difference between forced and planned outages becomes more obvious. This underscores the need to reduce the incidence of forced outages on the transmission line. In the main, any outage should be planned so as to reduce unintended power disruptions.

Fig 3.0 further details in comparative terms the relative positions of the total, forced and planned outages over the 10 – year period.

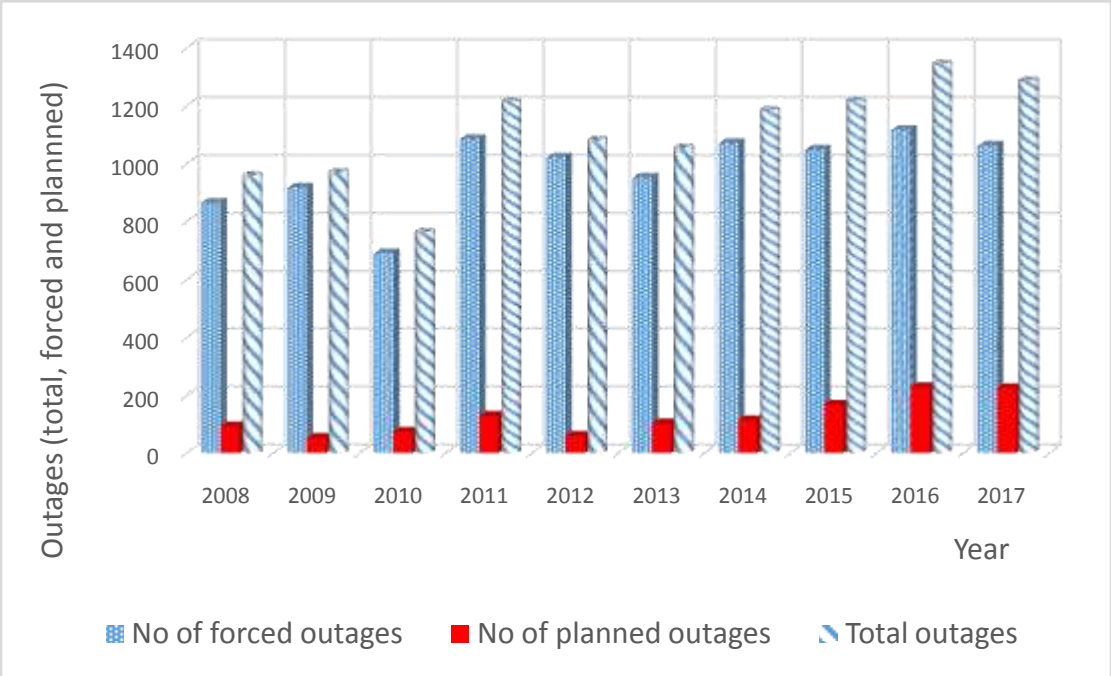

Fig. 3.0: Chart showing the relative positions of total number of outages in relation to the forced and planned outages by year.

The following measures would reduce the incidence of outages on the 132kV lines:

i. Most of the transmission lines and substations are very old. They were constructed more than 40 years ago. Consequently, they cannot withstand the strains and stresses of today's increasing load demand. Thus, they need to be upgraded, rehabilitated or re-enforced.
ii. Communication equipment is poor and outdated. For instance, the National Control Centre (NCC) finds it difficult to communicate with Katampe transmission station. Also due to trunk limitation, communication between NCC and Northern axis is yet to improve.System communication (PLC / Optic fibre) should be made available where required, to enhance communication between NCC and Northern axis of the grid.Trunk facilities especially between Kaduna and Kano should be increased.
iii. Vandalisation of transmission line and associated equipment must be stopped. Many high voltage conductors and towers all over the country have been vandalized. An example is the New Haven Nkalagu 132 kV line leading to the collapse of tower 75. As a result, Ebonyi State and Northern part of Cross River State were thrown into darkness for about one week (Okoye, 2015)
iv. There isinadequate modern spare parts for maintenance of the transmission equipment. Energy business is becoming more complex and demands equally good spares to enhance maintenance and performance of the network.
v. Double circuit should be encouraged rather than the common $150mm^2$, $100mm^2$single lines. The 132 kV single lines are not able to satisfy the n – 1 contingency. Thus, many areas are thrown into darkness whenever there is tripping of breakers associated with these lines.
vi. Transmission losses should be minimised using modern equipment. About 20 – 30% losses occur on transmission system TCN (2017). An estimated 20kVvoltage drop occurs between New Haven and Yandevand this results in low voltage profile and poor power quality supplied to these areas.
vii. Construction of additional new transmissionlines to increases wheeling capacity and improve voltage and system reliability.
viii. Training and re-training of manpower (human capital) to meet the challenges of production, transmission and distribution. The National Power Training Institute of Nigeria (NPTIN) should provide training especially in transmission sub-system.
ix. Indiscriminate erection of buildings / structures under the lines or near them should be stopped. Such practice leads to pollution of conductors and insulators, resulting in forced outages on these networks or lines.

x. Since these transmission lines are very long (e.gGombe – Maiduguri 132 kV circuit is 310km) emphasis should be laid on the appropriate installation of breakers at critical points on the lines; provision of by-pass facilities and upgrading of capacitor banks to improve grid integrity. The single circuit which links Aba with Itu, Calabar and Eket 132 k substations has only one circuit breaker with no by-pass facilities. (TCN, 2016). Consequently, the Aba – Itu 132 kV lines trips from time to time, plunging the entire area into darkness.

xi. Overloading of transmission lines and associated equipment is common. Most transformers on the grid are overloaded for hours with so many loaded. 100% and more of their ratings. The affected transformer banks should be urgently reinforced.

IV. CONCLUSION

Nigeria transmits power through the 132kV and 330 kV high voltage lines. These lines are radial and very long. The 132 kV lines covers a total distance of 7,780km with 132 / 33 / 11 kV substations and installed transformation capacity of 11,660MVA. They suffer a lot of system disturbances leading to forced outages and concomitant loss of load and productivity. A total of 11,062 outages occurred from 2008 to 2017 with 9823 (88.8%) occurring as forced outages while 1239 (11.2%) outages were planned (deliberate). The year 2016 recorded highest number of forced outages, accounting for 1116 while the least (689) was recorded in 2010. The causes and effects of these outages have been presented and measures for reducing their occurrence proffered.

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