

A Model for Assessment of Power System Outages on Nigerian Transmission Network.

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ABSTRACT

A power outage is a short or long-term loss of the electric power to an area such as faults at power stations, damage to electric transmission lines, substation or other parts of the power system. The Nigerian national grid is characterized 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 and circuit breaker problems. This paper develops a polynomial model for the assessment of power system outages on the Nigerian transmission network using curve fitting tools analysis. Data from the transmission network of the national grid were collected and used as input parameters for the computation of the statistical parameters to develop the power system outage model for the network. The results of the work showed that the statistical mean and median of the total outages were 73.11 and 203.50 respectively even though February was the modal month with an outage of 373 due to frequent interruptions experienced by customers during this month. Forced outages on the transmission network recorded the highest value of 44.8% while 32.5% were due to urgent outages and 22.7% were due to planned outages suggesting that the resistance of the network is very low resulting in very low efficiency and disruption in the lives of the citizenry. The result of the work also showed that the polynomial model developed for the assessment of the power system outages is of order 5 whose order increases as more outages are recorded on the transmission network. Ageing of equipment, lightning, vandalization and poor maintenance culture have been identified as some of the causes of power outages on the transmission network. The analysis of the paper can be used to emphasize that in order to ensure safety and security of the transmission network, there is the need for a proper protection of the transmission lines system.

Keywords: Power outages, Transmission lines, Planned outages, Forced outages, Urgent outages, Ageing of equipment, Vandalization, Interruptions.

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I. INTRODUCTION

The power stations in Nigeria are hydro and thermal plants. Electricity network in Nigeria comprises of 11,000km transmission lines (330 kV and 132 kV), 24000 km of sub-transmission lines (33 kV), 1900 km of distribution lines (11 kV) and 22,500 substations. It has only one major loop system involving Benin – Ikeja west – Ayede – Osogbo and Benin. (Stott et al, 2013) The absence of loops is responsible for the weak and unreliable power system in the country. The single line diagram of the existing 28 buses 330 kV Nigerian transmission network is shown in Figure 1 and identification of the buses are shown in Table 1.

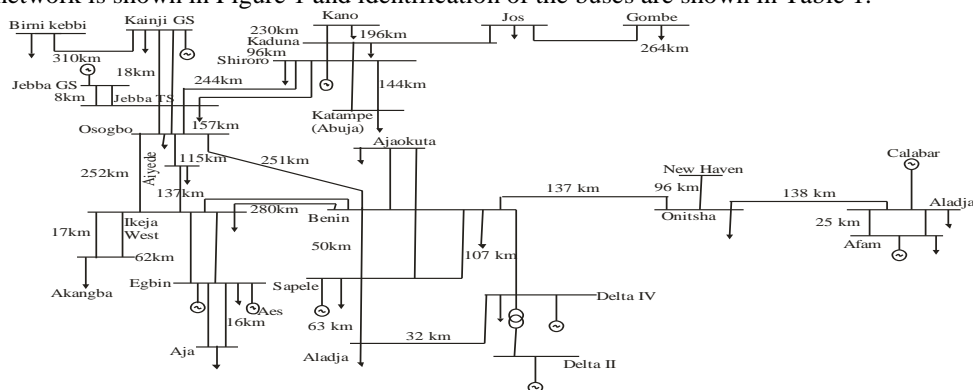


Figure 1: The National Grid System.

Table 1: Identification of the buses..

Bus No Names	Bus Names	Bus No	Bus
1	<u>Osogbo</u>		18
2	<u>AJA</u> <u>Benin</u>		19
3	<u>Ajaokuta</u> <u>Ikeja – west</u> <u>Haven</u>	20	N.
4	<u>Ayede</u>	21	<u>Alaoji</u>
5	<u>Jos</u> <u>AFAM GS</u>		22
6	<u>Onitsha</u>	23	<u>Jebba</u>
7	<u>Akangbe</u> <u>G.S</u>	24	<u>Jebba</u>
8	<u>Gboke</u> <u>G.S</u>	25	Kanji
9	<u>Abuja</u> <u>Kebbi</u>	26	B.
10	<u>Egbin – PS</u> <u>Shiroro</u>		27
11	<u>Delta, PS</u> <u>Kaduna</u>		28
12	<u>AES</u>		
13	<u>Okpan</u>		
14	<u>Calabar</u>		
15	<u>Aladja</u>		
16	<u>Kano</u>		
17	<u>SAP P.S</u>		

Electric power is generated and sent over transmission lines to substations which reduce the voltage level for distribution to end – users. Power outages can result from seasonal storms which often combine the furies of wind, rain, snow or ice. The more severe weather events usually cause the greatest damage to electric power transmission and distribution infrastructure as damage can result from trees or branches falling on electricity lines (Tinney et al, 2005). Power outages can affect manufacturing operations mainly through down time as workers are idled..It can damage equipment and production processes and also disrupt many other electric power dependent activities (Zollenkopf 2001).

High winds especially when combined with precipitation from seasonal storms, can cause damage to electricity utility systems, resulting in service interruptions to large number of electricity consumers, while most such power outages are caused by damage from trees and tree limits falling on local electricity distribution lines, which carry bulk power over long distances. Depending on the severity of the storm and resulting impairment, power outages can last a few hours or extend to periods of several days. This in turn can have real economic effects as power outages can impact businesses, through lost orders and damage to perishable goods and inventories (Grainger and Stevenson 2004).

Types of power outages.

Power outages are categorized into three phenomena relating to the duration and effect of the outage. A transient fault is a momentary loss of power which is caused by a temporary fault on a power line. In this case, power is automatically restored once a fault is cleared. A blown-out or a sag is a drop in voltage in an electrical power supply which can cause poor performance of the equipment or even incorrect operation (Shoultz 2004, Mehta and Madent 2006)..

A black-out refers to the total loss of power to an area and is the most severe form of power outage that can occur. Outages may last from a few minutes to a few weeks depending on the nature of the black-out and the configuration of the electrical network(Donald et al 2013, Bruce and Allen, 2006).

Mitigation of power outage frequency.

There are four mitigation networks namely:
 Increasing the critical number of failures causing cascading blackouts which decreases the frequency of the smaller blackouts and increase that of larger blackouts.
 Increasing individual power line maximum load which increases the frequency of smaller blackouts and decreases that of larger blackouts (Stott et al 2013, Momoh 2001).

Combination of increasing critical number and maximum load of lines which have a significance on either side of blackout..The resulting minor reduction in the frequency of blackouts is projected not to worth the cost of the implementation. Increasing the excess power available on the grid decreases the frequency of smaller blackouts and increases that of larger blackout (Clements et al 2014, Preston et al 2007, Pabio 2001) ..

II. MATERIALS AND METHOD.

In this research paper, the following procedural steps were taken:

- i. The statistical parameters such as mean, median, mode, standard deviation and variance were identified.
- ii. Data were collected on the transmission power outage based on annual reports for the study using the utility logbooks.
- iii. The power outages in the network were analyzed and the indentified statistical parameters were computed.
- iv. A power system outage model is developed using Curve fitting tools.

III. DISCUSSION OF RESULTS.

Figure 1 shows the variation of the planned outages versus the time from 2001 to 2005 (for each of the five years study period).In the months of January, June and November of year 2001, there was no planned outage at all due to the proper functioning of the equipment. The planned outages fluctuated between 1 outage in April 2001 and 8 outages in August in the same year, thus the total recorded planned outage was 35 in the year.. In year 2002, a least planned outage of 2 was recorded in March and June as a result of fewer numbers of interruptions experienced by the customers attached to the affected feeders. Planned outages were recorded in January, February and December due to the overloading of the transformers. The number of planned outages fluctuated over the months with a least planned outages of 2 in March, June and August, even though, a peak outage of 14 was recorded in January, February and December. There was a total of 101 planned outages which represents a high percentage increase in the planned outage as compared to 2001 due to poor maintenance culture on the transmission line equipment.

In 2003 the month of April recorded a least planned outages of 2 while in September of this same year, a total planned outages of 15 were recorded which appeared to be the highest in that year because many of the transformers on the lines were experiencing overloading which led to very low voltages. In 2004, the number of planned outages fluctuated appreciably with a least planned outages of 10 recorded in June due to lesser number of interruptions experienced by all the customers attached to these feeders in the month. There were 23 planned outages in October which appeared to be the highest in that year. In the year, there were 190 planned outages recorded implying that the maintenance culture on the equipment declined as more outages were noticed and recorded in 2004 unlike in 2003 where the number of planned outages was 90. In 2005, December recorded the least planned outages which could be due to the adequate and efficient maintenance culture as well as the determination to keep the machines/equipment in good working conditions before the beginning of the following year. In February and November, a largest planned outages of 20 were recorded. The first 20 outages recorded in February 2005 was due to prolonged interruptions experienced in this month while in November, the 20 planned outages was as a result of decline in the maintenance culture on the system equipment. The total number of planned outages in 2005 was 181 which was a decline in planned outages as compared to the previous year. It is observed that throughout the five years used as case studies, the month of April recorded the least planned outages of 36 which could be due to appropriate and adequate maintenance culture on the system equipment in this month. September has a highest planned outages of 67 throughout the study period due to failure to clear most of the prolonged faults on the feeders.

14 planned outages were recorded in January, February and December because of the overloading of the transformers. The number of planned outages fluctuated over the months of the year with a least planned outage of 2 recorded in March, June and August and a peak outage of 14 recorded in January, February and December. There was a total of 101 planned outages which represents an appreciable increase in the planned outage as compared to 2001 due to poor maintenance culture on the transmission line equipment. The statistical mean, median and the mode for planned outages during the five years study period are 49.8, 50 and 67 respectively even though the modal month was September.

The relationship between the forced outages and the time for the five years study period is shown in Figure 2. In 2001, a total of 244 forced outages were recorded out of which only 3 were recorded in July because most of the equipment were functioning effectively and with adequate maintenance during the month and 38 forced outages were recorded in February which could be traced to transmission line constraints on the feeders during this month.

In 2002, only 5 forced outages were noted in May and 35 forced outages were recorded in June and December which could be traced to vandalization of the lines.

In 2003, only 4 forced outages were recorded in March while 42 forced outages were recorded in December. The maintenance culture on the system equipment declined appreciably and many interruptions were experienced by all the customer attached to the feeders.

In 2004, there were 15 forced outages in April while in June, there were 30 forced outages even through, the forced outages fluctuated throughout the year .The statistical mean, median and mode for the forced outages were 98.3, 88.5 and 192 respectively even though, February was the modal month.

The variation of the urgent outages with time is shown in Figure 3.

In 2001, the least urgent outage was 8 and this occurred in June, August and December while the highest urgent outages of 19 were recorded in February due to shunt reactor problems experienced this month.

In 2002, there were 18 urgent outages in April and 7 outages in August as a result of corrective maintenance practices on the transmission lines.

In 2003, the urgent outages recorded in February, June, August and October were 125, 27, 8 and 3 outages respectively representing a drastic fall in outages over the year because the distribution transformers were well protected and very long and fragile lines were re-enforced to improve the voltage stability and efficiency of the network..

In 2005, the recorded urgent outages in February and June were 21 and 2 outages respectively because of the prolonged interruptions experienced on the lines in February suggesting that the resistance of the network was very low and resulting in very low efficiency and disruption in the lives of the citizenry.

Frequent outages which are due to aging of equipment / lines are some of the characteristics of Nigeria transmission network. These result in frequent conductor/jumper cuts, frequent earth faults and circuit breaker problems.

The statistical parameters (mean, median and mode) for urgent outages were 71.6, 61 and 192 even though, February was the modal month.

The total planned outages vary with time on monthly basis as illustrated in Figure 4. During the five years study period: a total of 40 planned outages were recorded in June which is more than half of the total planned outages recorded and this is evident from the figure.

Figure 5 shows the graphical representation of how the total forced outages vary with time on monthly basis. A total of 120 forced outages were recorded in June during the five years study period.

Figure 6 illustrates the variation of total urgent outages with time on monthly basis. A total of 190 urgent outages were recorded in February throughout the five years study period. This is the maximum total urgent outages recorded.

The relationship between the planned outages and the time in years is illustrated in Figure 7.

Figure 8 shows how the forced outages vary with time on a yearly basis while the variation of the urgent outages with time on a yearly basis is also illustrated in Figure 9.

The relationship between each of the three outages (planned, forced and urgent) and time on monthly basis is shown in Figure 10.

It is evident from the figure that a total of 190 urgent outages were recorded in February, 50 forced outages were recorded in October and 55 planned outages were recorded in November.

Figure 11 shows the variation of combined outages with time on monthly basis. During the five years study period, a total of 210 outages were recorded in March as evident from the figure.

The model developed for the assessment of the transmission network is

$$y = 0.080x^5 - 2.668x^4 + 32.33x^3 - 171.0x^2 + 351x + 75.04, R^2 = 0.965$$

Where y = total outages,

x = time

R^2 = coefficient of determination.

R^2 shows the extent of the relationship between the total outages recorded on the transmission network and the time. The model is a polynomial of order 5 whose order increases as more outages are recorded on the transmission network.

IV. CONCLUSION.

A polynomial model of order 5 has been developed for the assessment of power outages on the Nigeria transmission network. The analysis of the work showed that out of a total of 2632 outages recorded on the 132 kV and 330 kV transmission networks, forced outages recorded the highest value of 44.8% while 32.5% were due to urgent outages and the rest were due to planned outages suggesting the need for a proper protection of the transmission line systems.

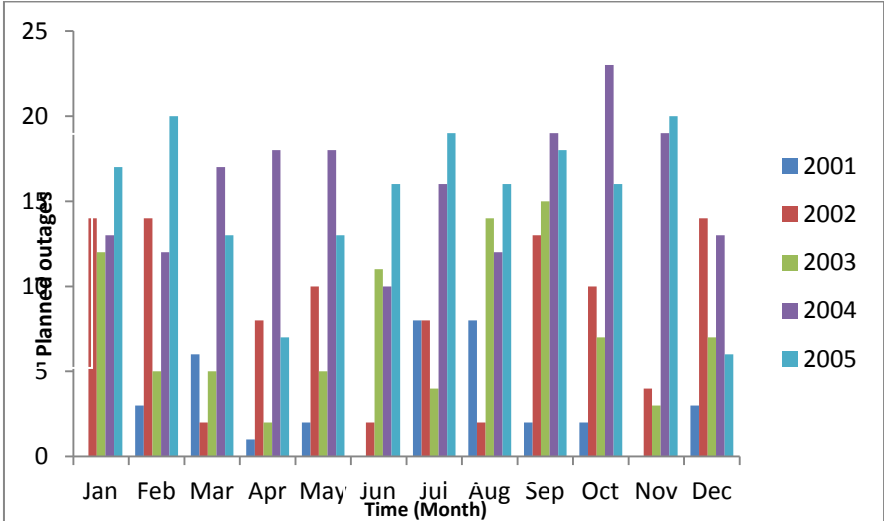


Figure 1: Planned Outages Versus Time for 5years

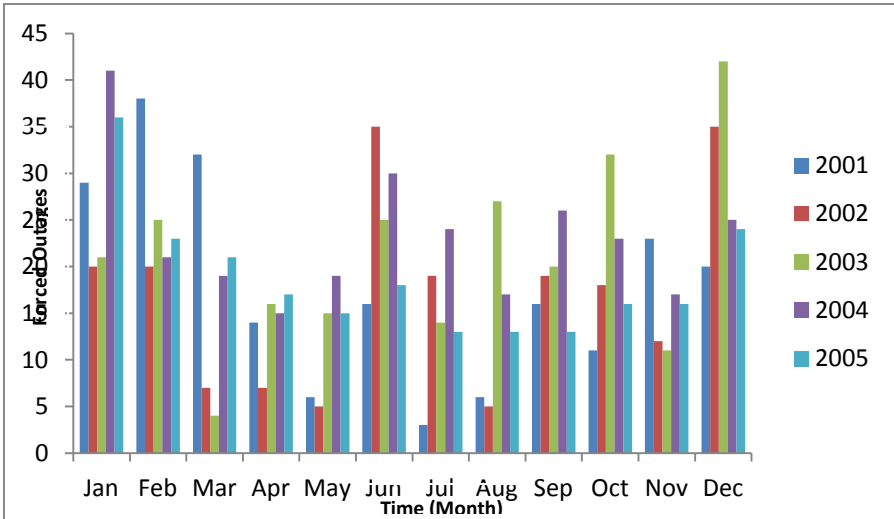


Figure 2: Forced Outages versus Time for 5years

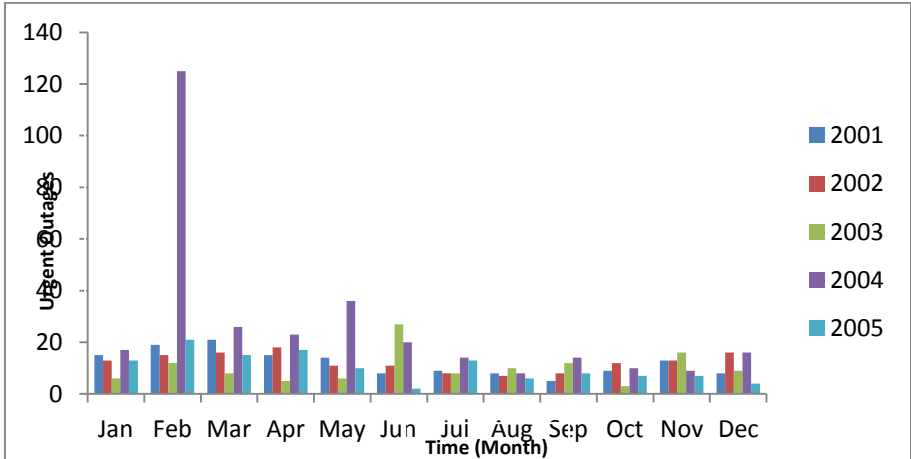


Figure 3: Urgent Outages versus Time for 5years

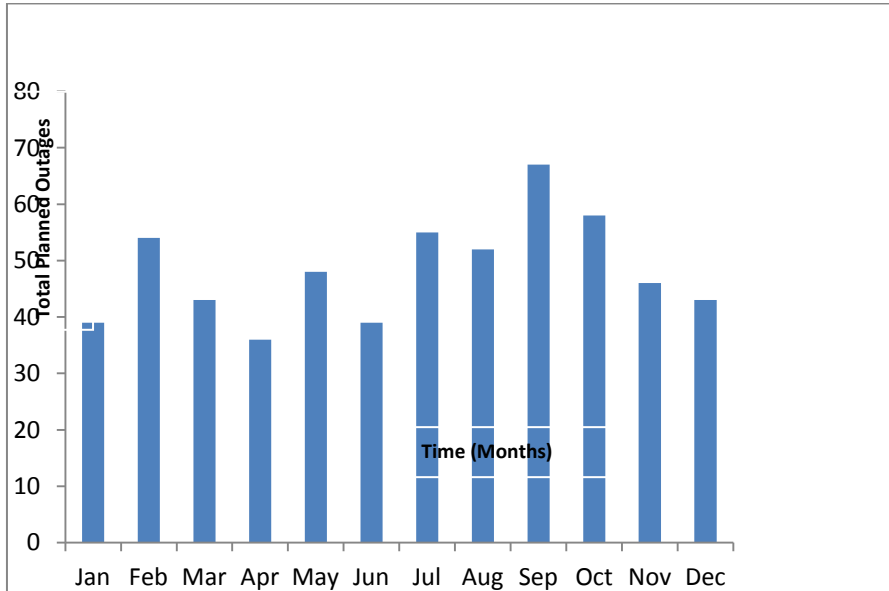


Figure 4: Total Planned Outages versus Time in Months

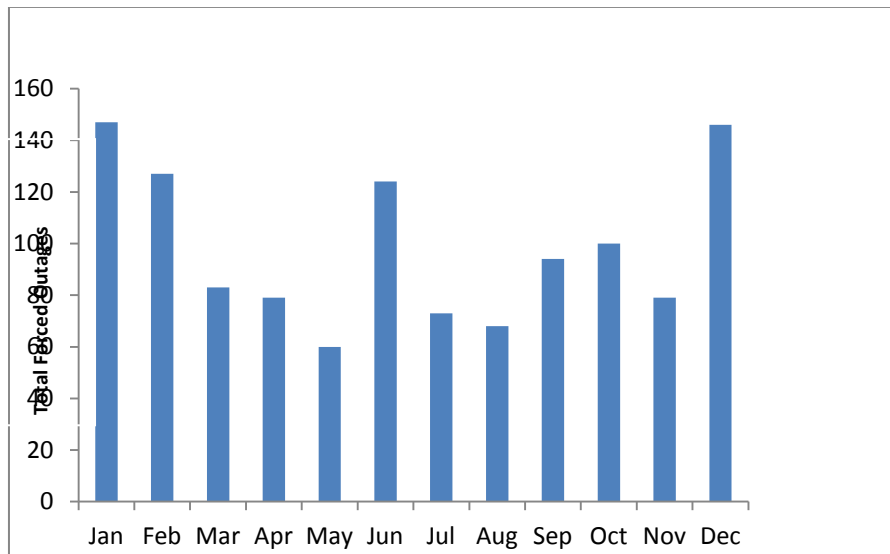


Figure 5: Total Forced Outages versus Time in Months

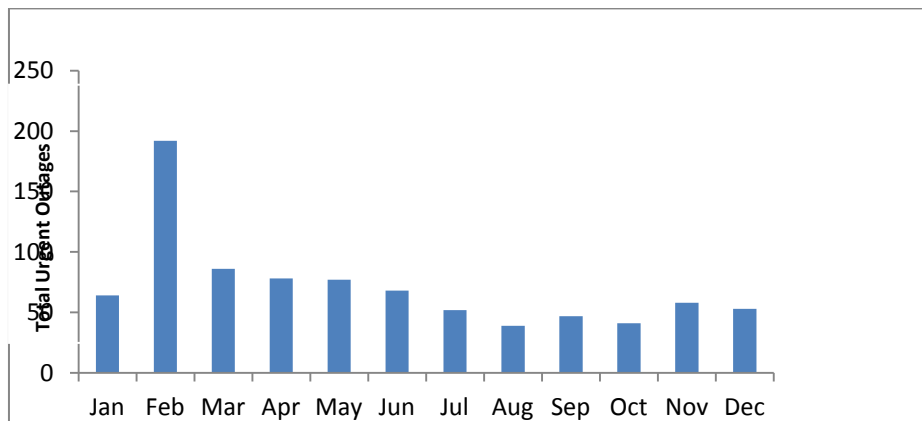


Figure 6: Total Urgent Outages versus Time in Months

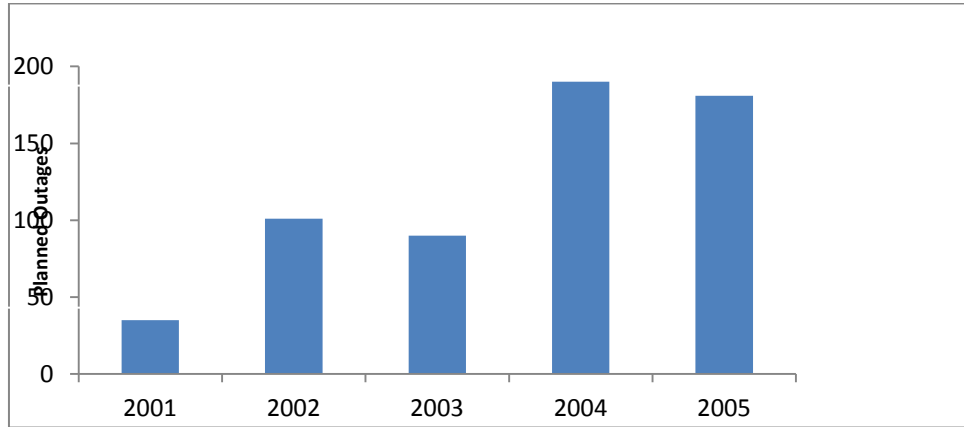


Figure 7: Planned Outages versus Time in Years

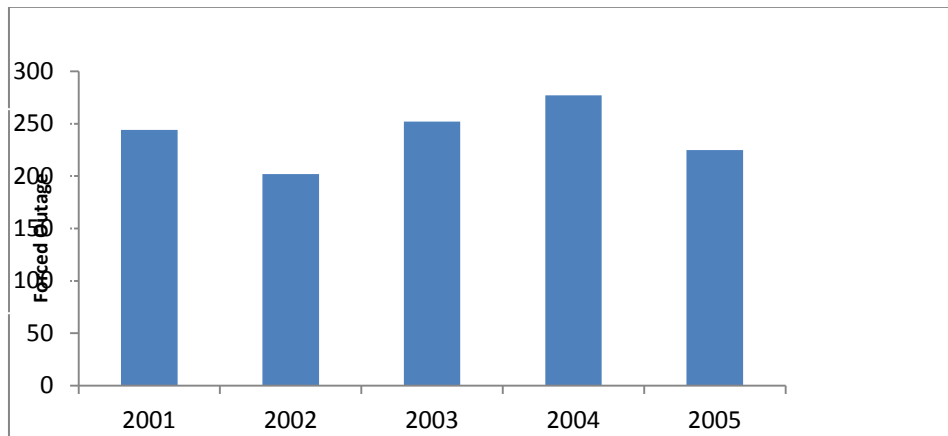


Figure 8: Forced Outages versus Time in Years

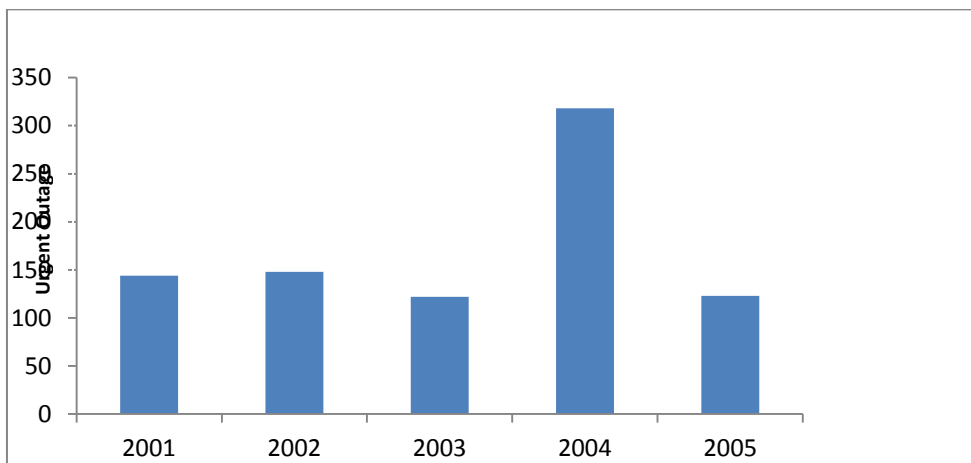


Figure 9: Urgent Outages versus Time in Years

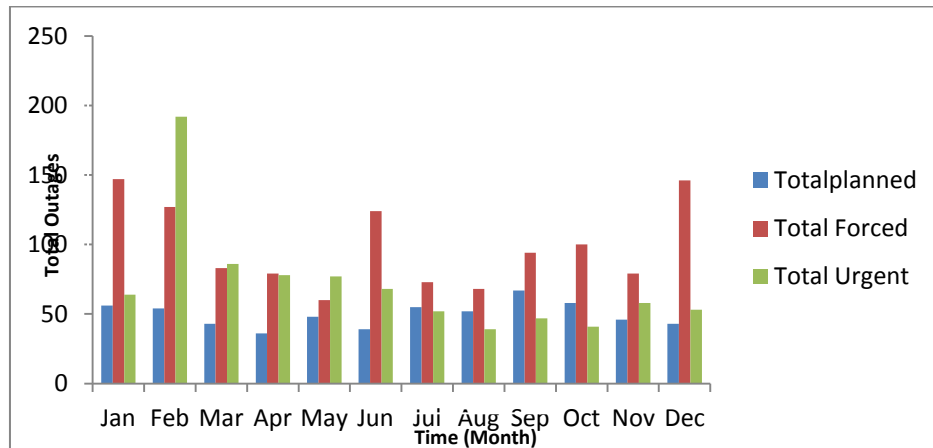


Figure 10: Planned, Forced and Urgent Outages versus Time (Months)

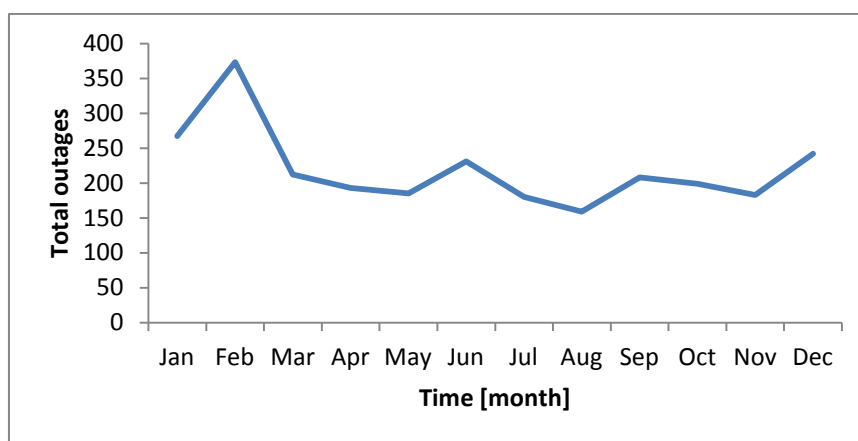


Figure 11: Total outages versus time (months)

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