

Research Article

Reliability Assessment of Distribution Network for Improved Feeder Bule Hora University, West Guji, Oromiya Regional State, Ethiopia

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Abstract

The knowledge of the reliability of distribution networks and systems is important consideration in the system planning and operations for development and improvements of power distribution systems. To achieve the target as minimum interruptions as possible to customers, utilities must strive to improve the reliability but at the same time reduce cost. It is a known fact that most of customer interruptions are caused by the failure in distribution system and the data and statistics were not easy to collect the reliability performance. The objective of the study was to examine the reliability distribution of networks and systems in the study area. In terms of methods, these studies used analytical methods to determine the reliability indices and effect of distribution substation configuration and network to the reliability indices performance. The key findings showed that there is always uncertainty associated with the distribution network reliability in the study area. The authors concluded that for evaluation and analysis of reliability, having data on the number and range of the examined piece of equipment, it is important to have database for failure rates, repair time and unavailability for each component in distribution network. Finally, the authors recommended that in order to improve the present status of the reliability distribution of network for improved feeder, training of workers, experts and customers strategies are very necessary. So that planners, policy makers, local communities, stakeholders and households need strong coordination to achieve the objective.

Keywords

Customers, Reliability, Network, Power, Satisfaction, Bule Hora University, Ethiopia

1. Introduction

Power distribution network system established mainly to provide adequate electricity supply to customers as economically as possible with reasonable assurance of reliability. Nowadays, the power distribution networks have grown exponentially in term of size and technology over the past few years [1]. As a result, utility company must strive to ensure that the customer's reliability requirements are met with op-

timum strategic planning and lowest possible cost. The ability of the system to provide adequate supply of electricity energy determine by the term reliability [3].

Reliability analysis of distribution network is not a new topic in electric power industries, a lot of studies and research have been carried out due to the increasing cost of blackouts and fault outages [2, 11, 12]. Over the past, distri-

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bution network system have received less attention devoted to reliability studies compared to generation and transmission system. The reasons being is the generation and transmission systems are capital intensive and the inadequacy can have widespread consequences for both society and environment [11, 15, 16]. However, a distribution system is slightly cheaper compare to the other two because its effects are localized. Analysis of the customer failure statistics of most utilities shows that distribution system makes the greatest individual contribution to the unavailability of electrical supply to customer.

It is very important to assess and evaluate the reliability of power system networks in order to obtain the most accurate and effective way in decision making especially in planning, operation, and maintenance. Historical assessment and predictive methods are normally used to evaluate the reliability of a distribution network. Most utilities focus more on historical assessment rather than predictive methods. Predictive methods are categorized into analytical and simulation methods [10, 17, 18]. Reliability assessment method for distribution system fall into two classes: simulation and analytical [10, 19, 20]. Simulation is the most flexible method but require extensive time in computational and also uncertainty in precision. Analytical method can be further divided into network modeling and Markov modeling [12].

Network modeling has been the most popular technique for distribution system reliability analysis due to the simplicity of the method and natural similarities between network model and the distribution topology [19]. The difference between simulation and analytical method is the way in which the system reliability indices are evaluated [20-22]. By applying both analytical and simulation method, the reliability indices for distribution systems will be determined such as System Average Interruption Frequency Index (SAIFI) and System Average Interruption Duration Index (SAIDI).

The probability distribution of SAIFI and SAIDI which give information about the variability of the indices also need to obtain in order to improve in decision making. However, such important issue was not studied in Bule Hora University yet. Therefore, the specific objective of this study is (i) to assess the Reliability of Distribution Network Points in Bule Hora University, West Guji Zone, Oromiya Regional State, Ethiopia.

2. Materials and Methods

2.1. Description of the Study Area

Bule Hora (formerly Hagere Mariam, older, alternative names were Alga, Kuku) is a town located in West Guji Zone, Southern Oromiya Region State, Ethiopia. The study area is paved about 469 Km from the capital Addis Ababa-Moyale highway, in the West Guji Zone of the Oromia Region. It is the largest town in this zone mainly inhabited by

the Guji communities of Oromiya Region. The study area is located between 50 11' 28" - 50 18' 20" N latitude and 37014' 00" - 37019' 00" E longitude. The study area is also bordered by Gedee Zone Administration in the North and Amaro Zone Administration in the West. The altitudes of the study area range from 100 m asl in the west to 2,500m asl in the eastern highlands, with mean annual temperature and rainfall of 12-25°C and 700-1,300ml, respectively.

The study area has a favorable climate condition which is suitable for farming and animal husbandry activities. The rainfall distribution of the study area is bimodal (from March to May and from September to November. Some of the major cereals crops grown in the study area are Maize, Barely, wheat, and teff crops. Nitosols are the most dominant soil type covering the highest proportion of the study area. According to [5] the soils in general are derived from volcanic rocks. 97% of the study population lives in rural areas and the rest 3% live in very small town centers.

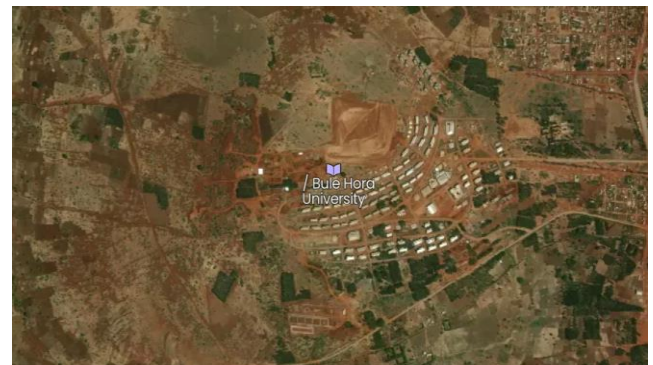


Figure 1. Areal photograph of the study area.

2.2. Design

Multistage sampling techniques were applied for the study. The targeted study Town was selected purposively due to its reliability and familiarity by the author. The researcher employed both quantitative and qualitative approaches. The quantitative data was collected from systematic random selected academic staffs respondents of Bule Hora University via questionnaire while qualitative data was collected from key informant interviews (KII) and focus group discussion (FGD) of participants of administration unit members of the university and different customers.

2.3. Source of Data

In order to meet the dedicated objectives of study, the researcher used both primary and secondary sources of data. The primary data was collected from household survey, focus group discussion, key informant interview, and personal observation. The secondary sources included documents, reports, research reports, books, published journals and newspapers were important secondary source of data.

2.4. Target Population and Sample Size Determination

Bule Hora University, the study University, has a total targeted population of 5,206 including Deans, teachers, administrative unit employees, electric power user customers including town and village resident respondents. Finally, the sample size was determined based on the formula proposed by [7] as follows

$$n = \frac{N}{1+N(e^2)}$$

$$n = \frac{5226}{1+5226(0.1)^2}$$

$$n = \frac{5226}{1+5226(0.01)}$$

$$n = \frac{5226}{53.26} = 98$$

where n = the required sample size

N = total households population

e = error limit

Therefore the complete survey of the study was administered on 98 respondents for the major data survey through questionnaire.

Table 1. List of population categories, proportion of categories and sizes of selected sample respondents.

Name of the study University	Population categories	population size of each categories	Purposively Selected sample sizes from each categories
Bule Hora University	Deans	4	1
	Academic staff (teachers)	3,141	57
	Administrative unit (employees)	2,061	30
	customers	20	10
	Total population	5,226	98

Source: Bule Hora University and Kebele offices (2023/24)

2.5. Sampling Technique

The study was used multistage sampling methods. The researcher decided to employ systematic random sampling method to select academic staff (teachers), administrative employees units and deans. Therefore, to select a total of 98 sample respondents whose name was listed in the in the university, the researcher used systematic random sampling method as follows.

$$K^{\text{th}} = N/n$$

Where

k^{th} = every respondent to be selected from the list

N = Total population (teachers and employees) in the University

n = The required sample sizes

$K^{\text{th}} = 5226/98$

$K^{\text{th}} = 53.3$ approximately = 53 Therefore, every k^{th} (starting from the 1st listed name in the University) the 98 sample survey respondents were selected from their list systematically using standard formula adopted [13]. However, random sampling method was used to select customers because it is not possible to get their name list in the university.

2.6. Data Analysis Methods

The collected data was analyzed with the help of Tables, graphs, charts, frequency distributions and percentages to give a condensed picture of the data-results. Finally, the data was analyzed using quantitatively and qualitatively and interpreted based on the conclusions and findings.

3. Results and Discussion

3.1. Socio-economic Characteristics of Sample Respondents

The average family size for each individual in the study areas was found to be 4.0. The statistical analysis result revealed that the educational background of the sampled households constituted 41%. Based on the results of the survey, about 88.33% of the study communities engaged in mixed agricultural activities. This result implies that agriculture is the primary economic backbone of the study communities.

The study area is found in West Guji zone where Bule-Hora University is located. The major crops which are grown

in the study zone include, maize, and teff crops mainly cultivated for consumption. All these are grown during the long rainy season (March to November). Beside to crop production, livestock rearing is the other secondary agricultural activity undertaken by respondents and the main livestock types that are commonly kept in the study areas which in-

clude: poultry, sheep, goat, ox, and cow. 96% of the study community's source of livelihood is mixed farming system (Figure 2). 81% of the FGD participants and 94% of the KII also realized that their main source of livelihood of the study communities is mixed farming system followed by livestock rearing and crop production (Figure 2).

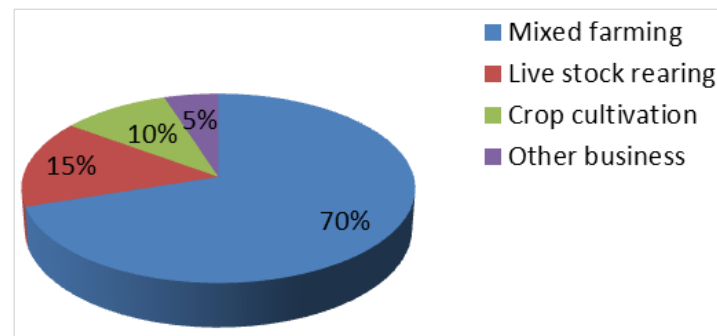


Figure 2. Major livelihood sources of the study communities.

3.2. The Concept of Distribution System Reliability

The function of an electric power system is to satisfy the system load requirement with a reasonable assurance of continuity and quality. The ability of the system to provide an

adequate supply of electrical energy is usually designated by the term reliability. The concept of power-system reliability is extremely broad and covers all aspects of the ability of the system to satisfy the customer requirements. There is a reasonable subdivision of the concern designated as system reliability which is shown in Figure 3.

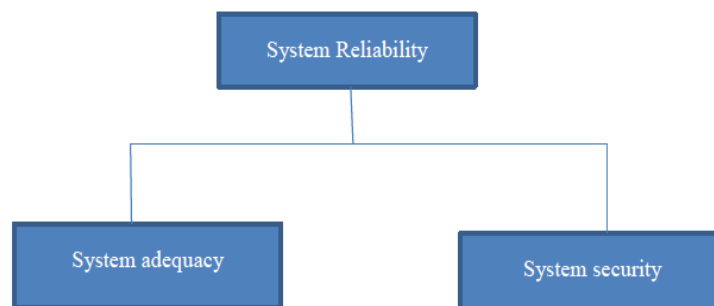


Figure 3. System Reliability Sub-divisions.

Adequacy: Relates to the existence of sufficient facilities within the system to satisfy the consumer load demand. These include

- 1) The facilities necessary to generate sufficient energy and
- 2) The associated transmission and distribution facilities required to transport the energy to the actual consumer load points.

Security: Relates to the ability of the system response to disturbances arising within that system. Security is therefore associated with the response of the system to whatever perturbations it is subject to.

3.3. Reliability Indices for Distribution System

To measure system performance, the electric utility of Bule Hora University has developed several performance measures of reliability. These reliability indices include measures of outage duration, frequency of outages, system availability, and response time.

3.3.1. The Common Distribution Reliability Indices

The most common distribution reliability indices include the System Average Interruption Duration Index (SAIDI),

Customer Average Interruption Duration Index (CAIDI), System Average Interruption Frequency Index (SAIFI), Momentary Average Interruption Frequency Index (MAIFI), Customer Average Interruption Frequency Index (CAIFI), Customers Interrupted per Interruption Index (CIII), and the Average Service Availability index (ASAI). Each of these the main indices will be discussed below one by one.

(i). System Average Interruption Frequency Index (SAIFI)

SAIFI is measure of how many sustained interruptions on average customer will experience over the course of a year. For a fixed number of customers, the only way to improve SAIFI is reduce the number of sustained interruption experienced by customers [4, 9, 14].

$$SAIFI = \frac{\text{total number of customer interruption}}{\text{total number of customer served}} = \frac{\sum \lambda_i N_i}{\sum NT}$$

Where

λ_i = number of interruptions at load point

N_i = number of customers connected to load point

NT = Total number of customers

(ii). System Average Interruption Duration Index (SAIDI)

SAIDI is a measure of how many interruption hours on average customer will experience over the course of a year. For a fixed number of customers, SAIDI can be improved by decreasing the number of interruptions or by decreasing the duration of these interruptions. Since both of these reflect reliability improvements, a reduction in SAIDI means an improvement in reliability [4, 6].

$$SAIDI = \frac{\text{sum of customer interruptions durations}}{\text{total number of customers}} = \frac{\sum \lambda_i N_i}{NT}$$

$$SAIDI = SAIFI \times CAIDI$$

Where,

λ_i = Restoration time, minutes.

N_i = Total number of customers interrupted

NT = Total number of customers

(iii). Customer Average Interruption Duration Index (CAIDI)

CAIDI is a measure of how long an average interruption lasts, and is used as a measure of utility response time to system incidents. CAIDI can be improved by decreasing the length of interruptions, but can also be decreased by increasing the number of short interruptions. As a result, a decrease in CAIDI does not necessarily mean an improvement in reliability [4, 7, 8].

$$CAIDI = \frac{\text{sum of customer interruptions durations}}{\text{total number of interruptions}} = \frac{\sum U_i N_i}{\sum \lambda_i N_i}$$

$$CAIDI = \frac{SAIDI}{SAIFI}$$

U_i = Restoration time, minutes.

N_i = Total number of customers interrupted

(iv). Customer Average Interruption Frequency Index (CAIFI)

Similar to SAIFI is CAIFI, which is the Customer Average Interruption Frequency Index. The CAIFI measures the average number of interruptions per customer interrupted per year. The CAIFI is,

$$CAIFI = \frac{\sum NO}{\sum N_i}$$

Where

NO = number of interruptions

N_i = Total number customers interrupted

(v). Customer Interrupted per Interruption Index (CIII)

Customer Interrupted per Interruption Index (CIII) gives the average number of customers interrupted during an outage. It is the reciprocal of the CAIFI and is,

$$CIII = \frac{\sum N_i}{\sum NO}$$

Where

NO = Number of interruptions

N_i = Total number of customers interrupted

(vi). Average Service Availability Index (ASAI)

The Average Service Availability Index (ASAI) is the ratio of the total number of customer hours that service was available during a given time period to the total customer hours demanded. This is sometimes called the service reliability index. The ASAI is usually calculated on either a monthly basis (730 hours) or a yearly basis (8,760 hours), but can be calculated for any time period. The ASAI is found as,

$$ASAI = \left[1 - \frac{\sum r_i * N_i}{\sum NT * T} \right] * 100$$

Where,

T = Time period under study, hours.

r_i = Restoration time, hours

N_i = Total number of customers interrupted

NT = Total number of customers served

This calculation, the restoration time, r_i , is in hours instead of minutes. Another way of looking at ASAI on an annual basis is,

$$ASAI = \left[\frac{8760 - ASIDI}{8760} \right] * 100$$

(vii). Total Energy Not Supplied (ENS)

The ENS (Total energy not supplied) is the sum of each load times its outage duration:

$$ENS = L * ri(Kwh/yr)$$

Where

L=Load (KW)

ri= Outage Duration

(viii). Average Energy Not Supplied (AENS)

AENS (Average Energy Not Supplied) can be calculated by dividing the ENS and the total number of customers:

$$AENS = \frac{\text{Total Energy not supplied}}{\text{Number of Customers}} (KWh/custoeryr)$$

Note: A customer here is defined as an electric meter, which can be an individual customer, a commercial entity or organization etc.

3.3.2. Reliability Assessment of Distribution System

Reliability assessment of a distribution system usually implicates evaluating the system's ability to consistently deliver power to customers without disturbances. This valuation

often uses various reliability indices to measure the frequency and duration of outages, as well as the accessibility of service to customers. Mutual indices include SAIFI, SAIDI, CAIDI, and ASAI. The assessment can also involve finding areas for enhancement, such as applying strategies like distributed generation or network reconfiguration.

Reliability assessment is of primary importance in designing and planning distribution systems that operate in an economical method with slight interruption of customer loads.

3.4. Calculation on February Reliability Indices for Bule Hora University

Representation of the above outage identification is as flows Institute of technology (IoT), Administration building, Techno library, Low library, Social science library, Male dormitory, Female library, Student cafeteria, Main Hale, Teaching cafeteria and Staff residential blocks.

From the above [Table 1](#), calculation of reliability indices for the specified time period, where ten outages have been recorded for the utility. The utility has a total of 45,000 customers.

Week one

Table 2. Reliability indices of Bule Hora University (1/07/20- 7/07/20, March 2020/21).

Outage identification	Number of customers	Duration (minute)	Customer-hours
1	120	0.25	0.5
2	200	0.25	0.833
3	40	0.25	0.167
4	24	0.25	0.1
5	36	0.25	0.15
6	1200	0.25	5
7	2000	0.25	8.33
8	160	0.25	0.67
9	8	0.25	0.033
10	72	0.25	0.3
All	3860		16.1

Source: Field survey result (2024)

Solution: The customer-hours are calculated for each outage and then they are summed for a total of 16.1 customer-hours or 996 customer-minutes.

$$\text{Customer- minutes} = 16.1 * 60 = 996 \text{ minutes}$$

$$SAIFI = \frac{\text{total number of customer interruption}}{\text{total number of customer served}} = \frac{\sum \lambda_i n_i}{\sum NT} = 3860/45,000 = 0.0858$$

The customer-hours are calculated for each outage and

then they are summed for a total of 16.1 customer-hours or 966.00 customer-minutes

$$SAIDI = \frac{\text{sum of customer interruptions durations}}{\text{total number of customers}} = \frac{\sum \lambda_i N_i}{NT} = 966/45000 = 0.021 \text{ min}$$

SAIDI = 0.021 * 1/60 = 0.00035 Hrs it is not reliable, because the value of SAIDI for reliable system is between 1.5 to 3 Hrs.

The customer-minutes are 996 and 3856 customers were interrupted.

$$CAIDI = \frac{966}{3860} = 0.26 \text{ Min}$$

CAIFI is evaluated as ratio between four events and 3856 customers' interrupted. It gives the average number of interruptions for a customer who was interrupted.

$$CAIFI = 10/3860 = 0.0026$$

Customer Interrupted per Interruption Index (CIII)
Gives the average number of customers interrupted during an outage. It is the reciprocal of the CAIFI and is,

$$CIII = \frac{\sum N_i}{\sum No} = \frac{3860}{10} = 386$$

Average Service Availability Index (ASAI)

$$ASAI = \left[\frac{8760 - ASIDI}{8760} \right] * 100$$

$$ASAI = \frac{8760 - 0.00035}{8760} * 100 = 99.999\%$$

Week two

Reliability indices Bule Hora University (8/06/20-14/06/20 on February 2020).

There were not any disturbance duration of interruption was zero Hours.

Week three. Reliability indices of Bule Hora University (15/06/20- 21/06/20 on February 2020).

Table 3. Reliability indices of Bule Hora University (1/07/20- 7/07/20, March 2020).

Outage identification	Number of customers	Duration (minute)	Customer-hours
1	120	15.923333	31.85
2	200	15.923333	53.1
3	40	15.923333	10.62
4	24	15.923333	17
5	36	15.923333	9.554
6	1200	15.923333	318.47
7	2000	15.923333	530.1
8	160	15.923333	42.46
9	8	15.923333	2.12
10	72	15.923333	19.11
All	3860		1034.384

Source: Field survey result (2020/21)

Solution; Customer- minutes = 1034.384 * 60 = 62,063.04

$$SAIFI = \frac{\text{total number of customer interruption}}{\text{total number of customer served}} = \frac{\sum \lambda_i N_i}{\sum NT} = 3680/45000 = 0.0856$$

The customer-hours are calculated for each outage and then they are summed for a total of 1034.384 customer-hours or 62,063.04 customer-minutes.

$$SAIDI = \frac{\text{sum of customer interruptions durations}}{\text{total number of customers}} = \frac{\sum \lambda_i N_i}{NT} = 62063/45000 = 1.38 \text{ min}$$

SAIDI = 1.38 * 1/60 = 0.023 Hrs it is *not reliable*, because the value of SAIDI for reliable system is between 1.5 to 3 Hrs.

The customer-minutes are 62063.04 and 3860 customers were interrupted.

$$CAIDI = \frac{62063.04}{3860} = 16.01 \text{ Min}$$

CAIFI is evaluated as ratio between four events and 3860 customers' interrupted. It gives the average number of interruptions for a customer who was interrupted.

$$CAIFI = 10/3860 = 0.0026$$

Customer Interrupted per Interruption Index (CIII)

Gives the average number of customers interrupted during an outage. It is the reciprocal of the CAIFI and is,

$$CIII = \frac{\sum Ni}{\sum No} = \frac{3860}{10} = 386$$

Average Service Availability Index (ASAI)

$$ASAI = \left[\frac{8760 - ASIDI}{8760} \right] * 100$$

$$ASAI = \frac{8760 - 0.023}{8760} * 100 = 99.999\%$$

Week four

Reliability indices of Bule Hora University (22/06/20-30/06/20 on February 2020).

During 22/06/20- 30/06/20 this time, there were no interruptions faced (zero Hrs duration of interruptions).

3.5. Calculation Reliability Indices for Bule Hora University (March, 2024)

Week one

Table 4. Reliability indices of Bule Hora University (1/07/20- 7/07/20, March 2020).

Outage identification	Number of customers	Duration (minute)	Customer-hours
1	120	6.36	12.72
2	200	6.36	21.2
3	40	6.36	4.24
4	24	6.36	2.544
5	36	6.36	3.816
6	1200	6.36	127.2
7	2000	6.36	212
8	160	6.36	16.96
9	8	6.36	0.848
10	72	6.36	7.632
All	3860		409.16

Source: Field survey result (2024)

Solution: Customer- minutes = 409.16 *60= 24549.6 minutes

$$SAIFI = \frac{\text{total number of customer interruption}}{\text{total number of customer served}} = \frac{\sum \lambda_i N_i}{\sum NT} = 3860/45,000 = 0.0858$$

The customer-hours are calculated for each outage and then they are summed for a total of 409.16 customer-hours or 24549.6 customer-minutes.

$$SAIDI = \frac{\text{sum of customer interruptions durations}}{\text{total number of customers}} = \frac{\sum \lambda_i N_i}{NT} = \frac{24549.6}{45000} = 0.5455 \text{ min}$$

SAIDI= 0.5455 *1/60 =0.0091 Hrs it is not reliable, because the value of SAIDI for reliable system is between 1.5 to 3 Hrs.

The customer-minutes are 24549.6 and 3860 customers were interrupted.

$$CAIDI = \frac{24549.6}{3860} = 6.36 \text{ Min}$$

CAIFI is evaluated as ratio between four events and 3860 customers' interrupted. It gives the average number of interruptions for a customer who was interrupted.

$$CAIFI = 10/3860 = 0.0026$$

Average Service Availability Index (ASAI)

Customer Interrupted per Interruption Index (CIII)
Gives the average number of customers interrupted during an outage. It is the reciprocal of the CAIFI and is,

$$CIII = \frac{\sum Ni}{\sum No} = \frac{3860}{10} = 386$$

$$ASAI = \left[\frac{8760 - ASIDI}{8760} \right] * 100$$

$$ASAI = \frac{8760 - 0.0091}{8760} * 100 = 99.999\%$$

Week two

Table 5. Reliability indices of Bule Hora University (8/07/20- 15/07/20, March 2020).

Outage identification	Number of customers	Duration (minute)	Customer-hours
1	120	1.62	3.24
2	200	1.62	5.4
3	40	1.62	1.08
4	24	1.62	0.648
5	36	1.62	0.972
6	1200	1.62	32.4
7	2000	1.62	54
8	160	1.62	4.32
9	8	1.62	0.216
10	72	1.62	1.944
All	3860		104.22

Source: Field survey result (2024)

Solution: Customer- minutes = 104.22 *60= 6253.2

$$SAIFI = \frac{\text{total number of customer interruption}}{\text{total number of customer served}} = \frac{\sum \lambda_i N_i}{\sum NT} = 3860/45,000 = 0.0858$$

The customer-hours are calculated for each outage and then they are summed for a total of 104.22 customer-hours or 6253.2 customer-minutes.

$$SAIDI = \frac{\text{sum of customer interruptions durations}}{\text{total number of customers}} = \frac{\sum \lambda_i N_i}{NT} = \frac{6253.2}{45000} = 0.139 \text{ min}$$

SAIDI=0.139 *1/60 =0.002316 Hours it is *not reliable*, because the value of SAIDI for reliable system is between 1.5 to 3 Hrs.

The customer-minutes are 996 and 3860 customers were interrupted.

$$CAIDI = \frac{6253.2}{3860} = 1.62 \text{ Min}$$

CAIFI is evaluated as ratio between four events and 3860 customers' interrupted. It gives the average number of interruptions for a customer who was interrupted.

$$CAIFI = 10/3860 = 0.0026$$

Table 6. Reliability indices of Bule Hora University (15/07/20- 21/07/20, March 2020).

Outage identification	Number of customers	Duration (minute)	Customer-hours
1	120	7.78	15.56
2	200	7.78	25.93

Outage identification	Number of customers	Duration (minute)	Customer-hours
3	40	7.78	5.1867
4	24	7.78	3.112
5	36	7.78	4.668
6	1200	7.78	155.6
7	2000	7.78	259.333
8	160	7.78	20.7467
9	8	7.78	1.0373
10	72	7.78	9.336
All	3860		500.5106

Source: Field survey result (2024)

Solution: Customer- minutes = 500.5106 *60=30030.636

$$SAIFI = \frac{\text{total number of customer interruption}}{\text{total number of customer served}} = \frac{\sum \lambda_i N_i}{\sum NT} = 3860/45,000 = 0.0858$$

The customer-hours are calculated for each outage and then they are summed for a total of 500.5106 customer-hours or 30030.636 customer-minutes.

$$SAIDI = \frac{\text{sum of customer interruptions durations}}{\text{total number of customers}} = \frac{\sum \lambda_i N_i}{NT} = \frac{30030.636}{45000} = 0.667 \text{ min}$$

SAIDI=0.667 *1/60 =0.011122458 Hours it is not reliable, because the value of SAIDI for reliable system is between 1.5 to 3 Hrs.

The customer-minutes are 30030.636 and 3860 customers were interrupted.

$$CAIDI = \frac{30030.636}{3860} = 7.78 \text{ Min}$$

CAIFI is evaluated as ratio between four events and 3860 customers' interrupted. It gives the average number of interruptions for a customer who was interrupted.

$$CAIFI = 10/3860 = 0.0026$$

Week four

Reliability indices of Bule Hora University (22/07/20-30/07/20 on March 2020). There were not any disturbance duration of interruption was zero Hours. SAIDI is calculated for each week, the monthly SAIDI is calculated by sum of the weekly values.

3.6. Observation

The following observations can be summarized from reliability analysis:

ability analysis:

- 1) Reliability indices (SAIDI, CAIDI and ENS) will not be improved if the Distribution Generation (DG) unit is installed at the distribution substation regardless of the DG size. This is because the failures in any section or distributor lateral within the circuit will not be mitigated as the DG unit will just act as an additional source to the distribution substation. However, in case of power interruptions from the main substation, the DG can be used to supply power to the system.
- 2) Reliability indices (SAIDI, CAIDI and ENS) improve as the DG is installed away from the substation and closer to the loads.
- 3) The best improvement is observed when the DG is placed at the end of the line.

4. Conclusion and Recommendation

This research paper presented the analysis of reliability with the inclusion of distribution generation. The different distribution system reliability indices such as SAIFI, SAIDI, CAIDI CAIFI, before distribution generation integration (base case) and the case when distribution generation is connected to the distribution system were compared. The result showed that by installing distribution generation with proper size and location of Bule-Hora university distribution system reliability was increased by 2 times. The other result also indicated that distribution system reliability indices depend on both the size and location of distribution generation in the distribution system which implies that reliability distribution network point is necessary for Bule-Hora University, South Ethiopia. Finally, the author recommended that both the location of distribution generation and the capacity of distribution generation must take into account to reach optimal condition in order to create the suitability and fairness for both utility and distribution generation.

Author Contributions

Kumilachew Chane is the sole author. The author read and approved the final manuscript.

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Data Availability Statement

The data used in this analysis are available with the corresponding author upon request.

Conflicts of Interest

The authors declare no conflicts of interest.

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