ISSN 2321 3361 © 2018 IJESC

Research Article Volume 8 Issue No.12

Analysis of Cause of Power Interruption and Reliability Improvement of Distribution System (Case of Dire Dawa)

Berhanu Deggefa Lemma
Department of Electrical and Computer Engineering
Dire Dawa University, Ethiopia

Abstract:
Now a day's distribution reliability improvement becomes a major issue for supplying utility. Distribution reliability improvement method applied to distribution system based on the reason which contributed to the interruption and failure of electric supply network. In This research Dire Dawa city distribution system is used as case study and reliability level of existing system was analyzed and the main causes of distribution interruption was identified. For identification of major cause of failure and evaluation of existing system reliability ten years second data and two moth primary interruption data is used. The main cause of interruption is temporary short circuit and permanent short circuit. In addition to frequent interruption the reliability index SAIDI of each feeder is much far from Ethiopia electric utility. The Ethiopia electric utility standard for SAIDI is (25 hour/customer /year) whereas the current worst reliability level of the fourth feeder is (433.5 hour/customer/year). So the auto recloser is applied to the network to sectionalize the network to reduce the total interruption at feeder level due to the fault at one potion of circuit. ETAP 16.00 software is used to carry out simulation by vary number of recloser circuit breaker. ETAP has in built the electronic controlled recloser with used. The reliability index like SAIDI and Energy not supplied is radically reduced as number of recloser increased. When the seventy switch is installed on feeder four (SAIDI of system ≤25hr/yr./customer).

Keywords: Analysis, ETAP, Improvement, Interruption, Recloser, Reliability

I. Introduction

The basic function of an electric power system is to supply customers with electricity. The continuity of energy supply can be increased by improved system structure, increased investment during the planning phase, operating phase or both. The distribution system is an important part that provides the final links between the utility and the customers. Most distribution systems in practice have a single-circuit main feeder and are radially configured [1].The radial distribution system is widely used because of its simple design, generally low cost and supportive protection scheme. But the drawback of radially configured system is a reliability problem. For radial system the reliability in a distribution system can be improved by network reconfiguration, which is accomplished by closing normally open switches and opening normally closed switches [2].Application of distributed generation (DG) on distribution networks is also the recent developments in the electric power and it is an effective method of reliability improvement when problems arising from construction and maintenance of large power plants [3]. the reliability is not enhanced without incurring additional cost. So it is evident the reliability of distribution system has directly related cost invested on distribution system upgrading and periodical monitoring. Different country has their own reliability standard, and our country Ethiopia has also the reliability index for reliability improvement.

Due to different cases distribution reliability decreases and customers are subjected to power interruption. Electric power distribution in Dire Dawa is also not free from this problem.Even there are times that electric power interruption occurs several times a day, not only at the low voltage but also at the medium voltage distribution systems. This problem impacts societal development and individuals' life. In addition to this Dire Dawa has a hot weather condition. The mean annual temperature of Dire Dawa is about 24.6 °C.

Table 1 SAIDI and SAIFI of different country [2]

Country	SAIFI(Int./Year/ Customer)	SAIDI((Hr./Year/ Customer)
USA	1.5	4
Australia	0.9	1.2
Denmark	0.5	0.4
France	1	1.03
Germany	0.5	0.383
Italy	2.2	0.967
Netherland	0.3	0.55
Spain	2.2	1.73
UK	0.8	1.5
Ethiopia	20	25

The average maximum temperature of Dire Dawa is 30.96 °C while its average minimum temperature is about 18.3 °C which indicate that supply interruption also affect the living condition due to regular need of ventilation and refrigeration [4].

The Dire Dawa City Administration is going to draft a new master plan for the old commercial town in eastern part of Ethiopia. To meet the growing demand the city administration has to expand the city and develop basic infrastructure and public services. Dire Dawa has an industrial zone that lies on 165 hectares of land in the outskirt of the city [5]. So in this industry and trade based city the reliable power system is important. The manufacturing industries that have given due attention are agro- processing industries, textile and clothing, food and beverage industries, tannery and leather goods, pharmaceutical industries, chemicals and chemical products industries.

II. Causes of interruption in Dire Dawa

A. Fault

The main cause of interruption for Dire Dawa distribution network is the fault .out of interruption recorded for ten year around 70 % is due to fault. The fault in this network is due to different contributing factor like wind condition, tree movement during wind, insulation failure on overhead line, and protection equipment failure. The fault can be reduced tree trimming, constant monitoring of insulation, cable replacements can reduce faults. Temporary faults are harder to point.

B. Storms and Weather

Utility's performance during storms does not necessarily represent the true performance of the distribution system. But the source of temporary short circuit is the windy condition which happen especially during rainy season. From short circuit condition happen on Dire Dawa network half of the problem is temporary short circuit. This occur due to instant phase contact due to windy air and sometime sudden contact of three with phase which create temporary earth fault.

C. Circuit Exposure and Load Density

Longer circuits lead to more interruptions. Dire Dawa distribution system consist of only six radial arranged feeder which covers several kilometer distance. Even in one radial system above one hundred transformer were installed with only one auto recloser at the initial of feeder. Due to this issue the number of interruption and duration increased. Especially for permanent short circuit the problem become head ache since they use isolator for later section they check each isolator to identify the location of fault.

D. Supply Configuration

The distribution supply greatly impacts reliability. Long radial circuits provide the poorest service. A distribution system can be reconfigured by changing the location of the normally open switches, effectively changing the allocation of the customers and the flow of power for the effective feeders. But Dire Dawa network is not mesh or ring so that it is no option to get power the main feeder is interrupted.

III. Reliability improvement strategy

The solution to problem due to different source of interruption varies according to their case. Depend on the case, different solution strategy like DG, lateral fuse, sectionalizing switch, network reconfiguration and a single phase protective device can be applied [6]. According the work of Ashish Ranjan, J N Ra [7] The percentage of system faults in a distribution network is more compared than that in other parts of a power grid system. The reduction of momentary and sustained outages reacting more quickly to system disturbances can be achieved by protection schemes and leading-edge equipment, such as modern remote-controlled switches, breakers, re-closers, and fault indicators. Accorded to this work the outer point out by partitioning the circuit using recloser it is possible to reduce the reliability problem. According to Tesfaye Gebreegziabher [8] Improvement of Power Distribution System Reliability, case study carried out on Addis Ababa District, by implementing smart re-closer breaker by increasing sectionalizing switch, reliability of distribution system can be increased. According the work of S. Chandrasekhar Reddy, P.V.N. Prasad and A.Jaya Laxmi [9] by optimal placement of DG units on the buses of distribution network at minimum power loss and the amount of power to be generated by these units, reliability and the quality of power of the system can be increased. According to this work initial step for identification of optimal locations of DGs is computation of power flow between the buses.

IV. Procedure followed

a) Interruption information collection

For Identify root cause of interruption, and analyze the current level of system reliability index, the interruption duration and causes of interruptions were collected.

Table 2 Feeder Interruption Frequency of Ten Years

Feeder	TSC	PSC	OL	CB/Fuse	E.F	ICSI	OI	Total
F1	395	242	3	8	19	35	442	1144
F2	270	184	0	2	45	120	198	819
F3	365	217	9	5	201	40	222	1059
F4	404	261	0	5	76	25	414	1185
F5	268	170	0	0	57	162	255	912
F6	14	15	0	0	3	15	4	51

Table 3 Feeder's Interruption Primary Data

month	Name	TSC	PSC	OI	E.F	CF	No int	Int. hr.
July	F1	13	6	8	11	0	38	5:59:0
	F2	1	7	11	13	2	34	10:9:0
	F3	18	19	17	33	1	88	49:36:0
	F4	10	6	15	40	6	77	25:51:0
	F5	13	2	7	21	3	46	26:46:0
	F6	1	0	0	2	1	4	4:12:00
Aug	F1	18	14	5	9	0	46	28:51:0
	F2	0	3	4	4	0	11	11:02:0
	F3	6	4	2	11	0	23	20:59:0
	F4	8	4	8	18	0	38	46:42:0
	F5	16	6	5	7	0	34	12:15:0
	F6	0	1	0	1	0	2	22:01:0

Summary of two months interruption Data			
Feeder name	Int. Frequency	Customer	hour
F1	84	Total	34:10:0
F2	45	Total	21:11:0
F3	111	Total	70:35:0
F4	115	Total	72:33:0
F5	80	Total	39:01:0
F6	6	Total	26:13:0

$$SAIFI = \frac{\sum_{i=1}^{n} N_i}{NT} \quad (1)$$

$$SAIDI = \frac{\sum_{i=1}^{n} r_i N_i}{NT} \quad (2)$$

Using the above formula and data the reliability index for each feeder is calucated.

Figure 1 Reliability of Each Feeder

Reliability index indicated in a table one the both SAIFI and SAIDI obtained from analysis is greater than required value. But the reason for interruption is mostly occurred due to temporary short circuit and permanent fault.

b) *Reliability analysis*

The usual method of evaluating the reliability indices is an analytical approach based on failure modes assessment and the use of equations for series and parallel networks. The parameter required for reliability index calculation in analytical approach are the expected failure rate (λ), the average outage time (r), and the expected annual outage time (U) [10]. Commonly used customer reliability indices are system average interruption frequency index (SAIFI), system average interruption duration index (SAIDI), customer average interruption duration index (CAIDI), average system availability index (ASAI) and expected energy not supplied index (EENS) [11].

$$CAIDI = \frac{SAIDI}{SAIFI} \quad (3)$$

$$ASAI = \frac{hourserved}{hourdemanded} \quad (4)$$

$$EENS = \sum_{i=1}^{n} r_i l_i \quad (5)$$

c) *Formulation of objective function*

The objective function of this research is focus on how to improve reliability at reasonable cost. The method employed or strategy for reliability improvement depend on causes of interruption. From interruption data over load has no much contribution for power interruption. Hence addition of electrical power is not required. Most the times the distribution system is a radial system for economic point of view. Dire Dawa distribution system is also among radial system topology. Hence the power flow is in one direction only. In radial distribution system if supply system is affected at input feeder level all customer will affected. The way to reduce the interruption frequency and duration is by sectionalizing lateral and line by number of switch so that a faulted part can be isolated without affecting other part. But when doing this cost of installation should optimum. The function is to minimization of a cost of installation and while the reliability requirement should within standard.

$$obj = \max\left(\frac{Mwhrsaved}{peryear} * t * \frac{\cos tofenergy}{Mwhr} * -n * \cos tofoneswitch\right)$$

$$\left\{\begin{array}{l} n \le 15kvlateral \\ t \le lifespanofswitch \le 10 \\ SAIDI(n) \le 25 \\ SAIFI(n) \le 20 \end{array}\right\}$$

Where t is life span of switch and n is number of switch.

d) Proposed method

An analytical algorithm is used to obtain reliability indices of mixed radial and meshed distribution systems. This algorithm basically uses the algorithm for radial distribution systems since the meshed network, if any, is first converted to a radial network. Therefore, the employed algorithm is quite efficient and suitable for large-scale distribution systems of general configurations. For simulation purpose ETAP 16.00 is used. ETAP generates crystal output reports showing the system input data, reliability indices results, element ranking information, and tabulation of the results. Some of these results can also be viewed directly from the one-line diagram using the Distribution System Reliability Display Options Editor.

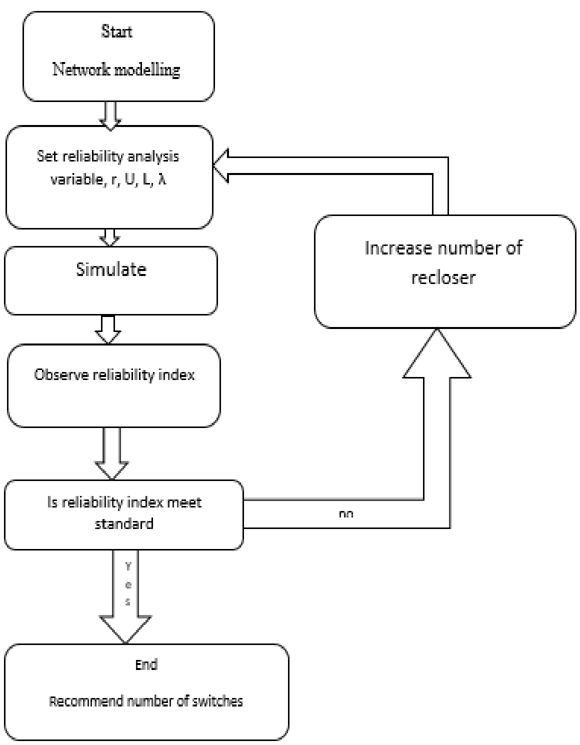

Figure 2 Step Employed In Simulation

ETAP has inbuilt equivalent components to model a circuit. To run the simulation on EATP the load is modelled as lumped load at power factor of 0.85. While transmission line, transformer and others components were modelled according to IEEE st483-1990. All transformer were modeled as oil filled transformer.

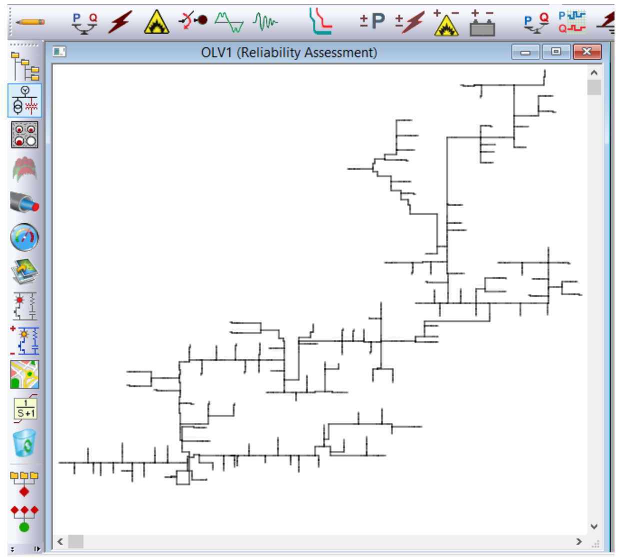

Figure 3 Circuit Diagram of Feeder F4 in ETAP

First the simulation is performed without insertion of recloser circuit breaker and the customer based reliability index is measured. So the reliability index like SAIDI and EENS is recorded. The SAIDI calculated from data is 433 while the simulation result indicate 433.9 which is almost the same. Again by dividing circuit into equivalent portion and inserting recloser between divided circuit the reliability index and energy not supplied is observed. When the recloser is placed the reliability index like SAIDI and EENS is radically reduced.

Table 4 Simulation Result

No of switch	SAIDI hr./cr/yr.	ASAI	EENS MW.hr/yr.	Saved MW.hr/yr.	SAIFI (f/cr.yr.)
0	433.9	0.950	8631.259	0	7.044
2	244.63	0.972	4745.577	3885.682	4.090
4	227.04	0.974	4483.89	4147.369	3.77
6	208.83	0.976	4118.215	4513.044	3.48
7	202.08	0.977	3889.031	4742.00	3.35

Both SAIDI and EENS decrease when number of recloser increased and size of network isolate from total circuit is reduced. But the rate by which SAIDI and EENS drop when number of recloser increases decline as the number of recloser rise. So when number switch should increase to only some reasonable level (where the reliability index required is meet). So advantage or economic benefit obtained also ceases as a number of recloser rise and at some level the gain will be null.

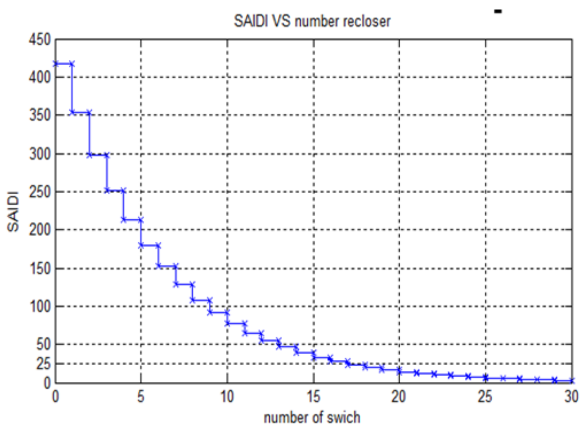

Figure 4 SAIDI VS number of recloser

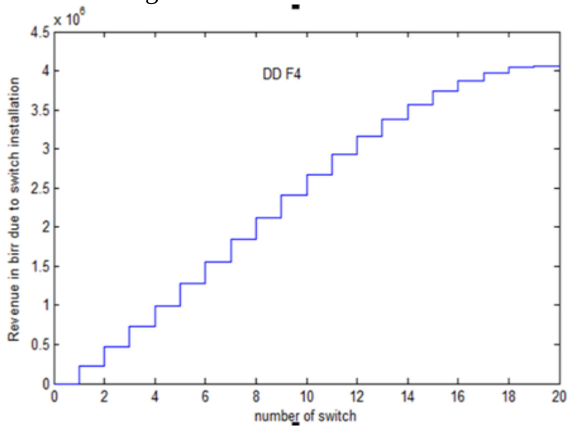

Figure 5 Revenue Obtained Vs No of Recloser

But it is know there is money incurred when reliability is improved by installing the auto recloser breaker in distribution system. In addition to the reliability index improvement the money invested on purchasing and installing recloser should returned as the income from reduction in EENS. The cost of 15 KV recloser is tabulated in table 5.

Table 5 Auto Recloser Cost [12

Breaker	Cost
Outdoor Pole Mounted 400A 630A 15KV Vacuum	US $1,300
ANSI auto vacuum circuit breaker 15kv recloser	US $7,000
High voltage 15kv recloser circuit breaker vacuum	US $5,000
Hot Sale 15kv recloser	US $750
15kv pole mounting Automatic circuit recloser	US $2,000
Sun young brand 15kv pole mounted	US $1,000
ZW32 630A 15kv Vacuum auto recloser	US $1,000

The minimum cost of recloser is 1000$, which is approximately 28000 birr. So the total cost incurred for n numbers of recloser is (28000*n) birr. But this cost is returned as revenue collected from reduction in energy not supplied throughout the recloser life time (which is ten year). Form the simulation performed using ETAP the energy not supplied is reduced. From this energy the money incurred will be collected as energy sold. The reduction in energy not supplied is represented by polynomial of degree four using least error square method and ($energysavedinMwhr = -11n^4 + 210n^3 - 1403.9n^2 + 3998.6n$). But according [2] the cost of electricity for 15 Kv industry during Peak hour is 0.7426 birr/Kwhr, while off peak hour cost is 0.5354 birr/Kwhr and cost of electricity for residential and commercial purpose is 0.6943birr/Kwhr. The average cost is 0.6574birr/Kwhr. The revenue collected as energy sold is obtained by multiplying energy with cost of energy and number of year to obtain total benefit throughout the recloser life time.

Which means $((-11n^4 + 210n^3 - 1403.9n^2 + 3998.6n) * t * 654.4)$ birr where t is the year from where recloser is installed. Hence the net benefit obtained is the difference between installation cost and revenue obtained from energy sold. Therefore total net saved money in ten years that would obtained from when number of switch installed given by equation below.

$$((-11n^4 + 210n^3 - 1403.9n^2 + 3998.6n) * 10 * 654.4) * -28000 * n \, .$$

If the distribution system reliability continues with current situation for next ten years the company will loss around (8631.259*10*657.4= 56.74 million birr).

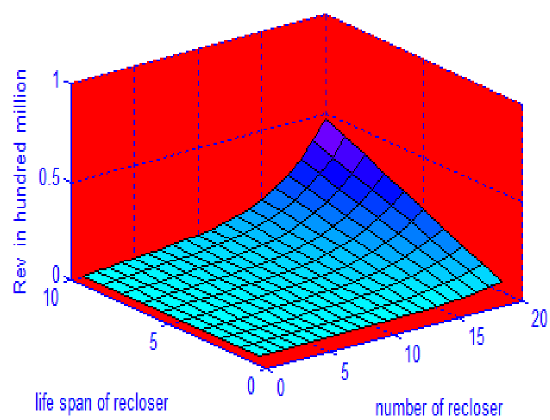

Figure 6 Benefit Obtained when Recloser is used on F4

V. Conclusion

In this research the auto-recloser is proposed as solution and tested using ETAP software. The simulation result indicated that it is high recommendable to sectionalize the radial system by using autorecloser breaker to isolate a repeatedly affected section so that the total system does not interrupted due to problem that occur in an isolated section and .addition the system reliability is improved as switch increased.

VI. Reference

[1] T. Gonnen, ”electrical power distribution engineering, california: Taylor & francis group, 2006.

[2] Study of distributed generation in improving power system reliability (Case study: Addis Center Substation), 2016.

[3] D. M. M. D. Dr. Mahdi Mozaffari Legha, "Loss Reduction and Reliability Improvement with Optimization of DGs Placement," International Journal of Scientific & Engineering Research,, vol. Volume 5, no. Issue 2, pp. 1206-1211, 2014.

[4] "https://en.wikipedia.org/wiki/Dire_Dawa," [Online].

[5] K. Bekele, "thereporter," 7 april 2018. [Online]. Available: https://www.thereporterethiopia.com. [Accessed 24 june 2o18].

[6] T. Short, ElECTRIC POWER DISTRIBUTION HAND BOOK, Boca Raton London New York Washington, D.C.: CRC Press LLC, 2004 .

[7] J. N. R. Ashish Ranjan, "Optimal Switch Placement in Radial Distribution using GA and PSO," International Journal of Scientific & Engineering Research, vol. Volume 5, no. Issue 5, pp. 1356-1361, 2014.

[8] Study on Smart Grid System for Improvement of Power Distribution ,Addis Ababa District,, 2014.

[9] Reliability Improvement ofDistribution System by Optimal Placement of Distributed Generator Using Genetic.

[10] T. Gonen, electric power distribution system engineering, california : Taylor & francis gropu, 2008.

[11] L. L. Grigsby, Electric Power Engineering Handbook, California: Taylor & Francis Group, LLC , 2007 .

[12] "alibaba," 24 september 2018. [Online]. Available: https://www.alibaba.com/showroom/33kv-auto-recloser.html. [Accessed 24 september 2018].