Reliability Analysis in Distribution system

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Abstract- Electricity is one of the greatest technological innovations of mankind. Though the electricity plays an important role, the reliability analysis also gains the equal importance in power distribution system. Reliability analysis is performed to evaluate, anticipate, and collate reliability indexes for various reliability improvements. This information helps engineers and managers at electric utility organizations to decide how to spend the money to improve reliability of the system by identifying the most effective actions/ reconfigurations. Reliability is affected by the following Variable loading, Switch/protective device placement, Switch operation times, Available alternative feeders, Equipment current limits, Equipment failure rates, Equipment repair times etc. Such typical substation outage events can contribute up to 20% of customer interruptions. The basic indices associated with indices such as System Average Interruption Frequency Index (SAIFI), System Average Interruption Duration Index (SAIDI), Customer Average Interruption Frequency Index (CAIFI), Customer Average Interruption Duration Index (CAIDI), Average Service Availability /Unavailability Index (ASAI), Energy Not Supplied (ENS) and Average Energy Not Supplied (AENS).

***Index Terms* – Distribution system, SAIFI, SAIDI, CAIFI, CAIDI, ASAI, ENS, AENS**

I. INTRODUCTION

The function of an electric power system is to provide electricity to its customers efficiently and with a reasonable assurance of continuity and quality. The task of achieving economic efficiency is assigned to system operators or competitive markets, depending on the type of industry structure adopted. On the other hand, the quality of the service is evaluated by the extent to which the supply of electricity is available to customers at a usable voltage and frequency. The reliability of power supply is, therefore, related to the probability of providing customers with continuous service and with voltage and frequency within prescribed ranges around the nominal values. A modern power system is complex, highly integrated and very large. Fortunately, the system can be divided into appropriate subsystems or functional areas that can be analyzed separately. These functional areas are generation, transmission and distribution. Reliability studies are carried out individually and in combinations of the three areas. The evaluation of transmission and distribution reliability is beyond the scope of this work. Nevertheless, the following remarks are important when assessing the reliability of the entire power system:

- The actual degree of reliability experienced by a customer will vary from location to location. Different functional areas may offer different degrees of reliability.
- There should be uniformity between the reliability of various parts of the system. It is useless to strongly reinforce a part if weaker areas exist on the supply chain.
- In deregulated systems, efficient pricing mechanisms for transmission and distribution must consider a reliability component.

Power reliability can be defined as the degree to which the performance of the elements in a bulk system results in electricity being delivered to customers within accepted standards and in the amount desired. The degree of reliability may be measured by the frequency, duration, and magnitude of adverse effects on the electric supply.

According to the North American Electric Reliability Council (NERC), reliability is "the degree to which the performances of the elements of [the electrical] system result in power being delivered to consumers within accepted standards and in the amount desired". In other words, reliability refers to the ability of power system components to deliver electricity to all points of consumption, in the quantity and with the quality demanded by the customer.

In general, reliability designates the ability of a system to perform its assigned function, where past experience helps to form advance estimates of future performance. A useful definition that illustrates the different dimensions of the concept is the following:

Reliability is the probability of a device or system performing its function adequately, for the period of time intended, under the operating conditions intended. Reliability is often measured by the frequency, duration and extent of power system disturbances and outages. A disturbances any unplanned event, including an outage that produces an abnormal system condition. An outage can be described in terms frequency, duration, and amount of load (or numbers of customers) affected.

Reliability can be measured through the mathematical concept of probability by identifying the probability of successful performance with the degree of reliability. Generally, a device or system is said to perform satisfactorily if it does not fail during the time of service. On the other hand, a broad range of devices are expected to undergo failures, be repaired and then returned to service during their entire useful life. In this case a more appropriate measure of reliability is the availability of the device, which is defined as follows. The availability of a repairable device is the proportion of time, during the intended time of service, that the device is in, or ready for service

Electrical energy has become a basic necessity for all human beings and vital for overall economic development of the state and country. Energy is a key input to all the development activities. Electricity sector consists of Generation, Transmission and Distribution companies. The main utilities in Karnataka's power sector are the Karnataka Power Corporation Ltd. (KPCL) -- the Public Sector generation utility, the Karnataka Power Transmission Corporation Ltd. (KPTCL) -- the Public Sector transmission utility, and its four regional distribution utilities – the Bangalore Electricity Supply Company (BESCOM), the Mangalore Electricity Supply Company (MESCOM), the Hubli Electricity Supply Company (HESCOM), and the Gulbarga Electricity Supply Company (GESCOM), currently in the Public Sector but expected to be privatized later. Karnataka was the first State in the country to separate distribution from transmission and 4 distribution companies namely BESCOM, MESCOM, HESCOM & GESCOM were started and later CESCO was started. The power transmitted to the distribution companies are distributed to 1.7crore consumers across various categories.

Reliability indices are widely used for assessing the effectiveness of continuity of supply in distribution systems. Their use is essential for setting up performance standards for the continuity of supply regulation. Presently we can define a power system as a system that delivers to its costumer's two different types of products: electric energy and reliability. As a matter of fact, the economic development of a country is strictly correlated with the reliability of its power system since most of its economic agents rely on this type of energy to boost up their activity. Therefore constant interruptions on electric energy supply can reduce dramatically their income forcing them to buy reliability, usually in the form of emergency generators. In the worst of scenarios the economic agent will be forced to move its activities to another country affecting not only the economic sector but also the social environment. Typically the short term government measures in order to avoid this situation are to offer these enterprises different types of benefits, like tax reductions, financial compensations or facilities in the acquisition of patrimonial assets. Nevertheless, in time, heavy investments in the electric power system will be needed since low reliability generally leads to an unsustainable development. The main aspect to be retained is that the power systems constitute a basic element for the improvement of both economic and social sectors of a modern society.

The first power systems were relatively small in size. Their first purpose was to supply the public illumination grid. The development of electric energy powered devices firstly for the industry and later for domestic use, lead to the widespread of electric energy consumption and consequently to the enlargement of the powers systems size. As a result the modern power systems are extremely complex, progressively more interconnected, with national or even continental dimensions. The high number of components, geographically distributed throughout a country or continent, coupled with the demand uncertainties and the availability of energy resources, make the design and operation of these systems a highly complex task.

The basic function of an electric power system is to supply the load demand as economically as possible within pre-defined continuity, quality and security patterns. However due to the enormous quantity of components in these systems, combined with their unique operation characteristics, there is a possibility of failure of the entire system simply by failure of a crucial or a group of crucial components. The good news is that these types of events have a low probability of occurrence. The most common security scenario is the strategic disconnection of a certain number of customers in order to maintain the security of supply. However the same question arises: how much does the frequent failure of the system cost, considering all its possible consequences. In order to decrease the probability as well as the frequency and the duration of these events investments have to be made. However the tendency is to postpone those investments and to operate the electric systems in their limits. Managing all these contradictory requirements is the constant struggle of the decision makers when it comes to reinforce the electric system in order to increase its reliability.

Recently the institutional changes in the electric sector, such as the progressive deregulation or the former electric utilities privatization, with the purpose of creating an electric market, have given another degree of importance to the continuity of service: now it is the responsibility of the electricity provider to assure a continuous power supply, usually established in a contract, especially in the case of a very important client. Moreover the operation paradigm of the electric power systems is also changing. New concepts as distributed generation, micro-grids and the raising penetration of energy from intermittent sources, have brought the need to fully describe the entire energy system in order to correctly evaluate its reliability.

II. Methods To Calculate Reliability Indices

There are two methods to calculate reliability indices they are Analytical and simulation method

- **Analytical method:** The analytical approach evaluates the indices by a set of mathematical equations and therefore analysis procedure is simple. The created reliability analysis using analytical method is fast enough to interactive design study on large system. Analytical method identifies the area that needs improvement. This can be carried on large scale and cheapest ways to analyze fault occurrence. The data available by the analytical method can be used by the design engineer to make improvements in existing design. With the advent of performance-based rates, utilities are taking a closer look at their reliability data and working to improve their indices. Applied for better understanding of station reliability as well as hands on-study of station performance. But System and load point indices determined as average values with no information in variability in indices and also Analytical methods use simplified assumptions that failure and repair times in distribution system are exponentially distributed.
- **Simulation method:** Simulation method is again classified into two types: Sequential Monte Carlo method: It simulates system operation by generating an artificial history of failure & repair events in time sequence and Non sequential Monte Carlo method. It determines system response to set of events whose order has no influence or significance. A sequential simulation approach can provide the additional information on the annual variability of the predicted indices. It gives detailed knowledge of the probability distributions of reliability indices but it is complicated to work on software It require through study of analysis & put into practice. Simulation method is not cheaper & handy to use. Results obtained from simulation method are not very accurate & hence not economical method. The simulation technique evaluates the reliability indices by series of trials and therefore the procedure is more complicated and requires a longer computer time. This method is much time consuming.

III. Objective of Reliability Monitoring

i) Furnish management with performance data regarding the quality of customer service on the Electrical system as a whole and for each voltage level and operating area.

ii) Provide data for an engineering comparison of electrical system performance among Consenting Companies.

iii) Provide a basis for individual companies to establish service continuity criteria. Such Criteria could be used to monitor system performance and to evaluate general Policies, practices, standards and design.

iv) Provide data for analysis to determine reliability of service in a given area (geographical, Political, operating, etc.) to determine how factors such as design differences, environment or Maintenance methods, and operating practices affect performance.

v) Provide reliability history of individual circuits for discussion with customers or Prospective customers

vi) To identify substations and circuits with substandard performance and to ascertain the causes.

vii) Obtain the optimum improvement in reliability per rupee spent for design, maintenance and operating programs.

viii) Provide performance data necessary for a probabilistic approach to reliability studies.

This can be done by comparing and consistently evaluating the effects on a system's performance of varying the configuration, protective methods, equipment, structural design and/or operating and maintenance practices. The purpose is to determine the design, operating and maintenance practices that prove optimum reliability per rupee spent and, in addition, to use this information to predict the performance of future transmission and distribution system arrangements.

IV. FACTORES RECKONED FOR RELIABILITY ANALYSIS

The reliability indices can be evaluated considering the following factors:

- 33 kV breakdowns
- 11 kV breakdowns
- Incoming supply failure at 132 kV substations.

- Daily roistering of 11 kV rural feeders.
- Failure of distribution transformers.

The following factors, which affect reliability indices, shall also be considered subject to availabilityof data

- Momentary interruptions on 33kV and 11kV feeders.
- Momentary incoming supply failures
- Pre-arranged shutdowns on lines and feeders
- Breakdown on LT feeders
- Blowing of transformer fuses both HV and LV individual fuse off calls

V. METHODOLOGY ADOPTED:

There are many indices for measuring reliability. The most common are referred to as SAIFI, SAIDI, CAIFI, CAIDI, MAIFI, CIII, ASAI defined as:

SYSTEM AVERAGE INTERRUPTION DURATION INDEX (SAIDI):

The most often used performance measurement for a sustained interruption is the system Average Interruption Duration Index (SAIDI). This index measures total duration of an interruption for the average customer during a given time period. SAIDI is normally calculated on either monthly or yearly basis. However, it can also be calculated daily, or for any other time period.

To calculate SAIDI, each in all interruptions during the time period is multiplied by the duration of the interruption to find the customer-minutes of interruption. The customer minutes of all interruptions are then summed to determine the total customer-minutes. To find the SAIDI value, the customer-minutes are divided by the total customers. The formula is,

$$\mathbf{SAIDI = \Sigma (ri * Ni) / NT}$$

Where, ri = Restoration time, minutes.
Ni = Total number of customers interrupted
NT = Total number of customers served

CUSTOMER AVERAGE INTERRUPTION DURATION INDEX(CAIDI):

Once an outage occur the average time to restore service is found from customer average interruption duration index (CAIDI). CAIDI is calculated similar to SAIDI except that the denominator is the number of customer interrupted versus the total number of utility customer. CAIDI is,

$$\mathbf{CAIDI = \Sigma(ri * Ni) / \Sigma(Ni)}$$

Where, ri = Restoration time, minutes.
Ni = Total number of customers interrupted

SYSTEM AVERAGE INTERRUPTION FREQUENCY INDEX (SAIFI):

The system average interruption frequency index(SAIFI) is the average number oftimes that a system customer experiences an outage during the year (or time period under study). The SAIFI is found by divided the total number of customers interrupted by the total number of customers served. SAIFI, which is a dimensionless number, is

$$\mathbf{SAIFI = \Sigma(Ni) / N_T}.$$

Where, Ni = Total number of customers interrupted
N_T = Total number of customers served

$$\mathbf{SAIFI = SAIDI / CAIDI}$$

CUSTOMER AVERAGE INTERRUPTION FREQUENCY INDEX (CAIFI):

Similar to SAIFI is CAIFI, which is customer average interruption frequency index. The CAIFI measures the average number of interruptions per customer interrupted per year. It is simply the number of interruptions that occurred divided by the number of customers affected by the interruptions. The CAIFI is,

$$\mathbf{CAIFI = \Sigma (No) / \Sigma (Ni)}$$

Where, No = Number of interruptions
Ni= Total number of customers interrupted

CUSTOMER INTERRUPTED PER INTERRUPTION INDEX (CIII):

The 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= Σ(Ni)/ Σ (No).

Where, No = Number of interruptions

Ni= Total number of customers interrupted.

MOMENTARY AVERAGE INTERRUPTION FREQUENCY INDEX (MAIFI):

The MAIFI is the Momentary Average Interruption Frequency Index and measures the average number of momentary interruptions that a customer experiences during a given time period. Most distribution systems only track momentary interruptions at the substation, which does not account for pole-mounted devices that might momentarily interrupt a customer. MAIFI is rarely used in reporting distribution indices because of the difficulty in knowing when a momentary interruption has occurred. MAIFI is calculated by summing the number of device operations (opening and reclosing is counted as one event) , multiplying the operations by the number of customer affected , and dividing by the total number of customers served.

MAIFI =Σ (IDi * Ni) / NT

Where, IDi = Number of interrupting device operations.

Ni= Total number of customers interrupted.

NT= Total number of customers served.

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 period to the total customer hours demanded. This is sometimes called the service reliability index. The ASAI 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 = [1 – (Σ(ri * Ni) / (NT * T))] * 100

Where,

T = Time period under study, hours.

ri = Restoration time, hours

Ni = Total number of customers interrupted

NT = Total number of customers served.

Data considered for feeder 2

NT = no of total installation = 114

Ni = no of interrupted installation = 25

ri = durationof interruption = 2.36

No = no of interruptions = 6

T = time period = 31*24 = 744

IDi = no of interrupting device operation = 1

Calculations made :

SAIDI=Σ (ri * Ni) / NT = (2.36 * 25) / 114 = 0.517

CAIDI=Σ (ri * Ni) / Σ(Ni) = (2.36 * 25) / 25 = 2.36

SAIFI= Σ (Ni)/ NT = (25 / 114) = 0.219

CAIFI = Σ (No) / Σ (Ni) = (6 / 25) = 0.24

CIII= Σ (Ni)/ Σ (No) = (25 / 6) = 4.1667

MAIFI = Σ (IDi * Ni) / NT = (1 * 25) / 114 = 0.219

ASAI= [1 – (Σ(ri * Ni) / (NT * T))] * 100 =[1- ((2.36*25) / (114*31*24))] * 100 = 99.93%

VI. THE OPERATION OF POWER SYSTEM

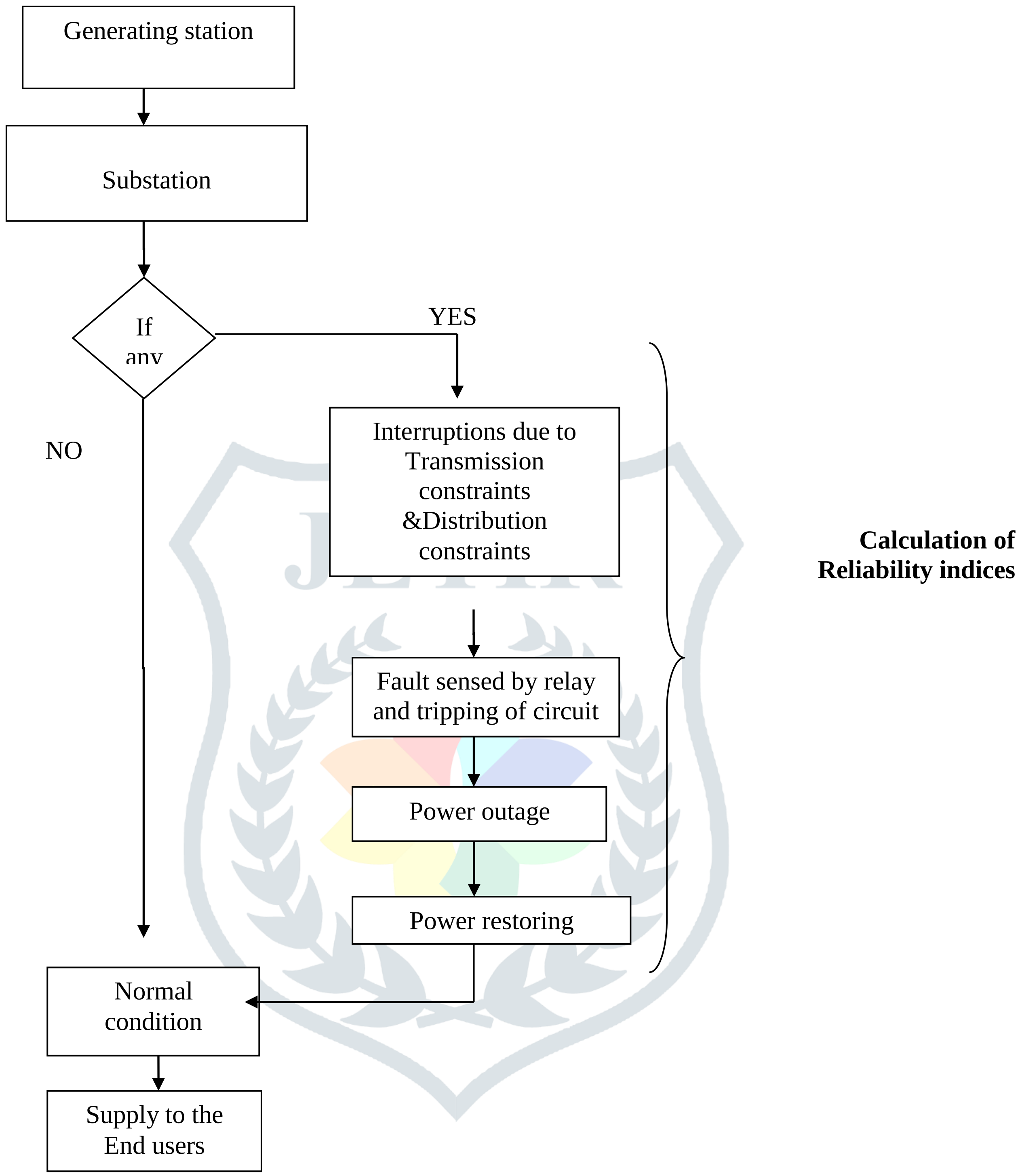

Fig: 1 Flowchart of the power system operation

VII. RESULTS AND DISCUSSION

a. Data Analysis And Interpretation

The graph below describes the peak loading of transformers 1,2&3 in the month of January ,We can see the peak loading of transformer-1 & 2 in the month of Jan of year one is 100.16% which is maximum. As Transformer 3 has not been installed in Jan its loading is taken as zero which is minimum.

Comparison of peak loading of Transformers 1,2&3

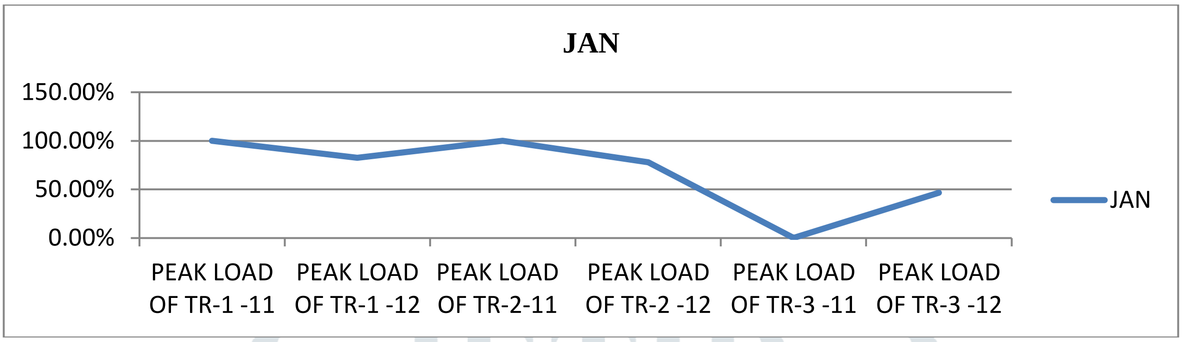

Fig: 2 Comparison of peak loading of transformers for the month of JAN

The graph below shows the peak loading of transformers 1,2 &3 in the month of February,We can see the peak loading of transformer-1 & 2 in the month of feb of year one is 100.16% which is maximum. As transformer- 3 has not been installed in Jan its load is shown minimum and in Feb transformer-3 capacity is 54.44%.

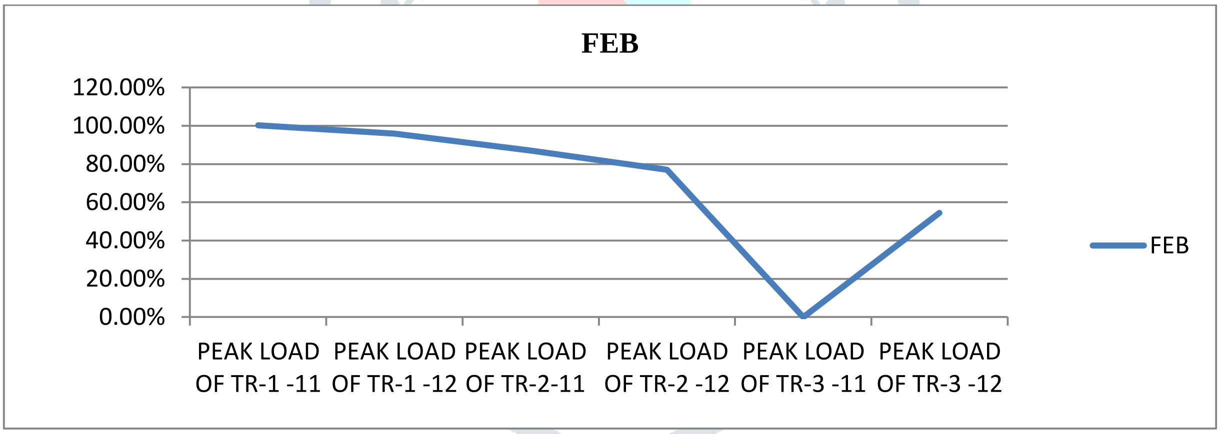

Fig: 3 Comparison of peak loading of transformer for FEB

The graph below shows the peak loading of transformers 1, 2 &3 in the month of March ,We can see the peak loading of transformer-1 & 2 in the month of Feb of first year is 105.96% which is maximum. As transformer- 3 has not been installed in Jan its load is shown minimum and in March, transformer-3 capacity is 54.44%.

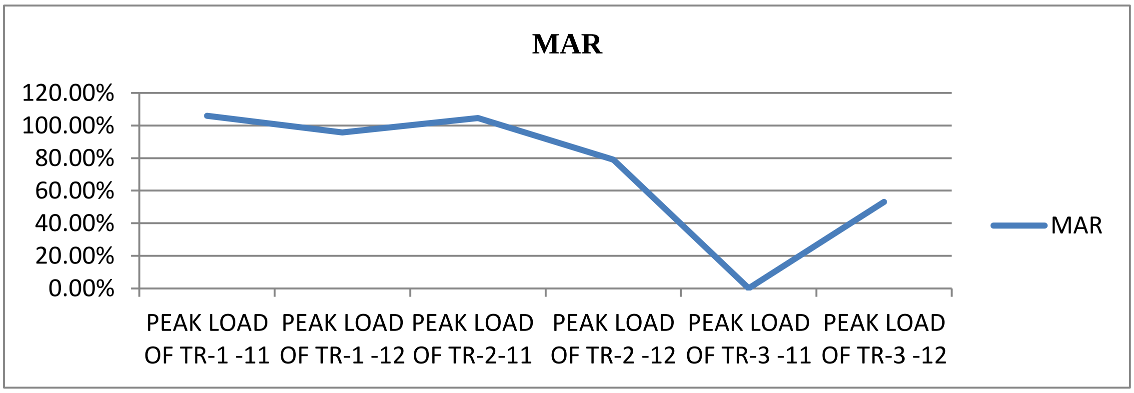

Fig: 4 Comparison of peak loading of transformer for MARCH

Comparison of Reliability of substation in JAN-MARCH

As seen from the graph the reliability of substation in first year January is 99.99%,February is 100%,march is 99.88%,april is 99.95%,may is 99.94%,june is 99.92%,july is 99.92%.august is 99.98%,September is 100%,October is 99.71%,November and December is 99.97%.

As for next year the reliability of substation in the month of January is 99.87% and that of February and March is 100%. Overall the reliability of substation in the month of January, February and March of 2nd year is more as compared to that of first year.

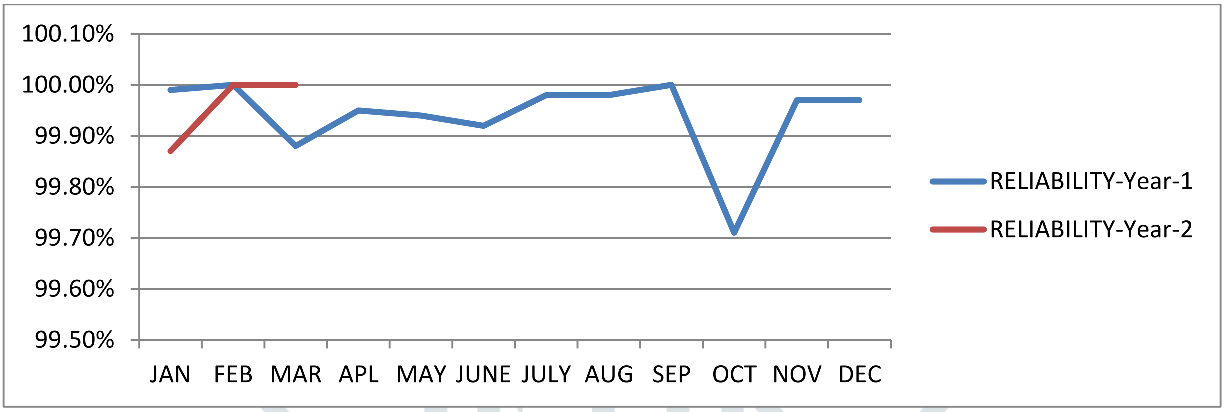

Fig: 5 Comparison of reliability of substation in Jan-March two years

Comparison of scheduled & unscheduled power outage duration of two years

As per the graph the power outage duration in the month of January of first year is more as compared to that of second year since high transmission line (HT) was taken to attend dc battery replacement.

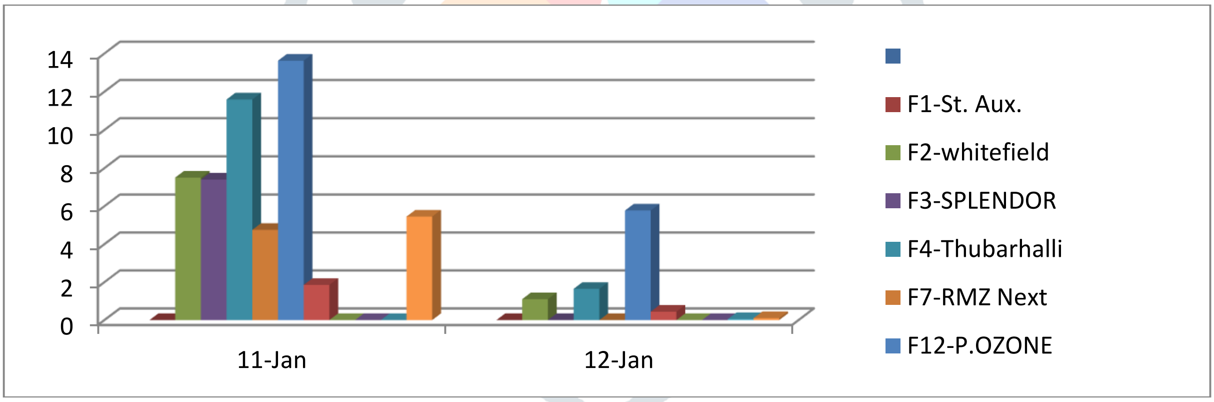

Fig: 6 Comparison of power outage duration of Jan with two years

As per the statistics the power outage duration in the month of February in first year is more as compared to that of second year .since 66KV incoming supply failed from receiving station.

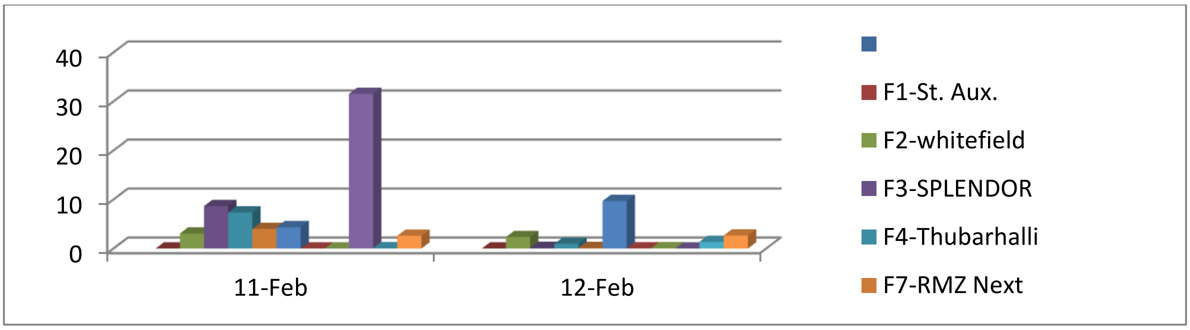

Fig: 4.6 Comparison of power outage duration of Feb for two years

As per the graph the power outage duration in the month of March of first year is more as compared to that of two years. Since 66kv incoming supply failed from receiving station and backup over current relay and backup earth fault relay is activated due to transformer 2 current transformer flash over.

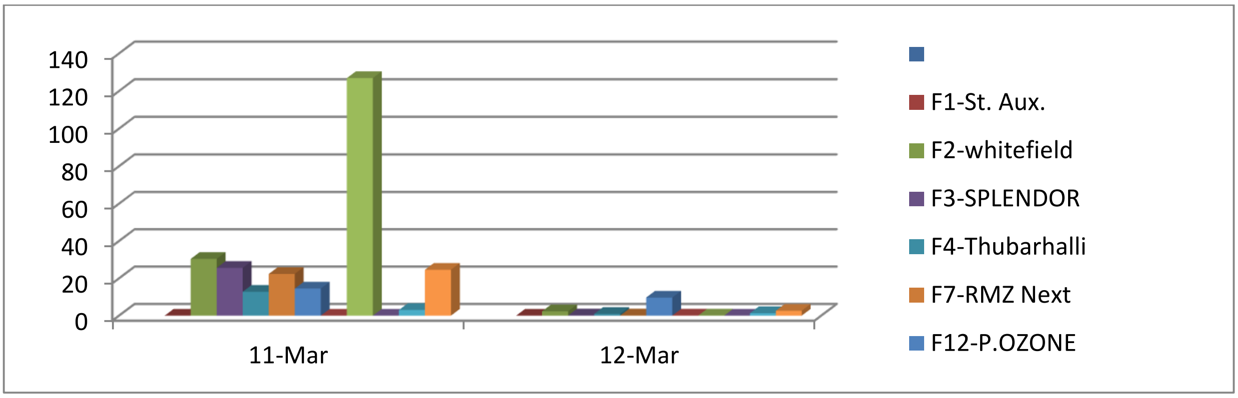

Fig 7. Comparison of power outage duration of March for two years

Seasonal comparison of power outage duration in first year

The year divided in to four seasons spring (December, January, February) ,summer (March, April, May), autumn (June, July , August) , winter (September, October, November) The power outage duration during summer is more as compared to that of spring, autumn and winter Since the demand is more in summer so there is a huge gap between generation and the supply.

The power interruptions in autumn, winter and spring are much lower than summer and the interruptions are in summer are noticeably high.

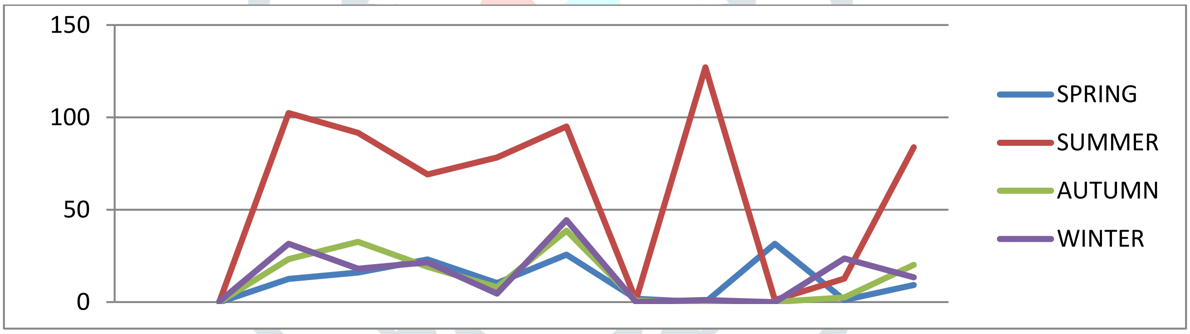

Fig: 8 Seasonal comparison of power outage duration of first year

VIII. CONCLUSIONS AND RECOMMENDATIONS

In the previous sections we have discussed the substation reliability and customer reliability. Analysis and suggestions are made for the improvement of reliability of substation. Details regarding major and frequent interruptions occurred at the substation and measures taken to overcome the same.

The incoming line was tripped on the back up over current relay fault (OCR) & earth relay fault (EFR) and the measure was Relay co-ordination should be done properly. Incoming line was tripped on distance relay and the measure was Proper maintenance and care should be taken to avoid causes for tripping. There was a fault on incoming underground line 1 and 2 the measure was Station load was transferred on overhead line during line clear period. Hence station supply not affected.

The following analysis were done, Comparison of peak loading of Transformers 1,2&3, Comparison of Reliability of substation in JAN-MARCH, Comparison of scheduled & unscheduled power outage duration of two years and Seasonal comparison of power outage duration in first year.

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