International Journal of Economy, Energy and Environment
2019; 4(2): 33-40
http://www.sciencepublishinggroup.com/j/ijeee
doi: 10.11648/j.ijeee.20190402.12
ISSN: 2575-5013 (Print); ISSN: 2575-5021 (Online)

Reliability Enhancement of Distribution Substation by Using Network Reconfiguration a Case Study at Debre Berhan Distribution Substation

Degarege Anteneh[1, *], Baseem Khan[1, 2]

[1]Department of Electrical & Computer Engineering Debre Berhan University, Debre Berhan, Ethiopia

[2]Department of Electrical & Computer Engineering, Hawassa University, Hawassa, Ethiopia

Email address:
dagim3763@gmail.com (D. Anteneh), baseem.khan1987@gmail.com (B. Khan)

[*]Corresponding author

To cite this article:
Degarege Anteneh, Baseem Khan. Reliability Enhancement of Distribution Substation by Using Network Reconfiguration a Case Study at Debre Berhan Distribution Substation. *International Journal of Economy, Energy and Environment*. Vol. 4, No. 2, 2019, pp. 33-40. doi: 10.11648/j.ijeee.20190402.12

Received: June 12, 2019; **Accepted**: July 17, 2019; **Published**: July 30, 2019

Abstract: Most of developing country including Ethiopia distribution systems has received considerably less of the attention to reliability modeling 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. This paper focuses on enhancement of distribution system of Debre Berhan distribution network. The reliability assessment has been done on four feeders of 15kV and 33 kV to assess the performance of the existing system and to predict the reliability analysis for the future. The interruption data of two years 2017-2018 G.C has been used as a base year. Different alternatives have been assessed using heuristic (trial and error) method and the alternative with low SAIDI, SAIFI and EENS with a reasonable cost has been preferred. The reliability of the Debre Berhan distribution system has been enhanced significantly by implementing reliability improvement solutions that are justified economically. Even if the uncertainty of the input data is taken into account, SAIFI has been reduced by 77.33% as compared with the average reliability indices values of the system in the base years. In the similar way SAIDI and EENS have been decreased by 80% and 77.77% respectively.

Keywords: Assessment of Reliability, EENS, Enhancement, Network Reconfiguration, Heuristic, SAIFI and SAIDI

1. Introduction

The primary function of electric power system is to deliver electrical energy to its customers as economically as possible with an acceptable degree of quality. Reliability of power system is one of the features of power quality [1–5]. There are two constraints i.e. Economic and reliability are competitive because increased reliability of supply generally requires increased capital investment. These two constraints are balanced in many ways from different countries and by different electric power utilities, although generally they are all based on various sets of criteria. A wide range of related measures or indicators can be determined using probability theory. A single all-purpose formula or technique does not exist. The approaches and their respective mathematical expressions depend on the defined problem and determined assumptions. Several assumptions must be made in practical applications of probability and statistical theory. The validity of the analysis is directly related to the validity of the model used to represent the system. The actual failure of distributions rarely complete fit the analytical descriptions used in the analysis, and care must be taken to ensure that significant errors are not introduced through oversimplification of a problem. The most important aspect of good modelling and analysis is to have a complete understanding of the engineering implications of the system. No amount of probability theory can circumvent this important engineering aspect.

There are two main categories of evaluation techniques [1]:

I. Analytical
II. Simulation.

Analytical techniques represent the system by a mathematical model and evaluate the measures or indicators from this model using mathematical solutions and simulation techniques estimate the measures or indicators by simulating the actual process and random behaviour of the system.

Probabilistic simulation techniques are a subset of simulation techniques that treat the problem as a series of real experiments. The input parameters of each simulated experiments are obtained using Monte Carlo selection of their values. Both categories of methods have advantages and disadvantages. The Monte Carlo simulation requires a large amount of computing time and is not used extensively if alternative analytical methods are available.

This paper out put a significant importance of measuring the existing network performance of reliability and provide reliability enhancement solutions 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

I. To indicate the influence of power interruption on the economy of customers and utility.
II. Assess average duration and frequency of power interruption per year in the system.
III. Enhancement of reliability by placement of switches and protective devices.

The following activities are done on this paper

I. Assessment of the existing network: assessment of Debre Berhan distribution system and understanding as well as adopting the system as a whole.
II. Data collection: two years (2017 & 2018 G.C) interruption data has been collected from Debre Berhan. The feeder length, number of poles, number and ratings of transformers has been collected from the existing system and the districts of Debre Berhan. The collected data has been used to clearly analyze the problems of the feeder under study.
III. System design and analysis: The distribution system is represented using single line diagram and enhancement of network topology reconfiguration with protection system has been developed.

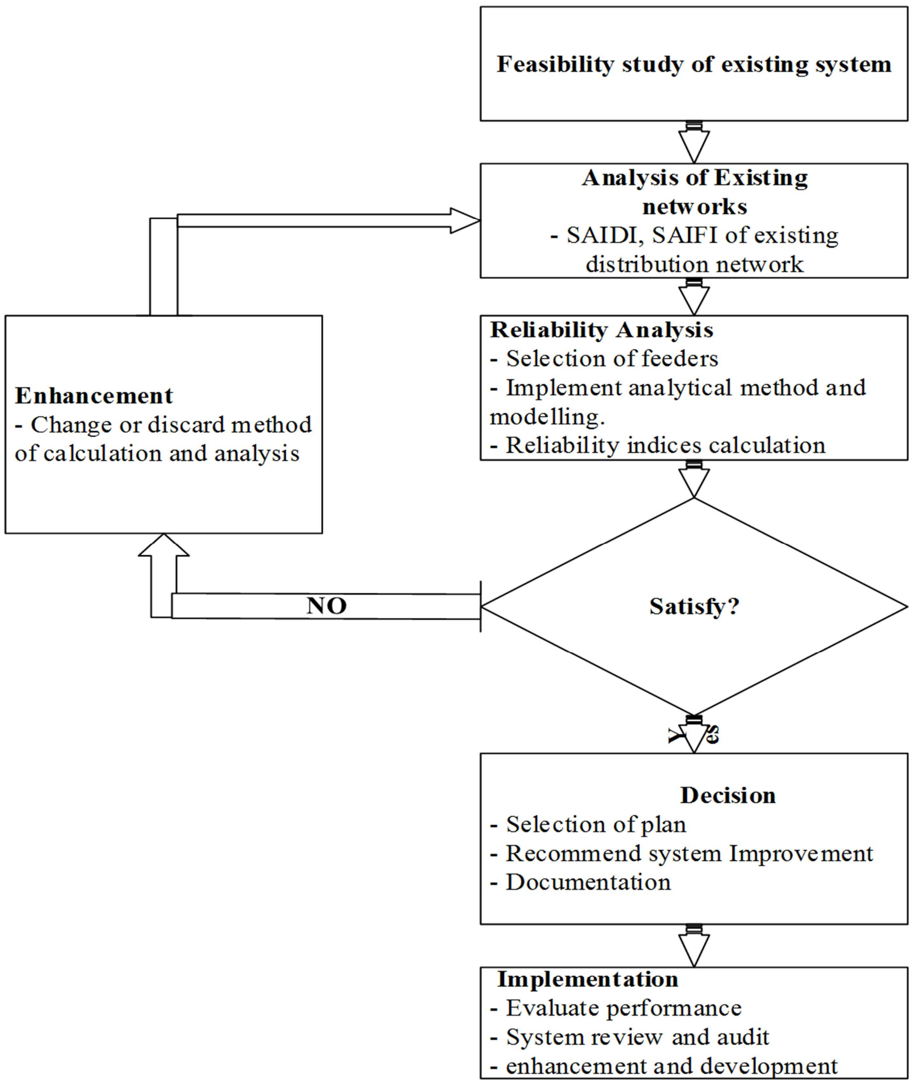

Figure 1. *Distribution network reliability enhancement of flow chart.*

Reliability indices have been calculated Debre Berhan distribution system for selected feeder and the modified systems. Based on the result of this analysis and assessment, reconfigured network with additional recloses have been evaluated for potential reliability enhancement. The system has been designed and simulated using latest Electrical software, ETAP 12.6.0.

The objective functions are to minimize SAIFI and SAIDI and minimize total cost (including customer interruption cost). The topology is achieved switches and protective devices can be installed in some of the feeders to allow for system reconfiguration.

Different techniques have been developed to determine the best topology for a distribution system. These include heuristic methods, linear programming, neural networks, expert systems, fuzzy logic, simulated annealing and genetic algorithms. The heuristic technique is the most commonly used due to produce fast results with good accuracy. Place and number of switches and protective devices are chosen by considering number of customers, feeder length, sensitivity of the area and economic benefits. The reliability indices SAIFI, SAIDI and cost benefits would be the main drivers for comparison of the alternatives using heuristic technique.

1.1. Related Works on Reliability Enhancement

Reliability assessment and enhancement of electric power distribution network has been studied by different researchers using different approaches. Some of the methodologies implied by various researches are briefly summarized below:

In [2] Leonardo Mendonça Oliveira de Queiroz has performed a research on “Assessing the overall performance of Brazilian electric distribution companies”; the concept of performance in this paper is focused on the service provided by companies. Traditional dimensions of quality of supply were considered, as well as more contemporary aspects whose consumers’ interests have grown in recent years.

Evaluating average annual unsupplied energy and system average interruption duration index (SAIDI) for a radial distribution network with arbitrary allocation of sectionalizes and tie-lines based on the genetic algorithm has been presented in [3]. The binary programming in [4] and genetic algorithm in [5] identify type and location of the protective devices on a distribution feeder based on the objective of minimizing the system average interruption frequency index (SAIFI).

In [6] Zhe Feng (2006) has applied both analytical and simulation methods to evaluate and assess reliability of distribution system and risk assessment using statistical history and reports of utilities. In addition he predicts the location of distribution generation place to minimized power interruption in distribution system. Several intelligent algorithms have been used to solve the problem of optimal placement of switches and protective devices in distribution networks [7].

In [8] Atinafu Alemu (2012) his thesis the reliability assessment of Bahir Dar city distribution system on 15 kV selected four feeders is done. Monte Carlo simulation systems and ETAP software is used to assess and simulate the overall behavior of the distribution system reliability indices. The researcher also recommend that the improvement techniques such as reconnection of the scheme and replacing old components are economical alternatives for further improvement using additional recloser, sectionalize-switches & load break switches in cost effective locations are the main alternatives.

In [9] Seema Saxena Tripta has also assessed the overall performance of Indian distribution utilities. This paper presents the measurement of technical efficiency for performance evaluation of electricity distribution utilities in India after the implementation of EA 2003.

1.2. Reliability Index

Different types of reliability indices can be done for the analysis of reliability to all electrical power parts (components) i.e. generation, transmission and distribution and comparing the reliability of different electric utility companies. Reliability indices are statistical aggregations of reliability data for a set of loads, components or customers. The reliability of the power supply is assessed using the known reliability indices. Distribution reliability needs well-defined units of measurements, which is known as metrics. The electric power utility has developed different performance measures of reliability assessment or reliability indices. Different types of reliability indices are utilized for the analysis of reliability of distribution system [1].

1.2.1. System Average Interruption Frequency Index (SAIFI)

It is tells how many sustained interruptions an average customer will experience in one year.

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

1.2.2. System Average Interruption Duration Index (SAIDI)

It is a measure of how many interruption hours an average customer will experience over the course of a year.

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

1.2.3. Customer Average Interruption Duration Index (CAIDI)

It is a measure of how long an average interruption lasts, and is used as a measure of utility response time to system contingencies.

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

1.2.4. Average Service Availability Index (ASAI)

It is the fraction of time the customer has power during the reporting time. A higher ASAI value indicts higher levels of reliability.

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

1.2.5. Customer Average Interruption Index (CAIFI)

It shows the trends in customers interrupted and used to determine the number of customers affected out of whole customer base.

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

1.2.6. Average Service Unavailability Index (ASUI)

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

1.2.7. Excepted Energy Not Supplied Index (EENS)

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

Where

Li is the average connected load at load point i

Ui is average annual outage time at load point i.

1.2.8. Average Energy Not Supplied Index (AENS)

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

2. Improving Reliability

There are many different methods of reducing long-duration interruptions such as [10]

Number of fault reduce: by tree trimming, tree wire, animal guards, arresters, circuit patrols.

Identify and repair faults faster: faulted circuit indicators, outage management system, crew staffing, better cable fault finding.

Number of customers interrupted limit: inserting (add) more fuses, reclosers etc.

Only interrupt customers for permanent faults: reclosers instead of fuses fuse saving schemes.

When we are trying to improve the reliability on one particular distribution network or trying to raise the reliability system wide, necessary steps are

I. Identify possible projects
II. Estimate the cost of each configuration or option
III. Estimate the improvement in reliability with each option
IV. Rank the projects based on a cost-benefit ratio

Techniques Used to Improve Reliability

Most methods have been developed for reconfiguration. However, not many take into account the optimal sizing of the DGs and capacitor. Reported works can be categorized into sequential and simultaneous techniques. For the former, the optimal size of the DGs needs to be determined prior to network configuration, while in the latter, optimal sizing of the DGs, capacitor and network reconfiguration are executed simultaneously. This paper reports a complete review of the currently available methodologies on network reconfiguration, DG and capacitor optimal sizing. The techniques discussed, divided into two major categories:

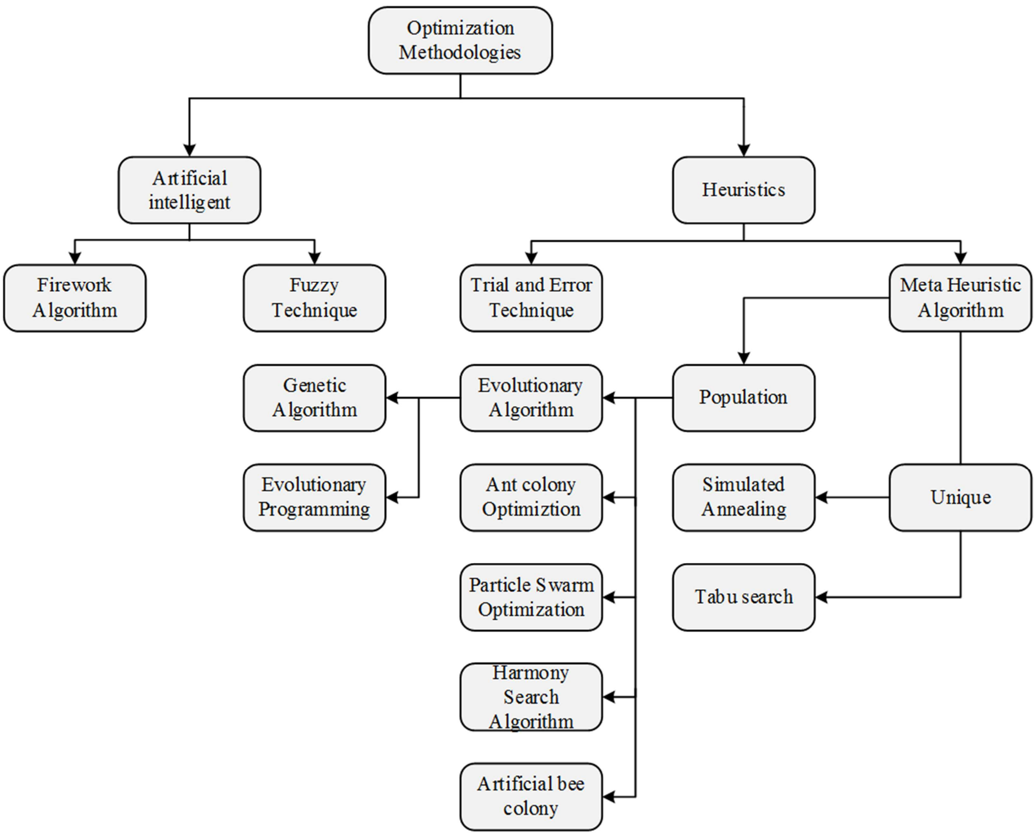

Figure 2. *Optimization methodologies of distribution network reconfiguration.*

3. Description of Debre Berhan Distribution System

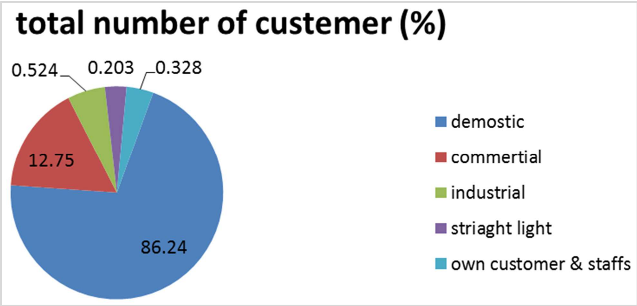

Figure 3. The energy consumption of DB distribution in 2017 and 2018 G.C.

Debre Berhan is found in Amhara region, which is the capital city of north shoa administrative zone, located at 9041°N latitude and 39031°E longitude, 130 km from Addis Ababa 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. Recently data indicts in Debre Berhan town distribution systems there are 15266 of total customers from these 1940 of them are commercial customers, 13165 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 eight (8) 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, Enway and AliuAmba and 15 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.

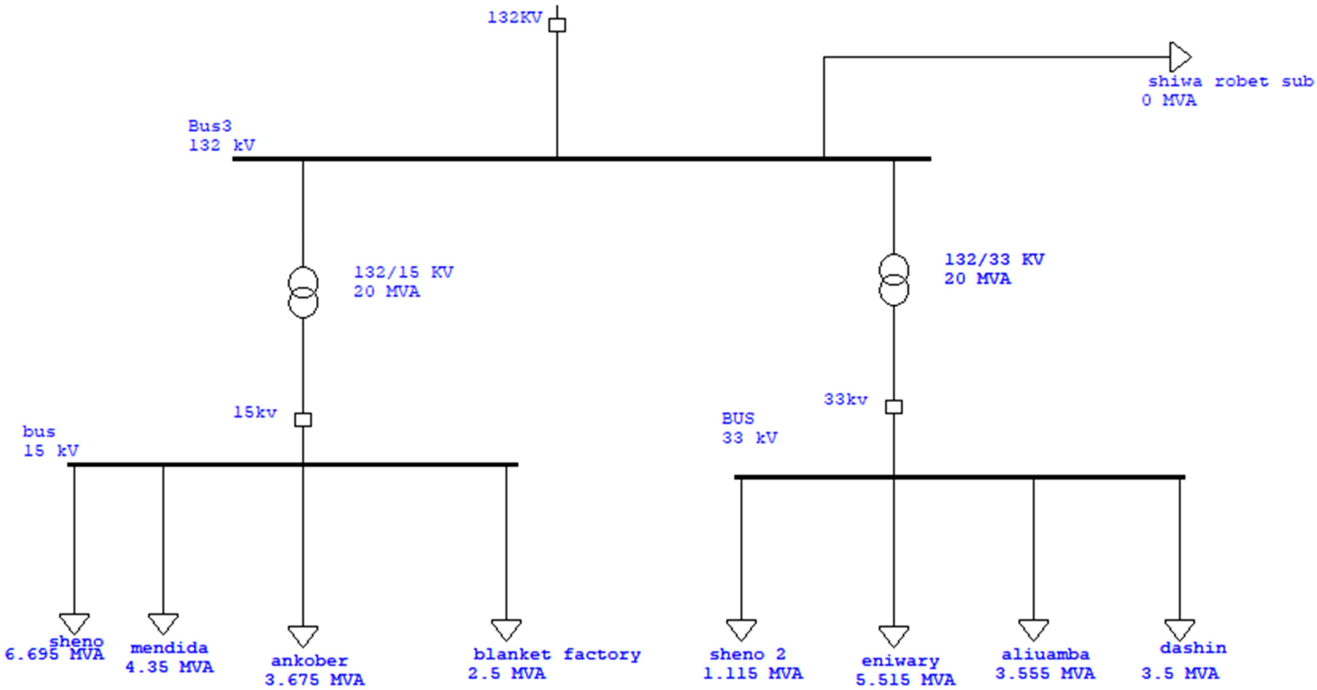

Figure 4. Single line diagram of Debre Berhan substation [1].

4. Results and Discussion

These are adequate for simple radial systems and more extended indices have to be used for general distribution systems. In this paper, the following alternatives which may enhance reliability of Debre Berhan distribution system (Sheno feeder) shall be considered:

I. Assessing of the DB distribution network
II. Change in the network configuration or reconfiguration of the distribution
III. Use of additional switches and protective devices

From the Beginning of existing system of Debre Berhan distribution design and calculating of the reliability indices in two years, this paper has evaluated different mitigation technique to enhancement of system reliability at low cost. Many cases have been analyzed by computer simulation. The simulation focuses on evaluating the effects of using reclosers and reconfiguration of the feeder on reliability of Debre Berhan distribution system. The recloser increases for utilities to implement automatic back feed restoration, fault finding and fault isolation. Automatic reclosers are designed for uses both overhead distribution lines as well as distribution substation applications for different voltage classes like 15kV, 27kV and 38kV [11].

4.1. System Modeling by ETAP

The Electrical Transient Analysis Program (ETAP) is totally graphical Enterprise package that operates on different Microsoft Windows operating systems. It is the most comprehensive analysis tool for the design and enhancement of power systems available. Figure 5 shows the project editor view, with the reliability page open. The parameters used in designing, assessment analysis and enhancement for reliability of any system are those shown on this page.

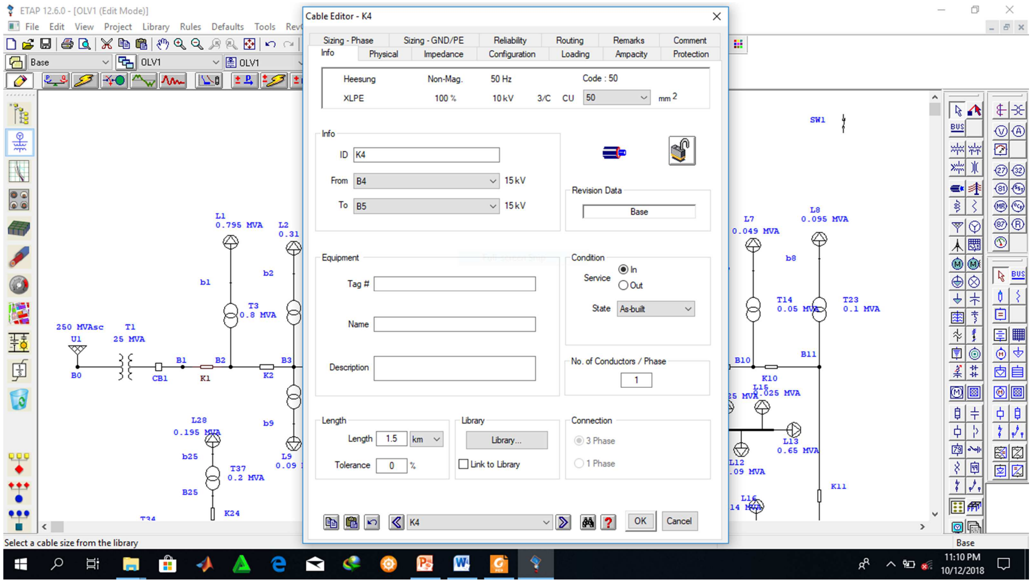

Figure 5. *Reliability assessment of existing network*

Using its standard offline simulation modules, ETAP can utilize real-time operating data for advanced monitoring, real-time simulation, optimization, energy management systems and high speed intelligent load shedding. ETAP can be combining the electrical, logical, mechanical and physical attributes of system materials in the similar database.

The simulation output of reliability analysis is obtained by performing the following steps in ETAP12.6.0 software.

I. Single line diagram of the existing system (Debre Berhan distribution at Sheno feeder) has been designed on the working plane of the software.

II. DB distribution (Sheno feeder) reliability calculations has been specified and entered.

III. All switches and protection devices has been specified based on type and operation.

IV. Then run the reliability assessment of exiting network.

Based on reliability assessment result place and number of automatic re-closers are chosen by considering

I. Number of customers of the feeder

II. Total lengths of Sheno feeder

III. Sensitivity of the area like industrial, commercial and offices

IV. Economic benefits as much as possible low cost both utility and customers

Reliability indices SAIFI, SAIDI and cost benefits would be the main drivers for comparison of the alternatives using heuristic technique.

For this paper, Nu-Lec 15kv outdoor pole mounted, automatic circuit recloser, is selected because it is available on the ETAP software library, allows protection coordination with other devices also it is applicable in the real world. Nu-Lec industries are Schneider electrics core business unit for recloser technology [12].

4.2. Simulation Results

4.2.1. Case 1: By Using One Recloser

When placing one recloser at line Ln 14 or between two buses (B14-B15) the output or the reliability indexes (SAIFI, SAIDI, ENNS…) of DB distribution had reduce. Always when we insert recloser and other protection device, we consider different factors like length of conductor, type of load, sensitivity of area and compare the reliability index value. So that, at these point when we insert one recloser and compare the existing network reliability index result as shown reduce to SAIFI 181.2946 f/cust.yer, SAIDI 370.3995 hr/cust and EENS 1967.120 MWHr/yr from the original reliability index. Line 14 select to insert recloser because of the line length is cover more part and the load are very sensitive (commercial, government office and industrial) loads are available.

4.2.2. Case 2: Using Two Reclosers

When Placing two reclosers at line 14 (B14-B15) and line20 (B21-B22) then simulate the ETAP, the output of reliability indexes more reduce from the exiting and case 1. The selection of recloser places are depends on like case 1 i.e based on sensitivity, types of loads and low values of reliability indexes. Based on case 2 the reliability indexes are reduce, SAIFI 175.7319 f/cust.yer, SAIDI 358.9016 hr/cust, EENS 1917.481 MWHr/yr and others.

4.2.3. Case 3: Using One Tie Switch and New Substation

In case-3 network reconfiguring of the feeder with the new substation and normally open tie switch has been added. The normally open tie switch separate the feeder load (based on number of customers) almost in to two equal parts, and using the tie switch paves the way to transfer the load from old substation to the new substation during outage condition. This has solved the problems related with overloads. So based on such condition the reliability indexes of the system has been reduce, SAIFI, SAIDI and EENS 108.8044f/cus.yr,205.22hr/cus.yr and 1080.683MWhr/yr respectively.

4.2.4. Case 4: Using One Tie Switch, Two Reclosers and with New Substation

Normally Sheno get electric power from two feeders (15KV and 33KV) to satisfy the customer. Feeder 33KV was under load, so by using tie switch to supply power to 15KV during fault condition and over load (peak load). The two reclosers and normally open tie switch are placed by considering length of the feeder, number of customers and location. Recloser (Rec-1) has been placed at a midpoint of old substation by considering the length and number of the customers and recloser (Rec-2) connected to the new substation side of 15KV feeder. Fieger below shows the single lie diagram at case 3. The ETAP results show below at table 1.

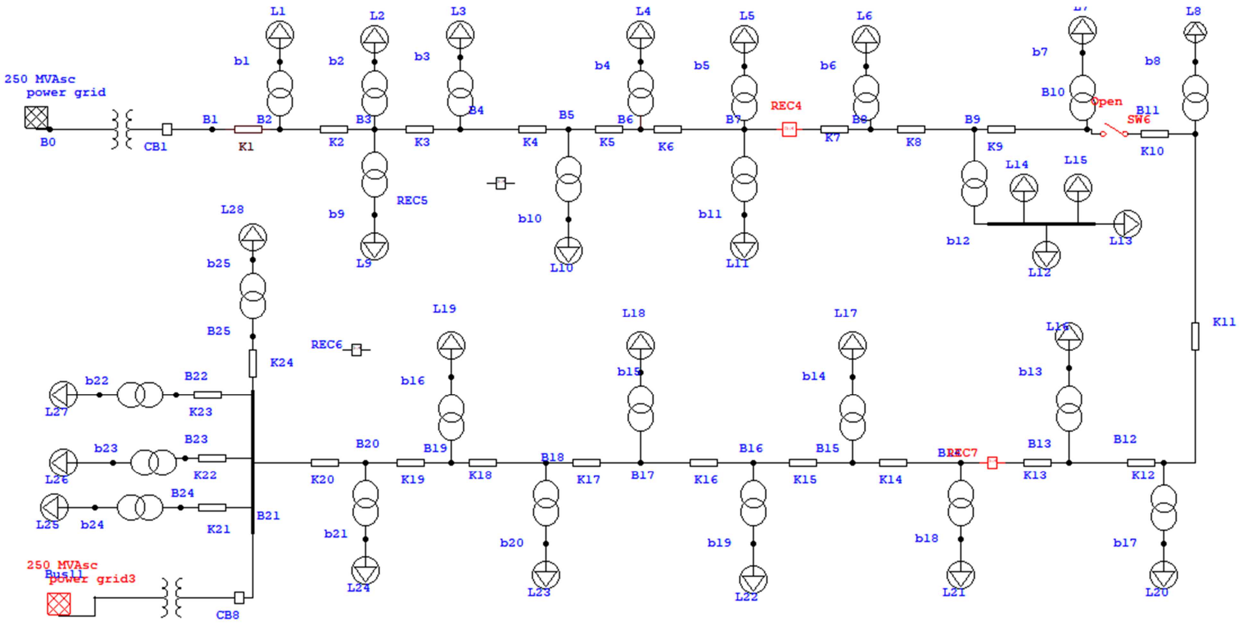

Figure 6. *Single line diagram of Sheno feeder with two recloser and tie switch.*

Table 1. *Reliability index output by placing of two recloser and tie switch.*

Reliability indexes	Simulation result
SAIFI	72.1797 f/cust.yr
SAIDI	128.0373 hr/cust.yr
CAIDI	1.774 hr/cust.inter
ASAI	0.9854 pu
ASUI	0.01462 pu
EENS	759.323 MW hr/yr
ECOST	3857615.00 $/yr

The table below shows the summary result of all cases and percentage reduction of the selected common indices with compared to the base years.

Table 2. *All case of reliability index output and the improvement of the system.*

Index's	Existing	Case 1	Case 2	Case 3	Case 4	Case 5
SAIFI	207.44	162.6989	157.658	108.8044	72.1797	47..0324
SAIDI	391.2166	308.0543	298.884	205.22	128.0373	79.1896
EENS	2053.23	1636.692	1598	1080.687	759.323	457.387
ECOST	10190840	8507866	8301463	5078767	3857765	2327708
%imp SAIFI	–	21.57	24	50.6	61.64	77.33
%imp SAIDI	–	21.257	24	50.7	69.5	80
%imp EENS	–	20.3	22.2	48.2	67.7	77.7
%imp ECOST	–	16.52	18.54	50	66.57	77.2

Based the result shown above table, case five is the best solution of Sheno feeder i.e using four reclosers and one tie switch. The total number of reclosers and tie switch place based on the total length of the feeder, sensitivity of loads and high reliability at low cost.

5. Conclusion

In this paper was conducted in one of the oldest administrative cities of Ethiopia, Debre Berhan city, which is poor electrical distribution system. The distribution network analysis and ETAP simulation study is carried out on one of the 15kV distribution feeder of Sheno to assess the performance of the present network and also the future reliability analysis to be predict. The interruption data of Sheno feeder years 2017 & 2018 G.C has been considered as a base. Based on two years interruption data of DB distribution about the causes of interruptions, it can be seen that Sheno feeder experienced highest number of interruptions and the interruptions are mainly due to overload, tree, windy rain, distribution equipment failures, scheduled outages and others. Four different alternatives or cases were outlined for enhancement the reliability of the Sheno feeder. All alternative includes a summary of the reliability indices reduction benefits and a cost effectiveness analysis, SAIFI, SAIDI and EENS of costs are used as the main comparative for evaluating of each case.

References

[1] D. Anteneh "Reliability Assessment of Distribution System Using Analytical Method: A Case Study of Debre Berhan Distribution Network" *Journal of Informatics Electrical and Electronics Engineering,* 2019.

[2] Leonardo Mendonça Oliveira de Queiroz," *Assessing the overall performance of Brazilian electric distribution companies", Washington, DC, April, 2016.*

[3] G. Levitin, S. Mazal-Tov, D. Elmakis, "*Genetic algorithm for optimal sectionalizing in radial distribution systems with alternative supply", Electric Power Syst. Res. 35 (1995).*

[4] Utkarsh Singh, *"Radial distribution system reconfiguration for loss minimization Using Exhaustive Search method", Thapar University, India, 2014.*

[5] L. G. W. da Silvs, R. A. F. Pereira, J. R. S. Mantovani, *"Allocation of protective devices in distribution circuits using nonlinear programming models and genetic algorithms", Electric Power Syst.*

[6] J.-H. Teng, C. N. Lu, *"A novel ACS-based optimum switch relocation method", IEEE Trans. Power Deliv. 18 (1) (2003) 113–120.*

[7] I. J. R. Rosado, J. A. D. Navarro, *"Possibilistic model based on fuzzy sets for the multi objective optimal planning of electric power distribution networks", IEEE Trans. Power Syst. 19 (4) (2004).*

[8] Atnafu Alemu, *"Reliability assessment of Bahir Dar town distribution system", Bahir Dar University, 2012.*

[9] Seema Saxena; Tripta Thakur, *"Performance evaluation of Indian electrical distribution utilities in the post Electricity", Int. J. of Engineering Management and Economics, 2011 Vol. 2.*

[10] Richard E. Brown, Electric Power Distribution Reliability, Second Edition.

[11] Roy Billinton and Ronald N. Allan, *"Evaluation of reliability worth," Reliability Evaluation of Power Systems, Second Edition, Plenum Press, New York, 1996.*

[12] Schneider–electric Company, (February 2017), Nulec, Available: http://www.schneider electric.co.za/ sites/…/nulec page.