



RELIABILITY IMPROVEMENT THROUGH IDENTIFICATION OF FEW SIGNIFICANT FAULTS IN A DISTRIBUTION FEEDER

I. K. Okakwu¹, O. O. Ade-Ikuesan² and E. S. Oluwasogo³

¹Ph.D. Scholar, Department of Electrical/Electronic Engineering, University of Benin, Nigeria

²Department of Computer and Electrical Engineering, Olabisi Onabanjo University,
Ago Iwoye, Ogun State, Nigeria.

³Department of Electrical and Computer Engineering, Kwara State University, Malete, Nigeria

Abstract: The reliability of a distribution system is an important issue for both utilities and customers. Fault is a major factor that impair on the reliability of distribution feeders. This paper presents the application of Pareto and Anti-Pareto principle in identifying significant few faults and insignificant many faults that, if attended to, will improve the reliability of distribution feeders. Data of power outages between July 2013 to June 2014 were collected from Power Holding Company of Nigeria (PHCN), Ajele Injection substation, containing nine feeders: CSS, New custom, Tafawa Balewa, Tokunboh, Freeman, NEPA I, NEPA II, Ajele local and Odunda feeders, all radiating from 3 x 15MVA transformers, 33/11kV, with about 30,000 customers. The result obtained provides justification for the use of Pareto principle in the reliability of improvement for a distribution feeder.

Keywords: Reliability, Distribution; Faults; Substation; Pareto improvement

I. INTRODUCTION

The main purpose of an electric power system operation is to satisfy the system load demand with reasonable assurance of continuity and quality. The ability of the system to provide an adequate supply of electrical energy to provide an adequate supply of electrical energy is usually designate by the term "Reliability". The effect of loss of electricity energy supply is usually significant on the utility supplying the energy, as well as the end users or customers. The power system is vulnerable to system abnormalities such as equipment failure, earth fault, broken poles, overload, human factors and same unknown factors. Therefore, maintaining system reliability is a very important issue for power systems planning and operation [1]. The Nigeria distribution system as a developing one with horizontally distributed customers is characterized by very long radial circuit, undersized distribution conductors, and transformers, system faults, which are major factors that impair on electric distribution system. It is therefore necessary to identify the factors that impact most on reliability and determine control measures to be adopted in order to reduce their effect [2]. In this paper, with the help of Pareto principle and Anti-Pareto principle, the effect of few significant fault would be identified. This approach will help the power system planners/designers on which fault to focus on, in order to improve the reliability of the feeders in the substation.

II. INDEX OF RELIABILITY

For the purpose of reliability evaluation in outage scheduling of distribution feeders, the following indices of reliability are defined to guide the scheduling [3].

1) **Failure rate (N):** This is defined as a measure of the frequency at which faults occurs. Also, for a repairable systems or items, the failure rate is expressed as the number of failure with occurs per unit-hour of operation. It is denoted by N. and expressed as:

$$N = \frac{\text{Number of time that occurred}}{\text{Number of unit - hour of operation}} \quad (1)$$

2) **Mean time between failures (MTBF):** This expresses the average time, elapse between consecutive failures of a repairable system or equipment. It is denoted by MTBF and expressed as:

$$MTBF = \frac{\text{Number of unit - hour of operation}}{\text{Number of failures}} \quad (2)$$

MTBF been a reciprocal of N, the longer its value, the more reliable the system.

3) **Mean time to repair (MTTR):** This is the average time needed to bring a system back to its normal operation. Hence, a low MTTR indicates good maintainability skill.

$$MTTR = \frac{\text{Total down tiwn}}{\text{Total number failures}} \quad (3)$$

4) **Availability (A):** A term which applied either to the performance of individual components or to a system. Availability is the long-term average fraction of time that a component or system is in service satisfactorily performing its intended function.

$$A = \frac{\text{Total operatingtime}}{\text{Expected uptime}} \times 100\% \quad (4)$$

5) **Unavailability (U):** The long-term average fraction of time that a component or system is out of service caused by failures or scheduled outage.

$$U = \frac{\text{Total down time}}{\text{Expected uptime}} \quad (5)$$

6) **Reliability(R):** The term describes the ability of continuous service without outage/failure/interruption. It is expressed as:

$$R(t) = \exp(-\lambda^t) \quad (6)$$

III. DATA COLLECTION

Historical power outage data were collected from Power Holding Company of Nigeria (PHCN) on Nine feeders: CSS, New Custom, Tafawa Balewa, Tokunboh, Freeman, NEPA I, NEPA II, Ajele local and Odunfa feeders, all radiating from the 3 x 15 MVA transformers, 33/11kV Ajele Injection substation, Lagos State, Nigeria and analysed using Microsoft Excel Database. The substation serves over 30,000 customers.

Table 3.1: Faults distribution in the Ajele injection substation feeders

Fault	Feeders								
	CS S	NEW CUSTOM	TAFAWA BALEWA(TBS)	TOKUNB OH	FREEM AN	NEPA II	NEP A I	AJELE LOCAL	ODUN FA
Earth fault	6	4	2	1	8	47	2	6	4
Broken pole/Cross arm	4	7	5	3	10	6	1	4	7
Maintenance/Repair	52	26	31	17	35	28	43	64	55
Animal(Bird,Snake,etc)	0	2	0	2	4	3	0	1	6
Jumper/Wire cut	9	5	12	7	16	12	9	8	11
Tree fault	1	0	3	4	7	1	3	5	2
11KV line failure	81	193	131	157	56	102	171	201	93
Phase-to-phase	23	8	16	26	11	31	15	12	19
Fuse closure	127	85	96	61	81	205	264	101	96
Overload	608	369	502	341	462	527	641	384	411
Unknown	8	1	7	5	9	5	6	10	8

Table 3.2: Downtime in hours for each feeders

Feeders	CS S	NEW CUSTOM	TAFAWA BALEWA(TBS)	TOKUNB OH	FREEM AN	NEPA II	NEP A I	AJELE LOCAL	ODUN FA
Number of faults	919	700	805	624	699	967	1155	796	712
Downtime(hours)	564	265.1	147	286.4	138.6	127.8	346	92.4	116.3

IV. PARETO PRINCIPLE

The Pareto principle also known as 80/20 principle, state that there is an inbuilt imbalance between causes and results, inputs and outputs, and effort and reward. Typically, causes, inputs, or effort divide into two categories: the majority, that have little impact and a small minority that have a major, dominant impact. The relationship between causes, inputs or efforts on the one hand, and results, outputs, or rewards on the other, is therefore typically unbalanced. When this imbalance can be measured arithmetically, a good benchmark for the imbalance is the 80/20 relationship, 80% of results, outputs, or rewards are derived from only 20% of the causes, inputs or effort [4]. The reverse of the Pareto principle is the Anti-Pareto principle.

V. METHODOLOGY

Pareto analysis uses the principle that problem solvers should focus on 20% of factors causing 80% of the problems instead of the 80% of factors causing only 20% of the problems (Anti-Pareto). The numbers 80 and 20 are not absolute. This principle was named after Vilfredo Pareto, an Italian Sociologist and Economist who observed that 80% of Italy's wealth was owned by 20% of the population. Hence, this analysis can be applied in electric power distribution systems because it is a principle centered on "significant few (Pareto) and the insignificant many (Anti-Pareto). A trace of 80% mark on the cumulative frequency of fault arranged in descending order identifies the significant few faults that must be attended to (Pareto).

Assuming the minimum 80% mark of CSS feeder = x

Reliability of CSS feeder = y

Unreliability = $1 - y = z$ (7)

The improvement due to the application of the Pareto principle is the product of the % of faults that requires attention (few significant) and unreliability. That is

$$k = xz \quad (8)$$

Thus, attending to this few significant fault will lead to unreliability reduction of xz. This fractional reduction of unreliability will lead to the same fractional increase in reliability using equation (8). Therefore, the feeders improved reliability becomes:

$$y + xz \quad (9)$$

VI. RESULTS AND DISCUSSION

For Pareto principle to be applied, the fault events are arranged in descending order. The relative and cumulative frequencies of each fault were calculated for CSS, New custom, Tafawa Balewa, Tokunboh, Freeman, NEPA I, NEPA II, Ajele local and Odunfa feeder are presented in Table 3.4 to 3.12 respectively.

Table 3.3: Faults arranged in descending order with relative and cumulative frequencies in CSS feeder

Fault	Frequency of fault	Relative frequency (%)	Cumulative frequency (%)
Overload	608	66	66
Fuse closure	127	14	80
11KV line failure	81	9	89
Maintenance/Repair	52	6	94
Phase-to-phase	23	3	97
Jumper/Wire cut	9	1	98
Unknown	8	1	99
Earth fault	6	1	99
Broken pole/Cross arm	4	0	100
Tree fault	1	0	100
Animal(Bird,Snake,etc)	0	0	100

Table 3.4: Faults arranged in descending order with relative and cumulative frequencies in New Custom feeder

Fault	Frequency of fault	Relative frequency (%)	Cumulative frequency (%)
Overload	369	53	53
11KV line failure	193	28	80
Fuse closure	85	12	92
Maintenance/Repair	26	4	96

Phase-to-phase	8	1	97
Broken pole/Cross arm	7	1	98
Jumper/Wire cut	5	1	99
Earth fault	4	1	100
Animal(Bird,Snake,etc)	2	0	100
Unknown	1	0	100
Tree fault	0	0	100

Table 3.5: Faults arranged in descending order with relative and cumulative frequencies in Tafawa Balewa feeder

Fault	Frequency of fault	Relative frequency (%)	Cumulative frequency (%)
Overload	502	62	62
11KV line failure	131	16	79
Fuse closure	96	12	91
Maintenance/Repair	31	4	94
Phase-to-phase	16	2	96
Jumper/Wire cut	12	1	98
Unknown	7	1	99
Broken pole/Cross arm	5	1	99
Tree fault	3	0	100
Earth fault	2	0	100
Animal(Bird,Snake,etc)	0	0	100

Table 3.6: Faults arranged in descending order with relative and cumulative frequencies in Tokunboh feeder

Fault	Frequency of fault	Relative frequency (%)	Cumulative frequency (%)
Overload	341	55	55
11KV line failure	157	25	80
Fuse closure	61	10	90
Phase-to-phase	26	4	94
Maintenance/Repair	17	3	96
Jumper/Wire cut	7	1	98
Unknown	5	1	98
Tree fault	4	1	99
Broken pole/Cross arm	3	0	100
Animal(Bird,Snake,etc)	2	0	100
Earth fault	1	0	100

Table 3.7: Faults arranged in descending order with relative and cumulative frequencies in Freeman feeder

Fault	Frequency of fault	Relative frequency (%)	Cumulative frequency (%)
Overload	462	66	66
Fuse closure	81	12	78
11KV line failure	56	8	86
Maintenance/Repair	35	5	91
Jumper/Wire cut	16	2	93
Phase-to-phase	11	2	95
Broken pole/Cross arm	10	1	96
Unknown	9	1	97
Earth fault	8	1	98
Tree fault	7	1	99
Animal(Bird,Snake,etc)	4	1	100

Table 3.8: Faults arranged in descending order with relative and cumulative frequencies in NEPA II feeder

Fault	Frequency of fault	Relative frequency (%)	Cumulative frequency (%)
Overload	527	54	54
Fuse closure	205	21	76
11KV line failure	102	11	86
Earth fault	47	5	91
Phase-to-phase	31	3	94
Maintenance/Repair	28	3	97
Jumper/Wire cut	12	1	98
Broken pole/Cross arm	6	1	99
Unknown	5	1	100
Animal(Bird,Snake,etc)	3	0	100
Tree fault	1	0	100

Table 3.9: Faults arranged in descending order with relative and cumulative frequencies in NEPA I feeder

Fault	Frequency of fault	Relative frequency (%)	Cumulative frequency (%)
Overload	641	55	55
Fuse closure	264	23	78
11KV line failure	171	15	93
Maintenance/Repair	43	4	97
Phase-to-phase	15	1	98
Jumper/Wire cut	9	1	99
Unknown	6	1	99
Tree fault	3	0	100
Earth fault	2	0	100
Broken pole/Cross arm	1	0	100
Animal(Bird,Snake,etc)	0	0	100

Table 3.10: Faults arranged in descending order with relative and cumulative frequencies in Ajele Local feeder

Fault	Frequency of fault	Relative frequency (%)	Cumulative frequency (%)
Overload	384	48	48
11KV line failure	201	25	73
Fuse fault	101	13	86
Maintenance/Repair	64	8	94
Phase-to-phase	12	2	96
Unknown	10	1	97
Jumper/Wire cut	8	1	98
Earth fault	6	1	99
Tree fault	5	1	99
Broken pole/Cross arm	4	1	100
Animal(Bird,Snake,etc)	1	0	100

Table 3.11: Faults arranged in descending order with relative and cumulative frequencies in Odunfa feeder

Fault	Frequency of fault	Relative frequency (%)	Cumulative frequency (%)
Overload	411	58	58
Fuse fault	96	13	71
11KV Line failure	93	13	84
Maintenance/Repair	55	8	92
Phase-to-phase	19	3	95
Jumper/Wire cut	11	2	96
Unknown	8	1	97
Broken pole/Cross arm	7	1	98
Animal(Bird,Snake,etc)	6	1	99
Earth fault	4	1	100
Tree fault	2	0	100

Thus, attending to few significant fault (Pareto principle), large insignificant fault (Anti-Pareto principle) will improve the reliability of the feeders as shown in Table 3.12.

Table 3.12: Reliability improvement indices for different feeders

Feeder	Actual Reliability	Reliability Improvement due to Pareto analysis	Reliability Improvement due to Anti-pareto analysis
CSS	0.068	0.814	0.254
New custom	0.138	0.828	0.31
Tafawa Balewa	0.106	0.92	0.186
Tokunboh	0.171	0.834	0.337
Freeman	0.143	0.88	0.263
NEPA II	0.068	0.87	0.198
NEPA I	0.037	0.933	0.105
Ajele local	0.11	0.875	0.235
Odunfa	0.138	0.862	0.276

Figure 1.0: Graph of reliability improvement

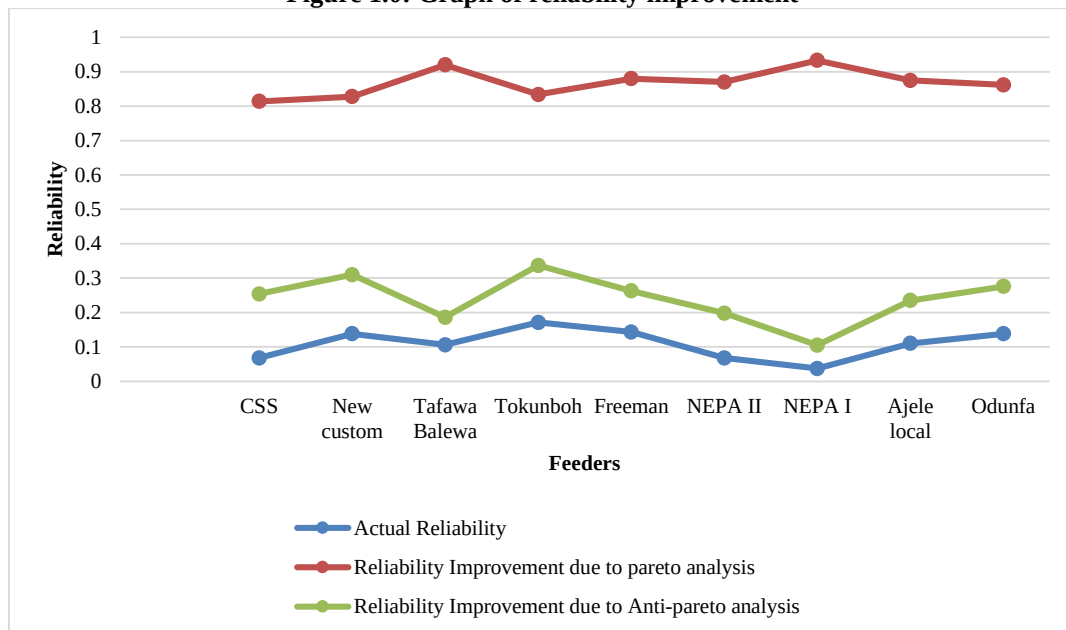
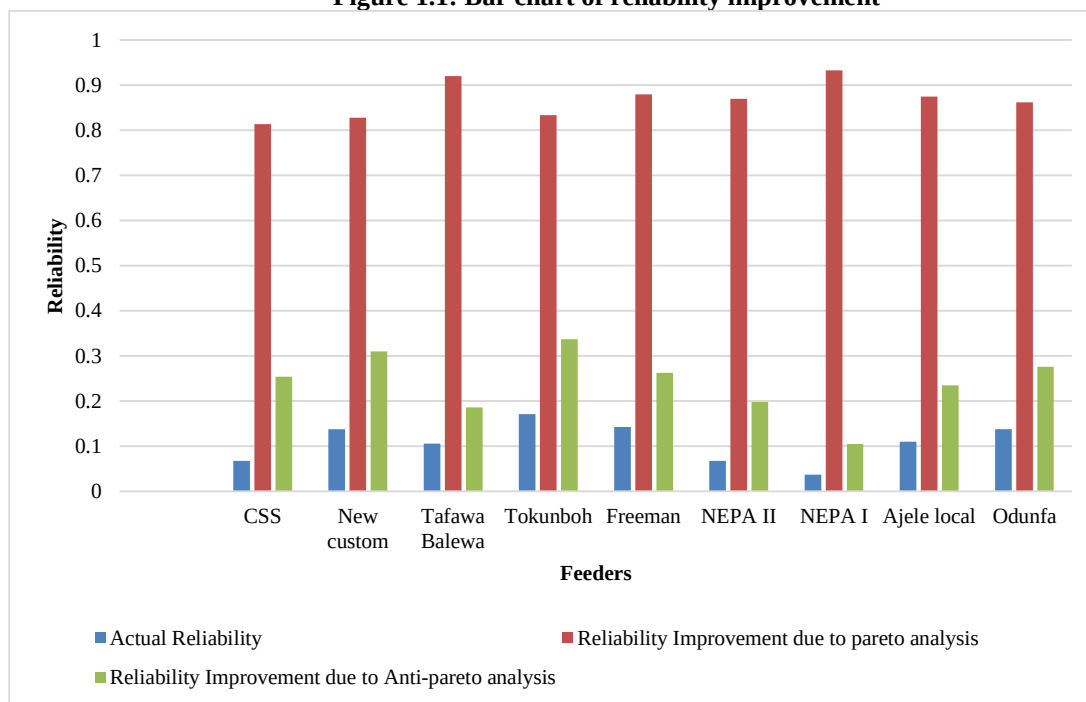


Figure 1.1: Bar chart of reliability improvement



VII. CONCLUSION

In this study, the reliability evaluation and improvement of Ajele Injection substation was successfully identified. Also, two techniques has been applied to improve the reliability of the substation. A comparison of these two techniques shows that Pareto principles performed better than Anti-Pareto principle. The analysis shows that the elimination of the 20% significant few faults (Pareto principle) in the distribution feeders will lead to having reliability of a least “8” in its first decimal place. The result also shows that overload is the most frequently occurring faults event in the 11kV feeders of Ajele injection substations.

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