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Estimation of Outage Cost on Distribution Network

Mohammed Dima Ali[1], Kalli B. Mai[2] , Tijjani B. Ngajia[3] and Y.A. Mshelia[4]

[1]Department of mechanical Engineering Technology, Ramat Polytechnic, Maiduguri,State, Nigeria

[2,3,4]Department of Electrical/Electronic Engineering Technology, Ramat Polytechnic, Maiduguri,State, Nigeria.

Abstract: There is increasing attention on the estimation of the customer interruption costs. The existing studies adopt outages data available in the control center the study is based on Maiduguri distribution network and reliability data. Different reliability assessments are being used for the study of electric power system component using particular parameter of assessment to obtain certain indices. The study presents an approach that considers a wider range of outage parameters (duration, load interruption, cause of outage, and frequency) as input .while the outage cost assessment was used to analyse the economic implications of outages on the 33 kV feeders.

1.0 INTRODUCTION

The outage cost is the monetary value of the electrical power energy that is not served to the consumers due to power supply outages. The outages can be basically categorized into forced outages and emergency outages. While the forced outages are caused by automatic tripping of the feeders due to fault on the line, the emergency outages are due to manual opening of the feeders for load shedding or maintenance work. There various papers on the worth of electric power reliability and the interruption cost of a customer. The comprehensive review published in 2015 brings together the academic work done in the fields of worth of electric power reliability and customer interruption costs assessment techniques from the year 1990 to 2015 (Küfeoğlu, *et al*,2016). Tiedemann, (2015) reminds that the interruption costs vary by duration, time of the day or the season. And it indicates that the lowest cost for an interruption among United States (US) commercial sector customers would be 1.17 $/kWh. The forced outage cost and emergency outage cost are the monetary value of the electrical power energy that is not served to the consumers due to forced outages and emergency outages respectively. The occurrence of forced outages is mostly caused by lack of proper maintenance culture. Thus, the value of outage cost of a feeder gives an insight to the relative amount worthy of allocating for the maintenance of the feeder (Billinton, 2011).

2.0 Causes of Feeder Outage

It is important for reasonable appreciation of the overall research objective to highlight the general causes of feeder failure. These include the following: (Leroy *et al,* 2011).

a) **Loading/increased activity**: Increased customer demands typically during peak periods increase the loading of the equipment. This may lead to tripping of the feeders on overload when the load current reaches the relay setting thus putting the affected areas in blackout. (Leroy *et al.,* 2011).
b) **Weather**: Adverse weather conditions during heavy rain along with strong winds, lightning or conditions like dusty and moist climates in general increase the tendency of the feeder to trip on fault. (Leroy *et al.,* 2011).
c) **Vegetation**: Vegetations ranging from trees to climber weeds and even moulds causes outages due to faults arising from part of the vegetation touching the lines or bridging phases of the line. This is the reason for utilities to maintain the "right of way" under the lines. (Leroy *et al.,* 2011).
d) **Animals and Pests**: The activities of animals like birds, ants and snakes result in outages when they get trapped or intertwined on the lines causing tripping on the lines to be detected as faults. Sometimes the faults may not be transient; it has to be cleared before the line closes back.
e) **Human Factors**: Even the most sophisticated power systems still involve human factor in operating them. For that failure may occur due to intentional or unintentional causes. The intentional ones are in the form of scheduled maintenance or manual load reduction to control system loading while the others are by accidents or errors and lead to outages or failure of the lines (Leroy *et al*., 2011).

2.1 Calculation of Outage Cost of A Feeder

The outage cost OC of a feeder for a study period is computed as follows:

$$OC = OE \ x \ IEAR \quad (1)$$

Where OE is the outage energy in MWH (mega watt hour), lEAR is the interruption energy assessment rate (in Naira for this research). The OE is calculated as:

$$OE = T \ x \ L \quad (2)$$

Where T is the length of time in hours that the load is interrupted on a feeder, and L is the interrupted load in MW (mega watts) (Illochi et al. 2010, Teoman et al, 2011 and William, 2011).

The calculation of the outage costs of the various feeders is useful for the following:

- Determining the monetary value of losses caused by the outage on each 33 kV feeder.
- Total energy lost in (mwH) by each feeder during outages.
- Monetary value of forced outages
- Monetary value of emergency outages.
- Determining the maintenance cost allocation to each 33 kV feeder
- Prioritizing of 33 kV feeders during load shedding activities.

The lEAR (Interruption Energy Assessment rate) is the cost of a unit of electrical energy in kwH fixed by National Electricity Regulatory Commission (NERC) act 2013.

3.0 Outage Cost Results and Analysis

The data used for the calculation of the outage cost of the 33 kV feeders are obtained from the same outage parameters data bank used in the analysis carried out in (Appendix I and III)

3.1 Calculation of Outage Cost of the 33 kV Feeder

a. **33 kV Bama Feeder**

From the outage data of the 33 kV Bama feeder already entered in Excel spread sheet format, the duration of time T, in hours that the load is interrupted on the feeder was extracted and placed on a separate column of the excel spread sheet. Also the corresponding load L, in megawatt (mw) interrupted during each outage was also extracted and placed on a separate column of the excel spread sheet. Using the values obtained for T and L, the outage energy OE in megawatt hour (mwH) for each outage was calculated using OE = T x L (equation 3.25), and the result placed on a separate column of the Excel spread sheet.

Then the outage cost OC was calculated using the formular

$$OC = OE \times IEAR \quad (3)$$

Where IEAR, Interruption Energy- Assessment rate is the cost of a unit of Electrical Energy in kwh fixed by the National Electricity Regulatory Commission Act, 2013.

This amount is currently fixed at N29.44 kwh for three-phase Residential customer excluding fixed charges (NERC Act 2013).

Therefore the OC for 33 kV Bama feeder is OC = OE x IEAR..

OE = 5213.9257mwh

IEAR = 29.44kwh

Therefore OC = 5213.9257 x 1000 x 29.44

= N153,497,972.60

b. 33 kV Benisheikh Feeder

OC = OE x IEAR

OE = 4094.8150 (from appendix I)

IEAR = 29.44kwH

OC = 494.8150 x 1000 x 29.44

= 120,551,353.60k

c. 33 kV Damasak Feeder

OC = OE x IEAR

OE = 3857.4150 x 1000 x 29.44

IEAR = 29.44kwH

OC = 3857.4150 x 1000 x 29.44

N113,562,297.60k

d. 33 kV Monguno Feeder

OC = OE x IEAR

OE = 7290.9167

IEAR = 29.44kwH

OC = 7290.9167 x 1000 x 29.44
N214,644,587.70k

e. 33 kV University Feeder

OC = OE x IEAR
OE = 842.2533mwH
IEAR = 29.44kwH
OC = 842.2533 x 1000 x 29.44
N24,795,937.15

3.2 Formulae and Results for the Calculation of Forced Outages and Emergency Outages Costs for the various 33 kV Feeders

Forced Outages Cost

I. 33 kV Bama Feeder

O/C = OE X IEAR
OUTAGE COST = OUTAGE ENERGY X IEAR
From Appendix III, which shows data on Total Energy lost in mwH due to force and emergency outages.
OE = 3649.7479mwH
IEAR = 29.44wH
OC = 3649.7479 x 1000 x 29.44
= ₦107,448,578.2k

II. 33 kV Benisheikh Feeder

O/C = OE X IEAR, from appendix III
OE = 2866.3705mwH
OC = 2866.3705 x 1000 x 29.44
= ₦84,385,947.52k

III. 33 kV Damasak Feeder

O/C = OE X IEAR
From Appendix III, OE = 2507.3198mwH
OC = 2507.3198 x 1000 x 29.44
= ₦73,815,494.91k

IV. 33 kV Monguno Feeder

O/C = OE X IEAR
From Appendix III, OE = 5468.1875mwH
OC = 5468.1875 x 1000 x 29.44
= ₦160,983,440.92k

V. 33 kV University Feeder

O/C = OE X IEAR, from appendix III
OE = 463.2393mwH
OC = 463.2393 x 1000 x 29.44
= ₦13,637,764.99k

Emergency Outages Cost

I. 33 kV Bama Feeder

OC = OE X IEAR
From Appendix III,
OE = 1564.1777mwH

OC = 1564.1777 x 1000 x 29.44
= ₦46,049,391.49k

II. 33 kV Benisheikh Feeder

OC = OE X IEAR,
from appendix III OE = 1228.4445mwH
OC = 1228.4445 x 1000 x 29.44
= ₦36,165,406.08K

III. 33 kV Damasak Feeder

O/C = OE X IEAR
From Appendix III, OE = 1320.0952mwH
OC = 1320.0952 x 1000 x 29.44
= ₦39,746,802.69k

IV. 33 kV Monguno Feeder

O/C = OE X IEAR
From Appendix III, OE = 1822.7292mwH
OC = 1822.7292 x 1000 x 29.44
= ₦53,661,147.65k

V. 33 kV University Feeder

O/C = OE X IEAR, from appendix III
OE = 379.0140mwH
OC = 379.0140 x 1000 x 29.44
= ₦11,158,172.16k

TABLE 1: OUTAGE COST OF THE 33kV FEEDERS

OUTAGE COST OF THE 33-kV FEEDERS				
FEEDER	*TOTAL ENERGY LOST (MWH)*	*FORCED OUTAGE COST (₦)*	*EMERGENCY OUTAGE COST (₦)*	*TOTAL OUTAGE COST(₦)*
BAMA	5213.9257	107,448,578.20	46,049,391.49	153,497,969.69
BENISHEIK	4094.8150	84,385,947.52	36,165,406.08	120,551,353.60
DAMASAK	3857.4156	73,815,494.91	39,746,802.69	113,562,297.60
MONGUNO	7290.9165	160,983,440.40	53,661,147.65	214,644,588.05

UNIVERSITY	842.2533	13,637,764.99	11,158,172.16	24,795,937.15

4.0 Result

The Bar charts in fig. 4.1, 4.2 and 4.3 show the results of the forced outage cost, emergency outage cost and total outage cost for all the 33 kV feeders connected to the Maiduguri 132/33 kV feeder substation.The 33 kV Monguno and Bama feeders have the highest forced outage costs of ₦160,983,440.92k and ₦107,448,578.2k respectively while the 33 kV University feeder has the lowest forced outage cost of ₦11,158,172.16k. This implies that the 33 kV Monguno and Bama feeders may be given preferential treatment for preventive maintenance cost allocation since spending money to reduce the forced outages on the feeder will help save a bigger percentage of loss due to its corresponding forced outages. Since forced outages are the ones that are caused by transient faults and can be reduced by effective preventive maintenance of the causes of the failure.The 33 kV University feeder with the lowest forced outage cost of ₦13,637,765,99k requires minimum preventive maintenance cost allocation. The 33 kV Monguno with the highest emergency outage cost of ₦53, 661,147.65k must be given highest priority during load shedding activities.

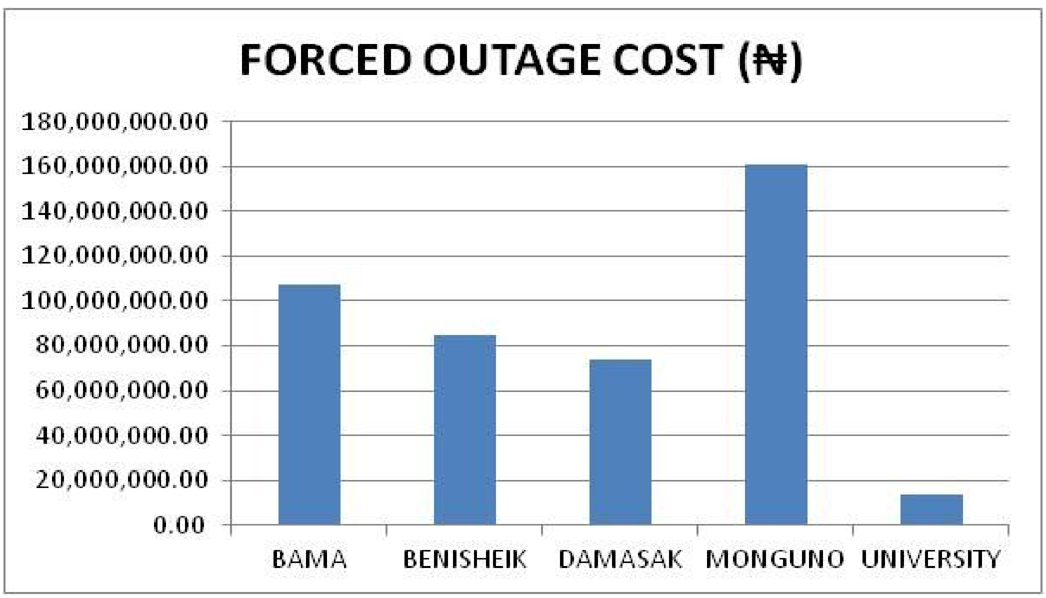

Fig 4.1: Bar chart of forced outage cost/ Feeders

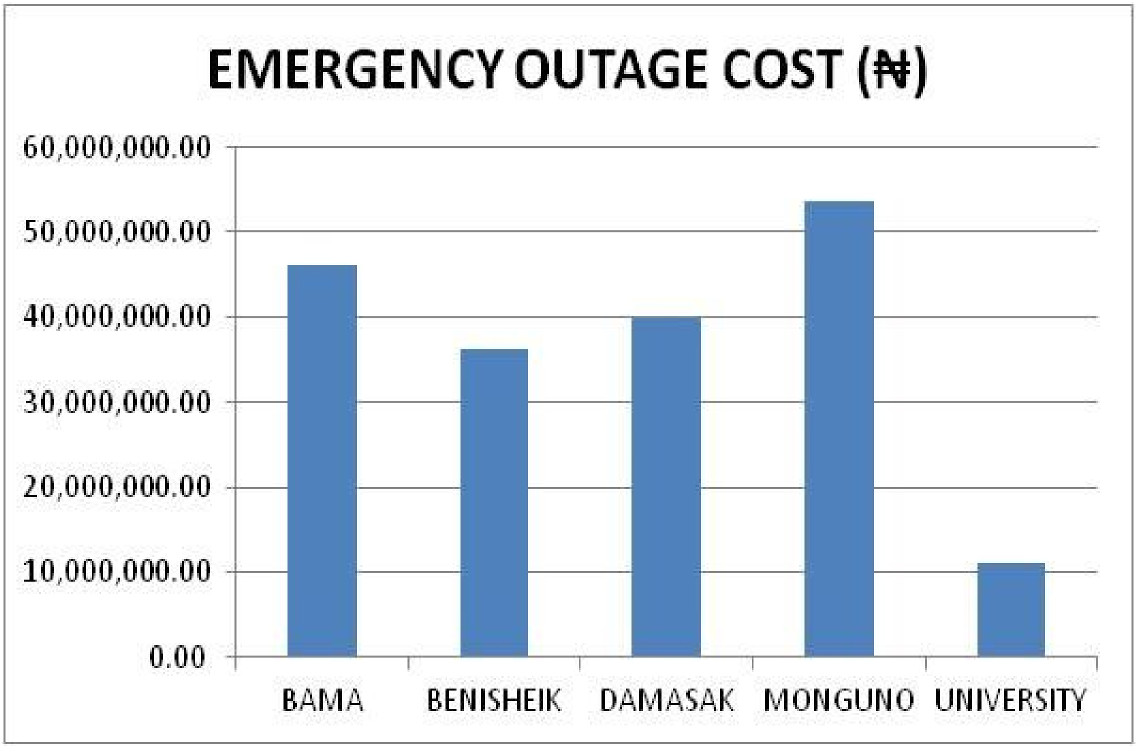

Fig 4.2: Bar chart of Emergency outage cost/ Feeders

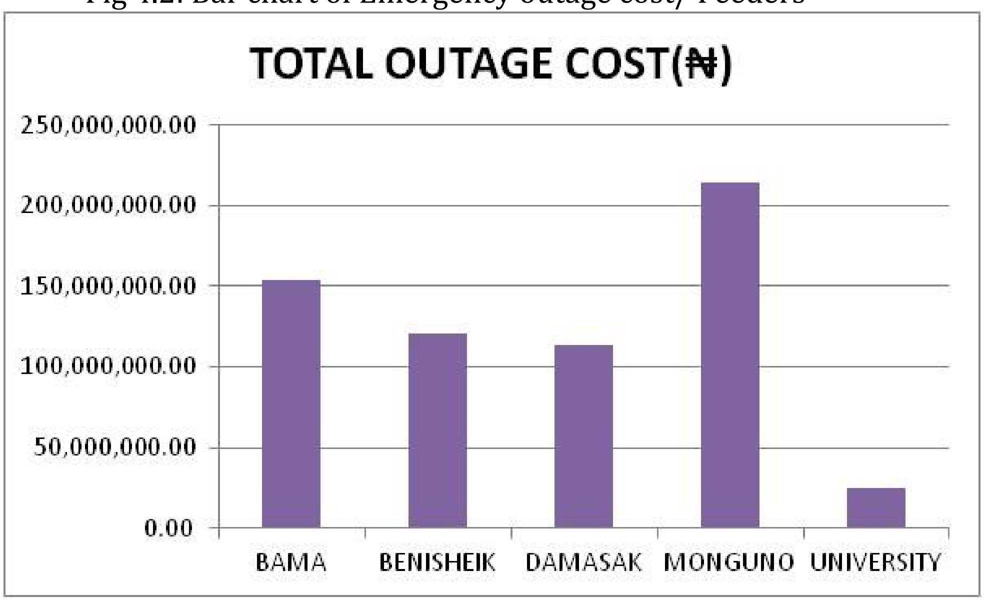

Fig 4.3: Bar chart of Total outage cost/ Feeders

5.0 Conclusions

It is quite essential to understand the costs of power interruption for planning purposes. Furthermore, protection of customers from long lasting blackouts is another driving factor behind the need of understating the impacts of power outages and their economic worth. Being a popular area of research, there have been numerous studies targeting this problem. However, in these work rely on outage record obtained from electricity Distribution Company.

The result obtained from the calculation of the forced outage cost of the 33 kV feeders indicates that 33 kV Monguno is having the highest outage cost value while 33 kV University feeder is having the lowest even though both feeders are having very close value of average duration of outage experienced by their respective customers (SAIDI). What this implies is that 33 kV Monguno feeder may be given first preference treatment for preventive maintenance cost allocation since spending money to reduce the forced outages on the feeder will help save a bigger percentage of loss due to its corresponding forced outages. Since forced outages are the ones that are caused by transient fault and can be reduced by effective preventive maintenance of the causes of the failure.

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Appendix i

Customers Population Data of the 33 kV Feeders in Maiduguri

33 kV FEEDER	NUMBER OF INTERRUPTION	CUSTOMER POPULATION	TOTAL ENERGY LOST (MWH)
BAMA	384	17,527	5213.9257
BENISHEIKH	338	12,961	4094.8150
DAMASAK	348	8007	3857.4150
UNIVERSITY	394	2410	842.2533
MONGUNO	534	12,573	7290.9167

Appendix ii

Data on outage Duration and Load Interrupted in MW for the 33 kV Feeders in Maiduguri

FEEDER	NUMBER OF INTERRUPTIONS	OUTAGE DURATION IN HRS	LOAD INTERRUPTED IN MW
33 kV BAMA	384	638.417	177.103
33 kV BENESHEIKH	338	441.670	139.690
33 kV DAMASAK	348	354.130	131.026
33 kV UNIVERSITY	394	559.467	28.609
33 kV MONGUNO	534	97.730	247.653

Appendix iii

Data on Total Energy lost in (mwh due to force outages and emergency otuages of the 33 kv feeders in Maiduguri

33 kV FEEDER	NUMBER OF INTERRUPTION	ENERGY LOST DUE TO FROCE OUTAGES (MWH)	ENERGY LOST DUE TO EMERGENCY OUTAGES (MWH)	TOTAL ENERGY LOST IN (MWH)
BAMA	384	3649.7479	1564.1777	5213.9257
BENESHEIKH	338	2866.3705	1228.4445	4094.8150
DAMASAK	348	2507.3198	1320.0952	3857.4150
UNIVERSITY	394	463.2393	379.0140	842.2533
MONGUNO	534	5468.1875	1822.7292	7290.9167