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Reliability Improvement of Power Distribution System using Auto recloser Case Study: Bedele Power Distribution System

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ABSTRACT*:* in this paper, the specific protection device for Reliability Improvement options has been identified for this case study.Reliability performance of existing distribution network with and without protection devices has been evaluated. The economic impact of power interruption to utility and Brewery Factory estimated. The collected interruption data analyzed and reliability of existing power distribution system is assessed. Power distribution system with protection device along the feeder evaluated using ETAP software. Comparing scenarios using reliability performance and protection coordination simplicity best scenario is selected. The simulation of the power distribution models shows that the application of reclosers can improve the reliability of the overall system from 47% to 83%. The study will be useful for power distribution system planners, load forecasting and decision makers since it presents a concern on how much demand is available at each section of power distribution system and reliability performance of each section can beevaluated easily. By minimizing unsold electrical energy EEU will benefits the corporation to earn more profit.

KEYWORDS*:* Reliability, power distribution system, Reclosers, Reliability indices, TCC curve, ETAP etc.

I. Introduction

Distribution utilities have a number of options available to improve the reliability of supply. These are: additional primary substations, additional feeder circuits, vegetation management using covered conductor, using underground circuits, feeder automation. Reliability gains can also made by increasing the protection capabilities. In this case study, the power distribution system is over head radial network and there is no any protection device used along the line. The following is existing network topology of Bedele city and Bedele Brewery factory feeder line drawing.

Due to their reclosing capability and most faults in this case study is temporary in nature,reclosers are selected to improve reliability of this power distribution system. There are two types of recloser currently in use. These are hydraulic and electronic reclosers. Electronic recloser is latest and has longer reclosing time. Unlike Hydraulic recloses, Min Trip is independent of the Reclosers continuous rating. Typical Reclosing intervals are 2, 5, and 15 seconds which is better than that of hydraulic reclosers. The minimum TCC Curve Separation between electronic reclosers must be greater than or equal to 0.30 second while between relay and electronic recloser is 0.25 second.

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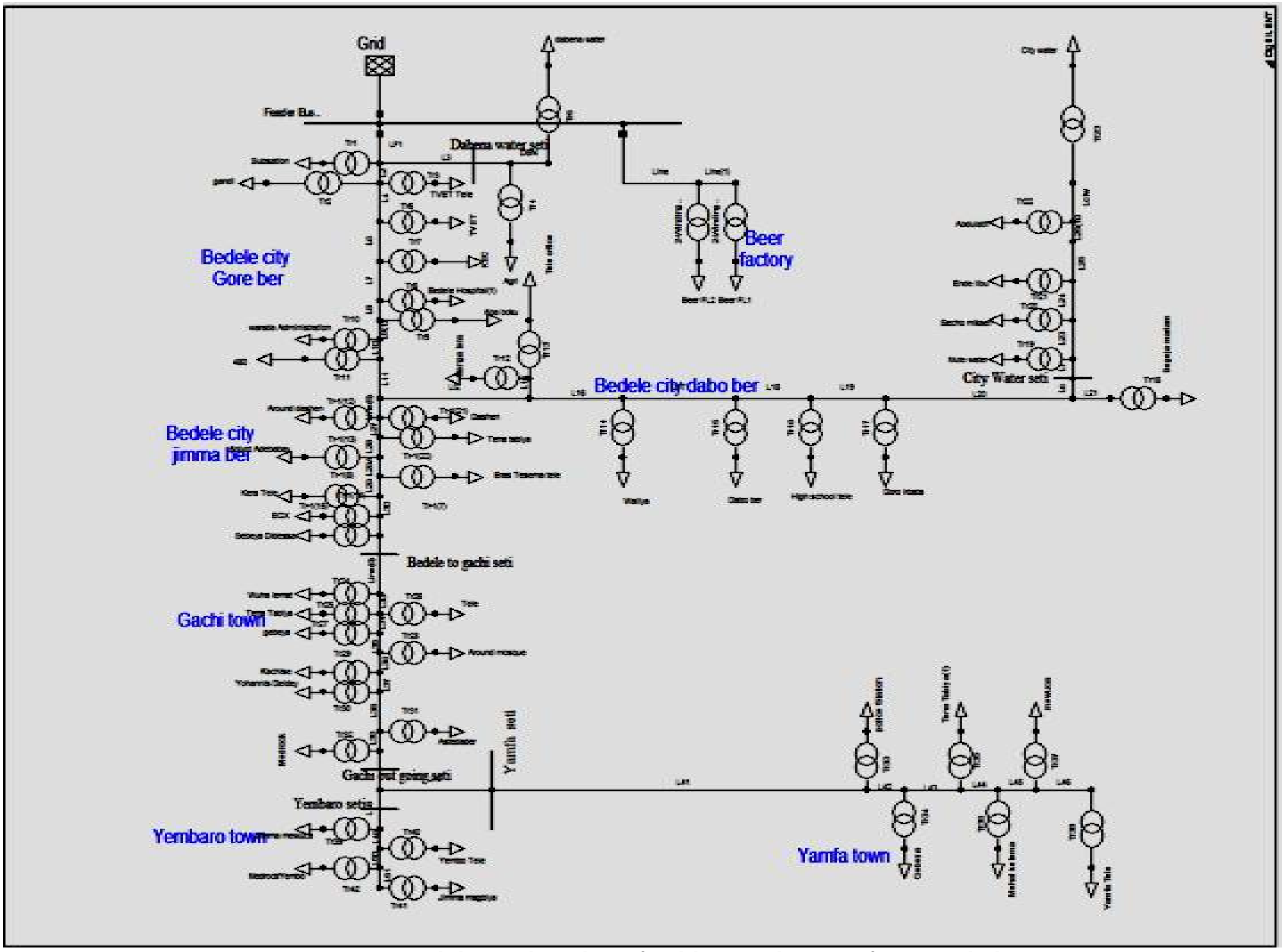

Figure 1: Existing Radial network topology of Bedele city and Brewery factory Feeder line

II. RELATED WORK

In this paper, different literatures related to reliability of power distribution system are referred. Then necessary data are gathered from concerned organizations. The collected data analyzed and reliability of existing power distribution system is assessed. Power distribution system with protection device placed along the feeder evaluated using ETAP software. Scenarios compared using payback period, reliability performance and protection coordination simplicity. Therefore, using necessary collected data this paper has been conducted.

The protection device, recloser, is placed depending on technical limitation of protection devices (coordination time interval limit), location of load or customers (beginning of branches or sections and end of sections are best candidate for placing) and load types (sensitivity of load for interruption) are considered.

Interruption data that causes of interruptions are identified by Relay type and number trial of Circuit breaker to re-energize outgoing line are collected from Ethiopian Electric power. These are: distribution transient earth fault (DTEF), distribution permanent earth fault (DPEF), distribution transient short circuit (DTSC), Distribution permanent short circuit (DPSC) and operational plan (OP). In Bedele substation there are two analogue relay that send command to Line circuit breakers. These are over current and earth fault relay.

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Table 1: The interruption duration [Hrs.] of both feeders for each fault types per year

Name of feeder	Year	Types of fault and their interruption duration per year				
		DPEF	DPSC	DTEF	DTSC	OP
Bedele Beer Factory	2014/15	27.28	81.32	3	17.32	13.7
Bedele Beer Factory	2015/16	272.2	152.6	8.32	55.03	9.15
Bedele city	2014/15	154	338.85	49.21	56.23	46.28
Bedele city	2015/16	18.55	207.45	11.25	460.08	76.9

From table 1 in 2014/15 and 2015/16Bedele brewery factory line face higher interruption duration for fault causes of DPSC and DPEF respectively. And Bedele city line faces higher interruption duration for fault causes of DPSC and DTSC in 2014/15 and 2015/16 respectively

As shown in Table 2 Bedele brewery factory line faces higher interruption frequency for fault causes of DTSC for both years. Similarly, Bedele city line faces higher interruption frequency for fault causes of DTSC in each year. This shows that most faults are transient.

Table 2: Frequency of interruption of both lines for each fault types per year

Name feeder	Year	Types of fault and their interruption frequency per year				
		DPEF	DPSC	DTEF	DTSC	OP
Bedele Beer Factory	2014 /15	22	67	4	72	7
Bedele Beer Factory	2015/16	55	68	20	218	11
Bedele city	2014/15	86	172	24	229	16
Bedele city	2015/16	10	296	5	354	42

III. RESULT AND DISCUSSION

A. Segmentation of feeder line using reclosers

The reliability indices which are evaluated using the active failure rate in number of failures per year per unit lengthand mean time to Repair of the power distribution system as input using ETAP.When the number of segments is increased by using additional reclosers, the reliability of the system will be improved more. Therefore, according to above different distribution system with different number of reclosers, when the numbers of sections are three (3) and two (2) reclosers, the reliability improvement is 47% (for SAIFI and SAIDI) and 65% for EENS. And also, when the numbers of sections are four (4) and three reclosers (3), the reliability indices will be improved by 66% (for SAIFI and SAIDI) and 72% for EENS.

Similarly, when the numbers of segments are five (5) and 4 reclosers used the reliability is improved by 69% (for SAIFI and SAIDI) and 74% for EENS. The last segmentation model shows that radial feeder of Bedele city segmented into six (6) section using five (5) Reclosers, the reliability indices will be improved by 72% (SAIFI and SAIDI) and 75% for EENS. So, this shows that further segmentation of radial feeder using protection device improve reliability of the distribution system.

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Table 3: Basic system and load reliability indices value for each segmented cases

Cases	No of segment	Number of recloser	Reliability Indices		
			SAIFI	SAIDI	ENS(MWh)
1	1	0	617	710	923
2	3	2	328	378	323
3	4	3	212	243	255
4	6	4	194	223	240
5	7	5	174	200	228

B.Auto restoration with open tie recloser

Another distribution line in Bedele city is Bedele brewery factory line which is 1.5 Km long.The line segmentation is used to minimize the number of customers affected and minimize the time required to patrol the line and locate the fault.Segmentation of

this feeder doesn't improve customer hour interruptions along the feeder since it is short line and supply only one customer. So, to improve reliability of this feeder reducing the factors of reliability problem is main solution.In order to reduce investment cost and protection coordination problem auto Sectionalizer can be used at gore ber and on Brewery factory line near to factory instead of recloser since both have same reliability improvement contribution here.

Table 4: Basic system and load Reliability indices value for each auto restoration cases

Cases	Number of Section	Number of Reclosers	Number of Automatic Sectionalizers	SAIFI	SAIDI	ENS (Mwh)
Existing	1	0	0	617	710	1115
A	4	3	1	326	322	272
B	5	4	2	214	193	203
C	6	5	2	197	173	188
D	6	5	2	200	176	196

As shown in above table 3, reliability indices changed radically from existing case to case A model. Again there is significant improvement from case A to case B on all indices. But, from case B to case C there is less improvement comparing to improvement from case A to case B. without increasing number of recloser, but with different placement, Case C and D has almost same reliability improvement. In case C, there are more than three reclosers in series which is not possible.

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C Payback period

Using Ethiopian Electric Utility Tariff and international cost of recloser, pay period of each network model is calculated.

.The investment cost can be calculated by using the cost of total smart reclosers used to design the system. Average cost of one Smart Recloser is $9,000 (USD) (Based on the currency exchange on May 20, 2016, $1 = 21.85 Birr) [23]. Hence, the cost of one Smart Recloser is: 9,000*21.45 = 193,050 Birr. And the cost of one auto Sectionalizer is $3,000(USD) (based on the currency exchange on May 20, 2016, (1$ = 21.485). So, price of one Sectionalizer is 64,350 Birr.

Table 5: Summary of estimated payback period for the feeder segmentation cases

Case	Total Reclosers	Total cost of recloser(birr)	ENS (Mwah)	Saving (birr/year)	Payback period(year)
1	-	-	923	0	-
2	2	393,300	452.27	290,190	1.35
3	3	589,950	295.36	323,307.95	1.82
4	4	786,600	258.44	330332.95	2.38
5	5	983,250	235.365	336,136.75	2.96

From above table payback period varies from 1.35 to 2.96 year in these models. This shows that as reliability of the power distribution system improved, the investment cost will increase.

But, since case 2 and case 3 have less improved reliability indices these models will not be recommended for implementation.

Table 6: Summary of estimated payback period for auto restoration cases

Case	Number of recloser	Number of Sectionalizer	Total cost of protection device (birr)	ENS (Mwah)	Saving (birr/year)	Payback period(year)
1	-	-	-	1115	0	-
A	3	1	655,500	468.3	448,161.75	1.46
B	4	2	917,700	282	481,533.6	1.91
C	5	2	1,114,350	236.8	488,788.35	2.28
D	5	2	1,114,350	242	484,919.15	2.3

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From above table payback period varies from 1.4 to 2.3 year in these models. Since there is no long time payback period all payback period are tolerable. Since case A and case B have less improved reliability indices these models will not be recommended for implementation. So, case D is best option compared to another options.

D. Protection coordination for Case D

Protection coordination is done for case D model using ETAP star. Star is a fully integrated system protective device coordination and selectivity module within ETAP. Star enables power engineers to easily and efficiently perform protective device coordination studies. Electronically controlled units are simply coordinated with manufacturer's time-current curves. Thus, for phase and ground fault protection, proper coordination is done using ETAP. Here, outgoing lines controlling relay setting is used as reference.

These base values are 1 sec for phase trip and 0.75sec for earth trip for Bedele city setting. While both phase and earth fault tripping time for Bedele Brewery factory is 1 sec. Using minimum 0.3 sec for recloser-recloser TCC curve separation and minimum of 0.25 sec for relay-recloser curve separation protection coordination is done for these new models.

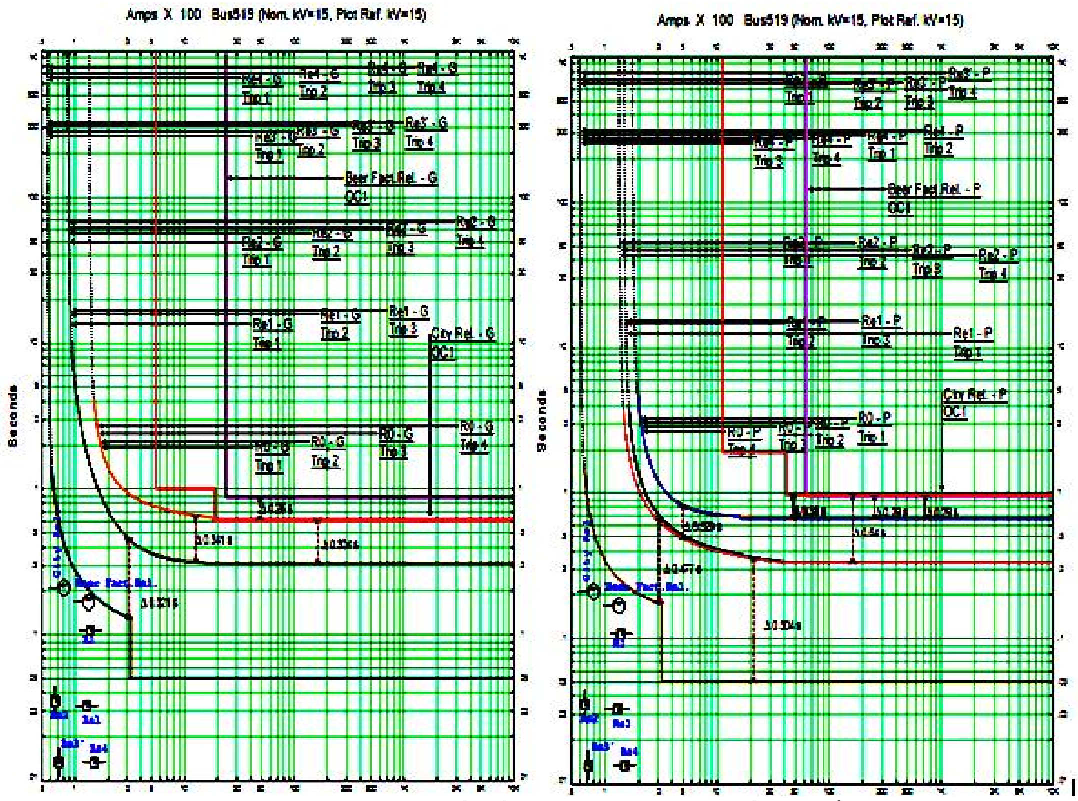

Figure 2: TCC curve that shows correct protection coordination of case D

In model D available protection devices are City Relay (City Rel), Recloser 1(Re1), Recloser 2(Re2), Recloser3 (Re3'), Recloser4(Re4), Recloser0(R0) and Beer factory relay (Beer fact.Rel). For this model proper protection coordination can be done properly as above. Here, there are enough time margins between series protection device. With minimum of 0.3sec TCC curve separation for electronic recloser and minimum of 0.25 sec for Relay to recloser TCC curve separation.

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IV. CONCLUSION

Based on the results of this research work, the reliability of the Bedele city power distribution system does not meet the requirements set by the regulatory body that is, Ethiopian Electric Agency (EEA). The average frequency of interruptions of Bedele city present feeder is 617 interruptions per customer per year and the average duration of interruptions is 710 hours per customer per year. Similarly, Bedele Brewery factory Distribution system Reliability is far from requirement set by regulatory body. The average frequency of interruption of this line at present is 272 interruptions per customer per year and average duration of interruption is 320 hours per customer per year.
In this paper different Distribution model proposed and analyzed. As above simulation result shows all Distribution models have different Reliability improvement contributions with 1.33 to 2.87 payback investment cost. All scenarios are tolerable in terms of investment cost. But, to improve reliability indices more and for proper protection coordination, case D is highly recommended. By implementing this model the overall reliability of power distribution is improved by 67.6%, 75.2% and 82.4% for SAIFI, SAIDI and ENS respectively. Similarly for Bedele Brewery Factory overall reliability is improved by 99% for both SAIDI and ENS.-

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BIOGRAPHY

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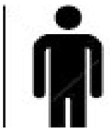

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