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Reliability Assessment of Electrical Distribution Network using Analytical Method: A Case Study of Maychew City Distribution System

Abrha Hiluf
Department of Electrical and Computer Engineering,
Hawassa University, Hawassa,
Ethiopia

Dr. Engineer Teshomen Goa Tella (PHD)
Department of Electrical and Computer Engineering,
Hawassa University, Hawassa,
Ethiopia

***Abstract*:- In the presence time the electrical power demand growth is increasing rapidly with the development of the technology and also the electrical power system is set to meet the required demand of customers .However the reliability of the power system is the major challenge to meet the required demand of customers.in Ethiopia a numbers of customers rise complain to Ethiopia electric power utility because of the power interruption. Therefore reliability analysis of distribution powers system is important to determine how much the power interruption is affecting the customers. This is enabling to the Power Company and customers to seek better solution to improve the reliability of the power system typically the maychew distribution system. This paper analysis the reliability of maychew city distribution system using the analytical method based on the outage data gotten from the northern Region electric power utility office. The monthly reliability of 5 feeders was evaluated for 2011E/C. From the evaluation the average availability of the ADISH, MAYCHEW, NEKSEGE, particle board factory and raya brewery factory were. The distribution experiences numbers of daily outage due to the fault. Generally I have conclude the distribution have poor performance.**

Key words:- Analytical, Assessment of Reliability, EENS, SAIDI and SAIFI

I INTRODUCTION

The electrical power system is setup to provide the electrical power to the all customers with enough reliability and security. This means that the system should deliver electricity supply with no or little power interruption and unavailability. Reliability can be defined as the probability of a device or a system performing its function adequately, for the period of time intended, under the operating conditions intended. While availability is the performance of the equipment or system to deliver the require function within the give period of time. Therefore reliability and availability are both the measure of system performance to ability of the system delivering the require tasks. The reliability of electric power system and be defined as the measure of adequate power supply electrical power for the specific period intended under the operating condition constrains.

The reliability of power system means that continuous supplying of qualified electricity for of customers. The reliability of power system have an economic, political and technological role in one country . in electrical power system there are three subsystems which are generation ,transmission and distribution. The electric power is generated at the generation and transmits through the transmission line to the distribution substation .while the distribution is the link between the consumer and the distribution substation. The problems of reliability in power system are more occurred at the distribution system. Therefore assesse the reliability of the distribution system in order to deliver reliable and safe electricity to the customer is the main subject of this study.

The reliability of distribution power system can be study by classified into two which system adequacy and the system security. The system adequacy is related to the existence of enough facility within the system to meet the required demand and to satisfy the customers at all time. While system security means related to the withstand of sudden disturbances such that the load conditions, short circuit or any fault on the system. Due to the fault at the system there may be power shedding for long period of time, power shedding for short period of time or any voltage dip9sag) at the end users. With the increasing of the electric power demand ,it important to deliver electric power with acceptable level of reliable, Quality and secure to the customer at all time with the more economical price.

The electric power company should be always asses, evaluate and improve the reliability of the system to satisfy customers. To analysis the reliability of distribution power system there two methods or technics which are

1 Analytical technic

2 Simulation technic.

1 Analytical technics evacuee the reliability using the mathematical models and evaluate the measures or indicator form this model using mathematical formula.

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2 Simulation technics in which estimate the measure or the indicators by simulating the actual process of random behavior of the system. When we are using simulation method there are different technics like that of Monte Carlo simulation, however The Monte Carlo simulation requires a large amount of computing time and is not used extensively if alternative analytical methods are available. But, if the analytical methods are too complex, the probabilistic simulations can give a good approximation of results.

The end of measures or indicators in both division of evaluation techniques are only as good as the model derived for the system, the appropriateness of the evaluation technique, and the perfect assumptions and input data used in the system.

Table 1 different in between analytical and simulation methods

Analytical	Simulation
✓ The analytical model always gives the same numerical result for the same system, same model and same set of input data	✓ Simulation method is dependent on the random number generator used and the number of simulations.
✓ The model used in the analytical approach is usually a simplification of the system. The simulation approach, however, can incorporate	✓ The simulation approach, however, can incorporate and simulate any system characteristic that can be recognized. ✓ Thus it gives a better description of practical system behavior
✓ The output of the analytical techniques is usually limited only to expected values.	✓ Simulation techniques can provide a wide range of output parameters, including, probability density functions and their respective moments.
✓ The solution time for analytical techniques is relatively short ✓ Due to this partially overcome by the development of modern computational facilities.	✓ The solution time for simulation techniques is relatively long ✓ The solution time still remains high in applications that demand several reliability assessments.

In electrical power system there three main components, these are generating, transmitting and distributing energy that also generates losses. These losses occur naturally from the dissipation of power in electricity components such as lines, transformers and measurement systems, and are known as technical losses. There are also losses that are caused by external actions to the power system, like errors in measuring and billing, theft and fraud. These losses are known as non-technical losses. The sum of technical and non-technical losses gives the total losses, which can be defined as the energy injected in the power system that is not sold.

Reliability means the probability that a system or components perform their assigned task for a given period of time under the operating conditions stumbled upon during its anticipated lifetime. To achieve an acceptable level of reliability, quality and safety at an economic price, the utility have to create and improve the systems reliability continuously depending upon the requirement of the customers. Reliability assessment methods allow the evaluation of the reliability of systems. The methods provide important information on how to improve a systems life to reduce safety risk and hazards [1, 2]. From these main components of electrical power, distribution system is a largest part of network in electrical power system. It can be defined as the part of power system this distributes power to various customers in ready-to-use form at their place of consumption. So, utilities have to ensure reliable and efficient cost effective service, while providing service voltages and power quality within the specified range.

Ethiopian electricity sector (EEPCO) constitutes relatively a very poor distribution system in several utilities. Despite the realization of the importance of the distribution sector, the performances of Ethiopian distribution utilities have not been measured empirically so far by the organization. The performance evaluation of the distribution sector is important in order to assess the impact of reform measures. Usually engineers try to achieve the required reliability level with minimal cost.

System reliability can be divided into two distinct categories

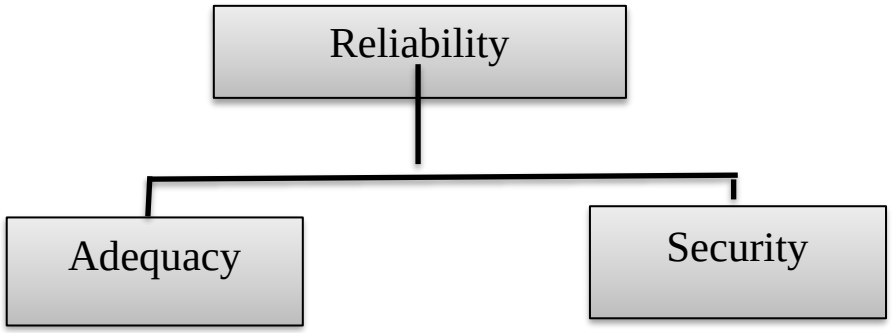

Figure 1 categories of reliability

Figure 1 represents two basic categories of power system reliability: system adequacy and security. Adequacy relates to the existence of sufficient facilities within the system to satisfy the consumer load demand. These include the facilities necessary to generate sufficient energy and the associated transmission and distribution facilities required to transport the energy to the

International Journal of Engineering Research & Technology (IJERT)
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actual consumer load points. Security relates to the ability of the system to respond to disturbances arising within that system. Most of the probabilistic techniques presently available for power-system reliability evaluation are in the domain of adequacy assessment.

This project out put a significant importance of measuring the existing network performance of reliability as well as serving as a benchmark for the prediction of the future in Maychewelectrical distribution network

In general it has the following advantages

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

II AVAILABILITY

Availability means that the probability of something being energized. It is the very basic aspect of reliability and is typically measured in percent or per-unit. The opposite of availability is unavailability.

Availability – means probability of being energized.

Unavailability – means probability of not being energized.

III RELIABILITY

The purposes of power system reliability assessment are to provide qualitative analysis and indices in power supply reliability for the operation and planning system. After the qualitative analysis, it is very important to find out weak network components. In recently, there are only two approaches, analytical approach and Monte-Carlo Simulation approach, used to calculate the reliability indices.

IV 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 / or 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 power system reliability is one of the features of power system quality in addition to required voltage and constant frequency. In electrical power system they are some reliability indices which measure the level of the reliability of the power system. Typically in distribution system there are different indices which can be indices the reliability of the system. the reliability indices are including the measure of the power outage duration , frequency of outage ,number of customers interrupted and the response timeNow a day IEEE defines the generally accepted reliability indices in its standard values [1]. These standards distribution and transmission reliability indices and factors that affect their calculation are collected and presented. The indices are intended to apply to power distribution and transmission systems, substations, circuits, and defined regions.

1 system average interruption frequency indices (SAIFI)

This the measure or the indicators of how much customers experienced sustained interruptions over the predefined period of time .in which it express in a year

$$SAIFI = \frac{frequency\ of outage}{number of\ costimers\ supplied}$$

2 System average interruption duration indices (SAIDI)

SAIDI is the measure of the total number of duration interruption over the predefined period or time.it is measure in customer-hours of interruptions

$$SAIDI = \frac{total\ duration\ in hours}{numbers of\ customers\ supplied}$$

3 customers average interruption duration indices (CAIDI)

CAIDI is the indicator which represents the time required to restart the system interruption.

This is express in uniting of time per interruption.

$$CAIDI = \frac{total\ duration\ in hours}{number of\ customers\ affected}$$

4 average service availability indices (ASAI)

The fraction of time that customer has supplying power during the specific reporting period of time I called ASAI.

International Journal of Engineering Research & Technology (IJERT)
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$$ASAI = \frac{customer\ hours\ serviceavaliability}{customerhours\ servie\ demand}$$

5 average service unavailability indices (ASUI)

ASUI can be express mathematical as

$$ASUI = 1 - ASAI$$

$$ASUI = \frac{duration\ of outage\ inhours}{totalhours\ demand}$$

The total hour demand is for one year which is 8760 hours

6 Excepted energy not supplied index (EENS)

$$EENS = \sum Li * Ui$$

Where
Li is the average connected load at load point i
Ui is average annual outage time at load point i.

7 Average energy not supplied index (AENS)

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

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

In distribution system the reliability of the system can be measure or evaluate using the above indices. The indices are calculated according to the data which is available with the power company or utility. In reliability the random variables are express in the function of frequency time. There is also one important factor which is use in this function which called failure rate. This failure rate can be calculated as $f(t) = \lambda e^{-\lambda t}$ and also the hazard rate is given as

$$\lambda(t) = \frac{f(t)}{1 - f(t)} = \lambda$$

then the failure rate(λ) can be calculate as

$$\lambda = \frac{\text{number os time that failure occured}}{\text{number}of\ unit - hours\ of\ operation}$$

there are also some parameters in which it helps to determine the reliability of the distribution systems

1mean time between failures (MTBF)

$$MTBF = \frac{total\ system\ peration\ hours}{numberof\ failures}$$

Mean time to repair(MTTR)

$$=MTTR = \frac{\text{total duration of outages}}{\text{fequencyof outage}}$$

$$Availability(A) = \frac{total\ duration\ of\ outages}{frequencyof\ outage}$$

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

V RELIABILITY EVALUATION

The main aim of reliability analysis should be to answer questions like: Is the system reliable enough? Which schemes will be effective? And where high capital should spent to improve the

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Vol. 9 Issue 08, August-2020

system? Reliability in power system can be divided in to two basic categories i.e historical and predictive. The predictive reliability is then followed to predict the changes in reliability measures after a change in system configuration or any improvement strategy is planned to be implemented.

VI RELIABILITY ASSESSMENT BY HISTORICAL

This method involves the collection and analysis of distribution system outage and customer interruption data. It is essential for electric utilities to measure actual distribution system reliability performance levels and define performance indicators to assess the basic function of providing cost-effective and reliable power supply to all customer types. Historical assessment generally is described as measuring the past performance of a system by consistently logging the frequency, duration, and causes of system component failures and customer interruptions.

VII DESCRIPTION OF Maychew DISTRIBUTION SYSTEM

Maychew city is one of the medium cities in Ethiopia which is capital city of the southern Zone of tigray . Located to the north from Addis Ababa and to the south from mekell in which 666km far from Addis Ababa. Maychew distribution substation getting 66KV form alamata transmission substation which 40km far from Maychew. In Maychew substation there are more than 120,000 customers which are commercial, industrial and residential type of customers. Maychew city distribution substation has 6 outage lines or feeders to different customers. The feeders in the town are configured radially with voltage level of 15 kV primary feeders, these are These feeders are connected to a total of more than 185 distribution transformers; most of them are pole mounted, for further step down to 380 V three-phase and 220 V single-phase for secondary distribution purpose..

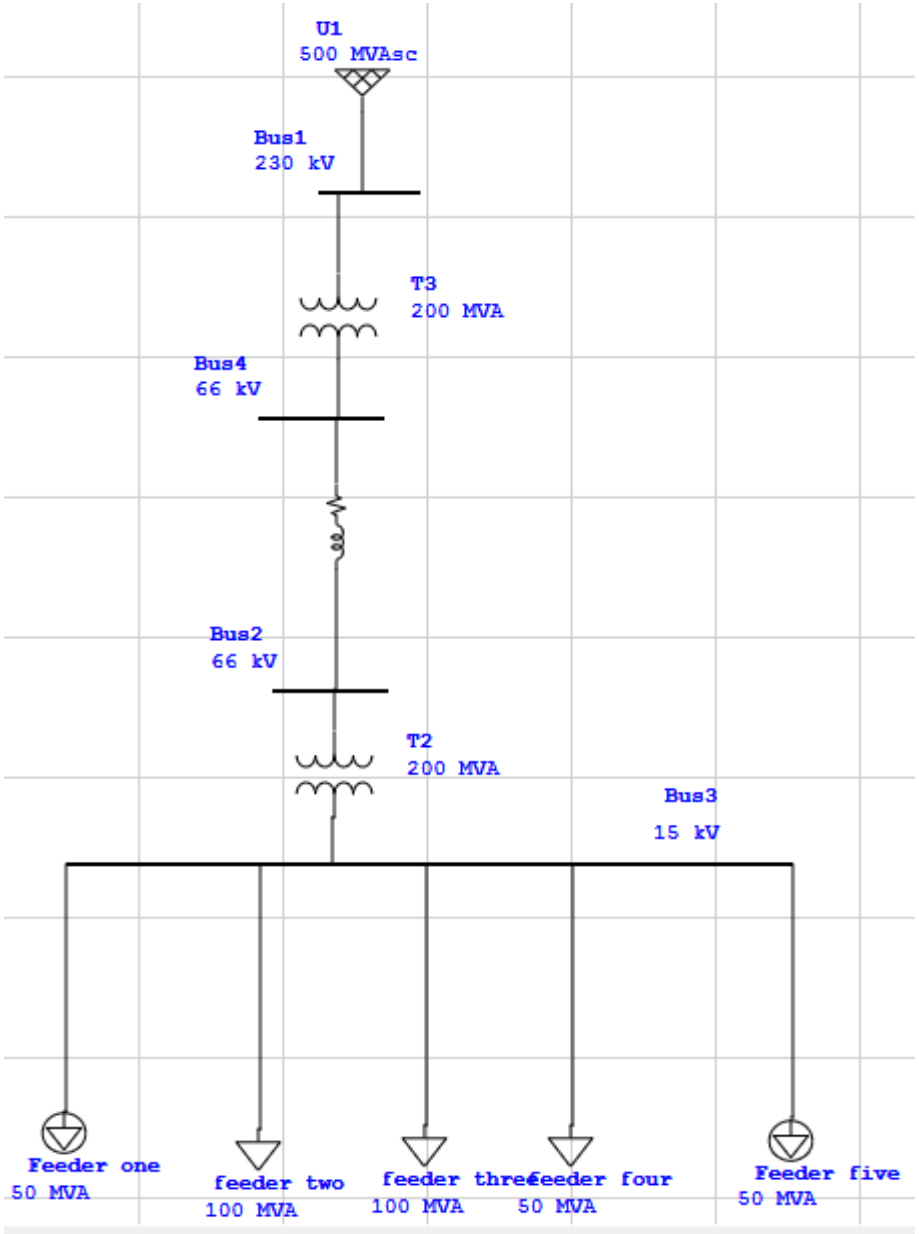

Figure 3 distribution network of maychew distribution system

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 9 Issue 08, August-2020

VIII DATA COLLECTION OF Maychew DISTRIBUTION

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

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

Power distribution of maychew town is radial distribution system type. Power is delivered to the customer from the utility in a one path only. There are no laterals and interconnection or mesh type network topology. Even if radial power distribution system is less costly in terms of design and protection, it's vulnerable to disturbance hence less reliable. Because of its radially this substation has a frequent interruption to the customer. Due to this reason the mesh or interconnected distribution is highly recommended to improve customer based reliability and power availability. Maychew substation has 14 outgoing feeders.

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

Table 3 Maychew distribution system voltage rating of feeders and type of breakers

Feeder Name	Voltage level in KV	Circuit breaker type
Feeder two ADISHO	33	Oil circuit breaker
Feeder one MAYCHEW	15	Oil circuit breaker
Feeder three MAYCHEW PARTICLE BOARD FACTORY	15	Oil circuit breaker
Feeder four NEKSEGE	15	Oil circuit breaker
Feeder five RAYA BREWERY FACTORY	15	Oil circuit breaker

IX CAUSES OF INTERRUPTION

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

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

The above and other causes are at the root of distribution reliability, and understanding them allows abstract topics like reliability modeling and computer optimization to be viewed from a practical perspective. Also, identifying and addressing physical root causes is often the most cost effective way to address reliability problems.

X ANALYTICAL RESULTS AND DISCUSSIONS

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

Table total number of costumers and average failure rate of each for three years

NO	Feeder name	No of customer	
1	Feeder one MAYCHEW	30325	
2	Feeder two ADISHO	15252	0.1780
3	Feeder Three MAYCHEW PARTICLE BOARD FACTORY	1(factory)	1.1022
4	Feeder four NEKSEGE	2125	1.0094
5	Feeder five RAYA brewery factory	1 (factory)	1.1453

Table Computed Basic Reliability Indices for 2009 E/C

Feeder name	SAIFI int/cus/yr	SAIDI (Hr/cus/yr	CAIDI (Hr/int)	ASAI (p.u)
Feeder two ADISHO	178.21	259.64	1.1998	0.5544
Feeder one MAYCHEW	216.4	279.25	1.2904	0.5963
Feeder three MAYCHEW PARTICLE BOARD FACTORY	187.94	398.78	1.8428	0.8516
Feeder four NEKSEGE	207.21	305.6	1.4122	0.6526
Feeder five RAYA BREWERY FACTORY	207.21	371.2	1.7153	0.7927

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Table Computed Basic Reliability Indices of 2010E/C for 5 feeders

Feeder name	SAIFI int/cus/yr	SAIDI (Hr/cus/yr	CAIDI (Hr/int)	ASAI (p.u)
Feeder two ADISHO	208.6	302.45	1.2519	0.6001
Feeder one MAYCHEW	198.74	310.4	1.2848	0.6465
Feeder three MAYCHEW PARTICLE BOARD FACTORY	223.1	368.01	1.5232	0.6827
Feeder four NEKSEGE	169.8	259.7	1.0749	0.6330
Feeder five RAYA BREWERY FACTORY	241.6	347.21	1.4371	0.5948

Table Computed Basic Reliability Indices of 2011 E/C for 5 feeders

Feeder name\	SAIFI int/cus/yr	SAIDI (Hr/cus/yr	CAIDI (Hr/int)	ASAI (p.u)
Feeder two ADISHO	174.125	269.254	1.545977	0.88786
Feeder one MAYCHEW	205.05	289.078	1.40598	0.68567
Feeder three MAYCHEW PARTICLE BOARD FACTORY	219.34	342.142	1.55987	0.71158
Feeder four NEKSEGE	159.15	287.987	1.80953	0.993699
Feeder five RAYA BREWERY FACTORY	236.5	363.002	1.53489	0.649002

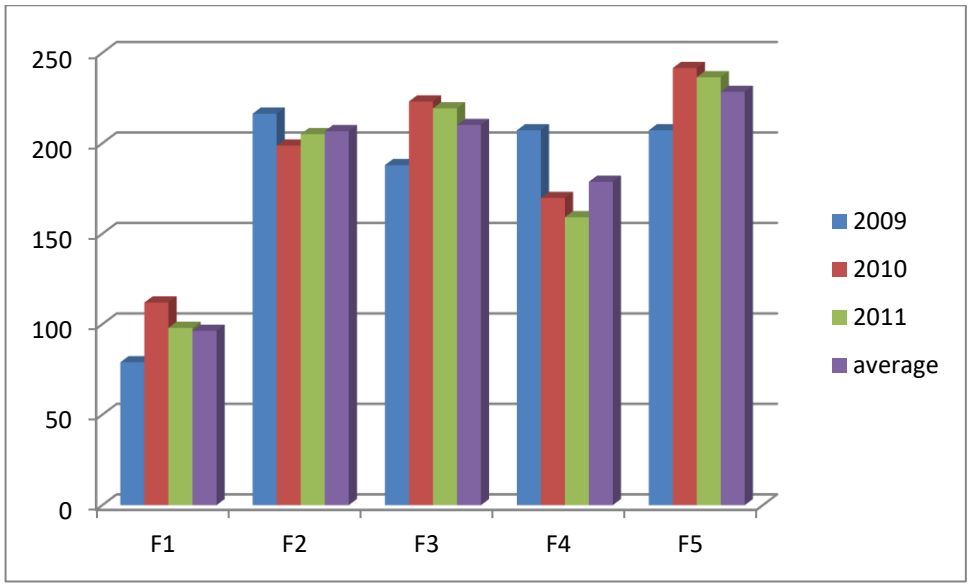
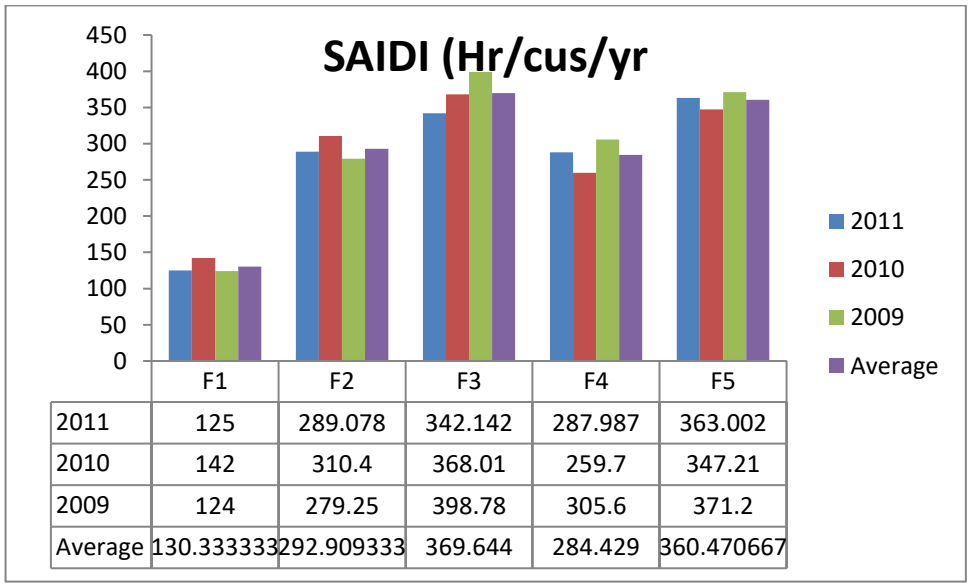


figure 3 Bar chart for SAIDI of three 2009-2011 E.C and average result of 5 feeders



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International Journal of Engineering Research & Technology (IJERT)
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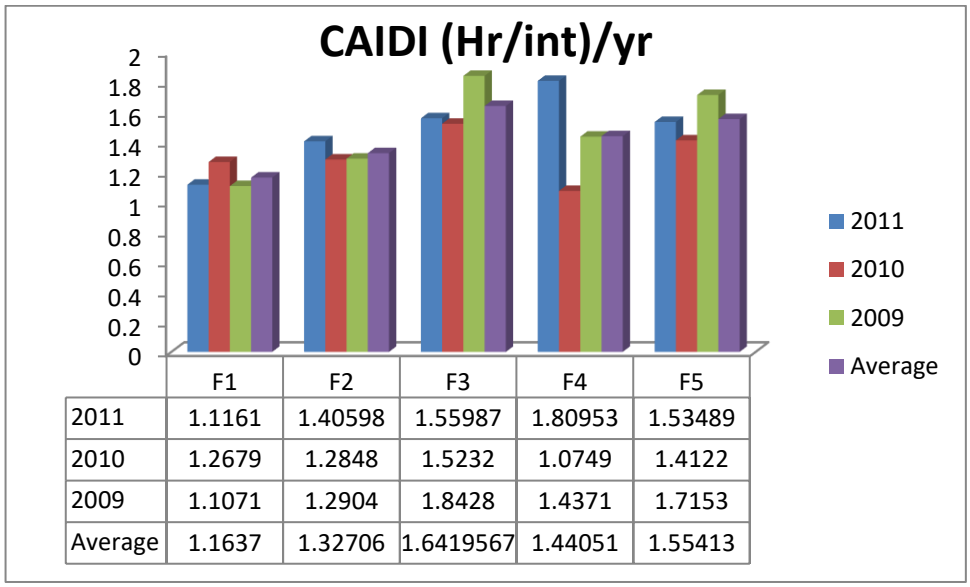
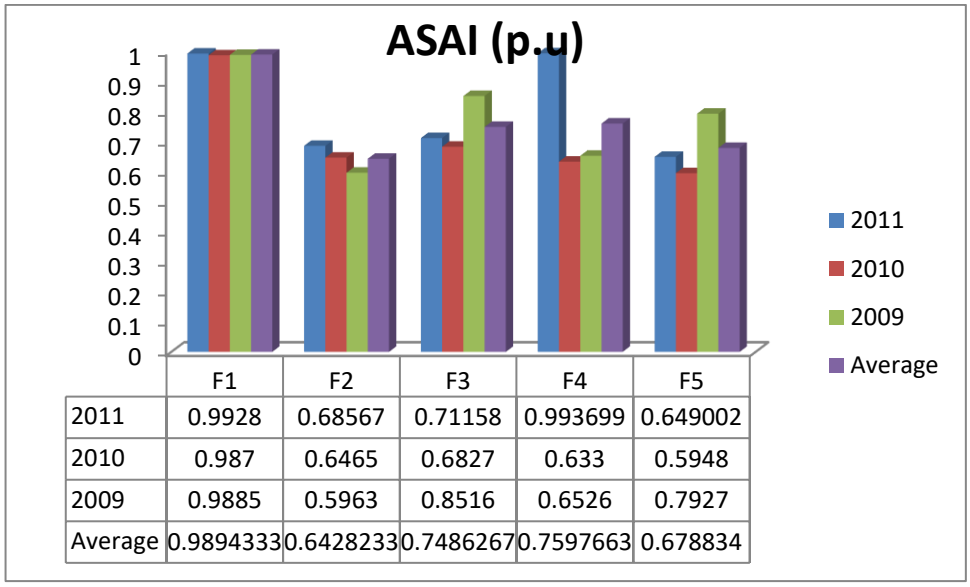


	F1	F2	F3	F4	F5
2011	1.1161	1.40598	1.55987	1.80953	1.53489
2010	1.2679	1.2848	1.5232	1.0749	1.4122
2009	1.1071	1.2904	1.8428	1.4371	1.7153
Average	1.1637	1.32706	1.6419567	1.44051	1.55413

Fig 4 Bar chart for CAIDI of three 2009-2011 E.C and average result of 5 feeders



	F1	F2	F3	F4	F5
2011	0.9928	0.68567	0.71158	0.993699	0.649002
2010	0.987	0.6465	0.6827	0.633	0.5948
2009	0.9885	0.5963	0.8516	0.6526	0.7927
Average	0.9894333	0.6428233	0.7486267	0.7597663	0.678834

Figure 5 Bar chart for **ASAI (p.u)** of three 2009-2011 E.C and average result of 5 feeders

XI CONCLUSION

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

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