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Reliability Assessment of Distribution System Using Analytical Method: A Case Study of Debre Berhan Distribution Network

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Abstract

Electric power delivers a predicable per condition for the technological, economic and political development of any countries and it is vital for each individual. Power outage is serious problem in Ethiopia at the whole of distribution network. This is due to most interruptions are frequently and much time service restoration, that is why most customers of Ethiopia their day to day activities highly affected and they are strongly complain to Ethiopia electric utility. But this power outage affected the cost of customer and Ethiopian utility. Power system is to provide an adequate and security electrical addressing to its demands as economically as alternative with reasonable level of reliability. Most electrical power distribution system reliability is one of the major issues for the demands. Reliability is the chance that a network or components done their assigned task for a given period of time under the working time stumbled upon during its anticipated lifetime. Most of developing country including Ethiopia electric power distribution network has received considerably less of the attention to reliability designing and evaluation than have generating and transmitting systems. Now a day life is directly or indirectly depends on electric power so that utility should deliver reliable power every day for 24 hours and each year for 8760 hours to satisfy human needs and to perform their works as much as possible with less economy.

Keywords

Analytical Method, Assessment of Reliability, EENS, SAIDI, SAIFI

1. Introduction

Electrical power system is utilized to deliver reliable power to the end users. Reliability is the one indicator in the quality of power supply, but now days; reliability is treated as separate problem in the power system. The reliability evaluation techniques can be classified into analytical and simulation techniques, which is presented in figure 1.

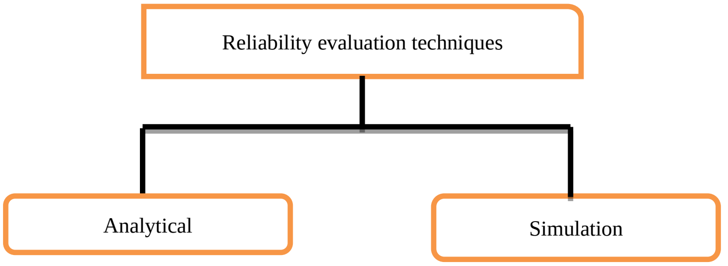


Figure 1. Evaluation technique of reliability

Mathematical design and analysis is utilized to represent the system in analytical methods. Simulation techniques estimated the indicators by means of simulating the process and network's random behavior. Table 1 presented the comparison between analytical and simulation techniques.

Table 1. Compression between analytical and simulation technique

Analytical	Simulation
• In this technique the design give constant output of numerical result to the same system, same design and same set of input document	• It depends on the selection data used and the total times of simulation.
• It is used to simplification of any electrical distribution network for give the output to short time simulation.	• This method, however, can incorporate and simulate any system characteristic that can be recognized. Thus it gives a best description of practical output.
• In this technique outputs are sometimes limited only to expected values.	• It can produce a wide range of output parameters probability density functions and their respective moments.
• Its solution time is relatively short due to this partially overcome by the development of modern computational facilities.	• The solution time for simulation techniques is relatively long • The solution time still remains high in applications that demand several reliability assessments.

In electrical power system, there are three main components; these are power generation, power transmission and at end power distribution to each customer, these electrical components also generate power losses. Based on the nature of losses can classified in two these are technical and nontechnical losses. Technical losses are due to the electrical power dissipation of electrical materials like lines of transmissions &distributions, transformers, different measuring systems and equipment's and others are under technical losses. Nontechnical losses are caused by external actions to the power networks, such as errors in measuring, billing theft and fraud. Therefore, Total Distribution losses = Technical losses + Non-technical losses .

These losses which can be affect both utility (unsold energy) and customer (production cost) and finally system power interruption or outages are occurred. Reliability means the chance that a system or components perform their assigned task for a given period of time under the working conditions stumbled upon during its anticipated lifetime. To achieve an acceptable level of reliability, quality and safety at an economic price, the utility have to create and enhance the systems reliability continuously depending upon the requirement of the customers. Reliability assessment methods allow the evaluation of the reliability of systems. The methods provide important information on how to increase a systems life to reduce safety risk and hazards [1, 2]. From these main components of electrical power, distribution system is a largest part of network in electrical power system.

Ethiopian electricity utility (EEU) has various reliability issues in distribution system. Despite the realization of the importance of the distribution sector, the performances of EEU have not been measured empirically so far by the organization. Usually engineers try to achieve the required reliability level with minimal cost. System reliability can be divided into two distinct categories.

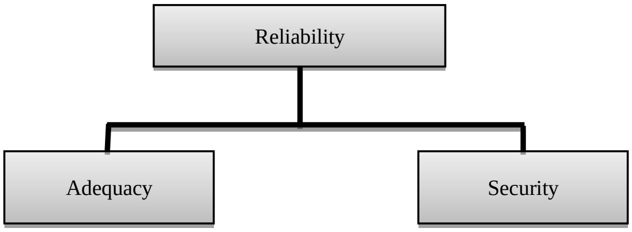


Figure 2. categories of reliability

The above fig 2 shows basic categories of electric power network reliability: security and adequacy. This paper provides a significant importance of measuring the existing network performance of reliability as well as serving as a benchmark for the prediction of the future in Debre Berhan electrical distribution network. In general it has the following advantages:

- To indicate the influence of power interruption on the economy of customers and utility.
- Assess average duration and frequency of power interruption per year in the system.

2. Reliability Index

Different types of reliability indices are utilized for the analysis of reliability of distribution system.

2.1 System average interruption frequency index (SAIFI)

$$\frac{\text{Total number of interruption}}{\text{Total number of customerserved}} \quad int/cus\ /\text{yr} \tag{1}$$

$$\text{SAIFI}= \frac{\sum Ni}{Nt}$$

2.2 System average interruption duration index (SAIDI)

$$\frac{\text{Total duration ofall interrupions in customers}}{\text{total nomber of customer served}} \ \text{hr/int/yr} \tag{2}$$

$$\text{SAIDI} = \frac{\sum ri*Ni}{Nt}$$

2.3 Customer average interruption duration index (CAIDI)

$$\text{CAIDI}=\frac{\sum \text{customer interruption duration}}{\text{total number of customer interruption}}\text{hr} \tag{3}$$

2.4 Average service availability index (ASAI)

$$\text{ASAI} = \frac{customer\ hours\ service\ avalilabale}{customer\ hours\ service\ demand}\text{pu} \tag{4}$$

$$\frac{8760\ \text{hours/yr} - \text{CAIDI}}{8760\ \text{hours/yr}}$$

2.5 Customer average interruption index (CAIFI)

$$\text{CAIFI}= \frac{\text{Total number of customer interruption}}{\text{Number of customer affectted}} \quad (5)$$

2.6 Average service Unavailability index (ASUI)

$$\text{ASUI}= 1\text{-ASAI} \quad (6)$$

$$\frac{\text{SAIDI}}{8760\ \text{hours/yr}}$$

2.7 Excepted energy not supplied index (EENS)

$$\text{EENS} =\sum Li * Ui \quad (7)$$

Where, Li represents average connected load at load point *i*, Ui represents average annual outage time at load point *i*.

2.8 Average energy not supplied index (AENS)

$$\text{AENS}= \frac{\text{Total energy not supplied}}{\text{Total number of customer served}} \quad (8)$$

$$\frac{\sum \text{Li} * \text{Ui}}{\sum \text{Ni}}$$

The above indices equations are customer-oriented indices and the last two equations are load and energy-oriented indices. These indices can be tells not only to assess the past performance of a distribution system but also to predict the future system performance.

3. Evaluation of Reliability

The predictive reliability is followed to predict the changes in reliability measures after a change in system configuration or any improvement strategy is planned to be implemented.

4. Description of Debre Berhan Distribution System

The town of Debre Berhan is located at 9041oN latitude and 39031oE longitude, 130 km from Addis Ababa, Amhara region, north shoa administrative zone, and district of Debre Berhan Zuria. The Debre-Berhan town Distribution system has started electrifying since 1969 in G.C from mini hydropower of Abogedam which is found at the north of river Veresa and from diesel source. Currently in Debre Berhan town distribution systems there are 15,266 customers from these 1940 of them are commercial customers, 13,165 customers are residential and 161 of them are higher industry customers, street lights and others. These loads mainly supplied from a single substation. This substation has 9 radially configured feeders are engaged to distribute primary voltage level power to the distribution transformer and industrial loads. The feeders in the town are configured radially with voltage level of 33 kV and 15 kV primary feeders. 33 kV feeders have three outgoing lines, these are: Sheno, Enwary and AliuAmba and15 kV feeders have four outgoing lines such as blanket factory, Ankober, Mendida and Sheno. These feeders are connected to a total of more than 170 distribution transformers; most of them are pole mounted, for further step down to 380 V three-phase and 220 V single-phase for secondary distribution purpose. Figure 3 presented the single line diagram of selected distribution system.

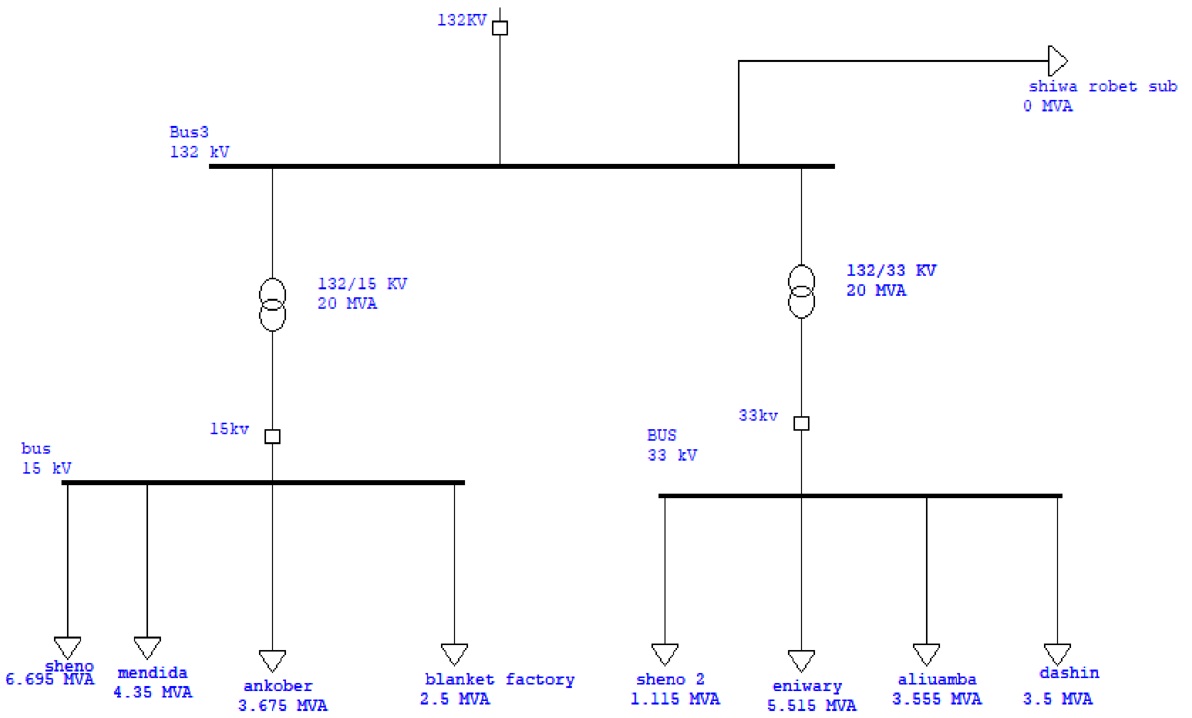


Figure 3. Single line diagram of DB distribution substation

5. Data of Debre Berhan Distribution System

In debre Berhan distribution network site survey, the primary data necessary for my project were

- Length of the feeder
- Rating and type of each transformer
- Topology and layout of the system
- Conductor type, topography and others.

Table 2. DB Distribution network power capacity and connected load of each feeder

Feeder name	Capacity (MVA)	Active power (MW)	Reactive power (MVAr)	NO of trans-former	No of customer
Sheno (33kv)	1.115	1.0156	0.986	15	2262
Sheno (15kv)	6.695	5.96	4.18	33	2321
Ankober	3.675	3.125	2.589	31	2353
AliuAmba	3.555	3.154	2.698	32	2286
Enway	5.515	4.898	3.987	37	2460
Mendida	4.35	3.986	2.987	27	3582
Blanket factory	2.5	2.253	1.968	2	2

Power distribution of Debre Berhan town is radial distribution system type. Power is delivered to the customer from the utility in a one path only. There are no laterals and interconnection or mesh type network topology. Even if radial power distribution system is less costly in terms of design and protection, it's vulnerable to disturbance hence less reliable. Because of its radially this substation has a frequent interruption to the customer. Due to this reason the mesh or interconnected distribution is highly recommended to improve customer based reliability and power availability. Debre Berhan substation has seven outgoing feeders. Tables 2, 3 and 4 presented the data of Debre Berhan substation.

Table 3. DB distribution system voltage rating of feeders and type of breakers

Feeder Name	Voltage level in KV	Circuit breaker type	Peak load in MW
Sheno	33	Oil circuit breaker	1.0156
Sheno	15	Oil circuit breaker	5.96
Enwary	33	Oil circuit breaker	4.898
AliuAmba	33	Oil circuit breaker	3.154
Ankober	15	Oil circuit breaker	3.125
Mendida	15	Oil circuit breaker	3.986
Blanket factory	15	Oil circuit breaker	2.253

Table 4. The total transformer and their ratings of DB distribution network

Feeders Name	Capacity in KVA									
	25	50	100	160	200	315	630	800	1250	Total
Sheno (15KV)	3	2	8	0	4	6	1	3	0	27
Enwary	6	10	5	0	14	1	0	0	1	37
AliuAmba	5	8	6	0	5	0	1	1	0	26
Ankober	3	10	5	0	13	0	0	0	0	31
Blanket factory	0	0	0	0	0	0	0	0	2	2
Sheno(33 KV)	6	3	5	0	0	1	0	0	0	15
Mendida	3	5	7	1	8	1	0	1	0	33
Total(KVA)	650	1900	3600	160	8800	2835	1260	3200	5000	171

6. Causes of Interruption

In Debre Berhan; each interruption, interruption duration and loads of each feeder per hour is recorded but the causes of interruptions are not in detail. So to put an appropriate mitigation technique for the reliability problem Debre Berhan area; it is critical knowing the causes of interruptions. There are different causes of distribution network power interruptions. These are as follows:

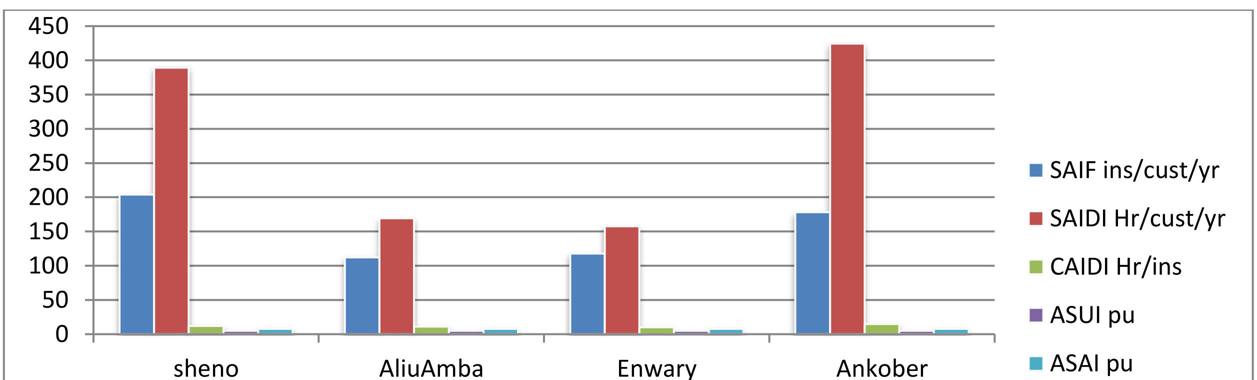
- Failing of trees
- Lighting
- Car accident
- Animals
- Maintenance
- Failures of equipment

7. Results and Discussion

Based on mathematical or using reliability indexes the following output available and the data take to DBU for two years interruption and time duration of outage. Table 5 shows two years reliability index of Debre Berhan distribution networks.

Table 5. Reliability of existing network

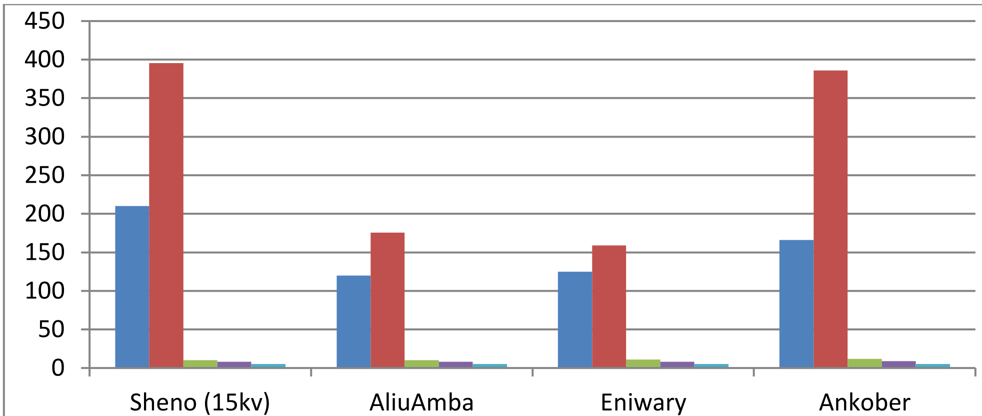
Feeder name	Reliability index	2017	2018	Average
Sheno	SAIFI int/cus/yr	204	210	207
	SAIDI Hr/cus/yr	389.55	395.5	392.525
	CAIDI Hr/int	1.8833	1.90956	1.89643
	ASAI pu	0.955531	0.9548516	0.9551913
AliuAmba	SAIFI int/cus/yr	112	120	116
	SAIDI Hr/cus/yr	169.25	175.61709	172.433545
	CAIDI Hr/int	1.51116	1.463475	1.4873175
	ASAI pu	0.980679	0.9799524	0.9803157
Ankober	SAIFI int/cus/yr	118	125	121.5
	SAIDI Hr/cus/yr	157.416667	159.1309	158.2737835
	CAIDI Hr/int	1.3334	1.273044	1.303222
	ASAI pu	0.98203	0.9818344	0.9010672
Enwary	SAIFI int/cus/yr	178	166	172
	SAIDI Hr/cus/yr	424.4	385.7605	405.08025
	CAIDI Hr/int	2.3843	2.3238945	2.35409725
	ASAI pu	0.95155	0.955596	0.955596



Feeders	SAIF ins/cust/yr	SAIDI Hr/cust/yr	CAIDI Hr/ins	ASUI pu	ASAI pu
sheno	204	389.55	1.90956	0.044469	0.955531
AliuAmba	112	169.25	1.51116	0.019321	0.980679
Enwary	118	157.416667	1.3334	0.01797	0.98203
Ankober	178	424.4	2.3843	0.048448	0.95155

Figure 4. Reliability assessment result of Debre Berhan distribution substation (2017)

Figure 4 presents the reliability assessment of Debre Berhan distribution substation for the year 2017. Figure 5 presented the reliability assessment of Debre Berhan distribution substation for the year 2018. Table 6 presented the comparative results of EENS for Debre Berhan distribution substation.



feeders	SAIFI int/cust/yr	SAIDI Hr/cut/yr	CAIDI Hr/int	ASAI	ASUI
Sheno (15kv)	210	395.5	1.8833	0.9548516	0.045148
AliuAmba	120	175.61709	1.463475	0.9799524	0.0200476
Eniwary	125	159.1305	1.273044	0.9818344	0.0181656
Ankober	166	385.7605	2.3238945	0.955596	0.044037

Figure 5. Reliability assessment result of Debre Berhan distribution substation in (2018)

Table 6. EENS of Debre Berhan distribution

Feeders name	EENS MW/year		
	2017	2018	Average
AliuAmba	533.026	536.18	534.603
Ankober	1325	1206.25	1265.625
Enwary	768.986	783.68	776.33
Sheno	2318	2360.16	2339.08

8. Conclusion

The reliability index of Debre Berhan distribution systems (SAIFI, SAIDI) is high which mean that the system is very low reliable. That is why most customers in Debre Berhan are more compile daily to Ethiopia utility. The EENS also high which tells the company losses its money by power interruption in addition to transmission, generation and distribution power losses.

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