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Reliability Prediction of 220 kV Kerala Power system using Neural Network

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Abstract*— Power system reliability is an important factor to be considered in the operation of modern electrical power system. The ability of the system to provide an adequate supply of electrical energy is usually defined by the term reliability. Reliability analysis methods used here is fault tree analysis and event tree analysis. Due to the complex nature of the power system, it can cause interruptions to the system due to failures. Failures are the events where the system fails to operate. The method here takes into account the effect of line faults and failures of power system. Fault tree helps for finding the failure probability. From the analysis, Minimal cut sets and important reliability indices can be calculated. Event tree helps for classifying whether the system is safe or failed. Also it gives the different consequences of a system after the occurrence of a fault. Also the failure rate and reliability prediction was done using Genetic Algorithm based neural network.

***Index Terms*—Event Tree, Fault Tree, Neural Network, RAM Commander.**

I. INTRODUCTION

The main function of electric power system is to supply electrical energy to the consumers continuously without any disturbance. The ability of the power system to supply adequate energy is termed as reliability. The word 'reliability' means the science of predicting and analyzing failures over time. Power system stability is the ability of the system to withstand sudden disturbances such as short circuits, line faults etc [1]. It depends on the number of outages or power failures that will occur in the service period. It is the ability of the system to perform its intended function, where the past analysis of the system helps to estimate future performance of the system [2]. Power system instability may be caused due to protective action which is delayed or failed [3]. Reliability is defined as the probability of a device or system performing its function adequately, for the period of time intended, under the specified operating conditions. According to the working of components in a system, its failure rate varies. The random parameters of the reliability are represented by probabilistic functions. Probabilistic methods help to determine weak points in the power network and to find out solutions to improve reliability [4]. The problem here is to compute the probability that the system is working which we call as the reliability of system. In some paper, probabilistic approaches are done by developing a power system model for analysing the dynamic behaviour of the system [5], [6]. In this paper the reliability evaluation of whole 220 kV substations in Kerala are considered. Different reliability parameters of 220 kV feeders in Kerala are calculated. The reliability assessment methods here used are Fault Tree Analysis and Event Tree Analysis. Fault tree analysis is the one of the most widely used methods in system reliability analysis. It is a graphical model of pathways that can lead to undesirable event. Many papers deal with the reliability of protection but they didn't consider the consequences of failures of power system [1]. Event tree which helps to determine the consequences of single failure for the whole system reliability. Fault tree is said to be a deductive approach as it moves from system failure to its reasons and event tree is an inductive approach which starts from basic failures to its consequences. Also the failure rate and reliability value was predicted using GA based neural network.

II. RELIABILITY TERMS AND DEFINITIONS

Reliability parameters are the essential factors that influence the overall system reliability. Some of the reliability terms and indices are explained below.

Failure rate is the rate with which a system or component fails. Failure rate is also known as hazard rate. It is defined as the number of units that fail during an interval by the number of units alive at the beginning of the interval. We use Mean Time to Failure (MTTF) as a measurement of Failure Rate, and MTTF is simply the reciprocal of failure rate. Refer to (1) for its expression.

$$\lambda = \frac{1}{MTTF} \tag{1}$$

Repair rate is the rate at which a system is under repair. A repairable system, when failure occurs is restored to operation by any repair action without replacing the entire system. It is the reciprocal of Mean time to Repair.

$$\mu = \frac{1}{MTTR} \tag{2}$$

Unavailability is the fraction of time a device cannot work. Availability is the steady state probability that a component or a system is in service. As reliability increases, availability also increases.

$$Availability = 1 - Unavailability \tag{3}$$

$$Availability = \frac{\mu}{\lambda + \mu} \tag{4}$$

Reliability is the ratio of survivors at any given time to the total initial population. Also reliability can be found from the failure rate and total unscheduled hours during the period.

$$\text{Reliability, } R = \exp^{-(\lambda t)} \tag{5}$$

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The fundamental issue in reliability analysis is the uncertainty in failure occurrences and consequences. Reliability analysis aims at the quantification of the probability of the failure of the system. In power systems, reliability analysis and assessment are essential factors for the continuous operation of the system [7]. Each 220KV substations and generating stations in Kerala are represented by their schematic symbols. Power system model is composed of eight generators and 23 buses. Fig 1 shows the Kerala grid map of 220kV substations.

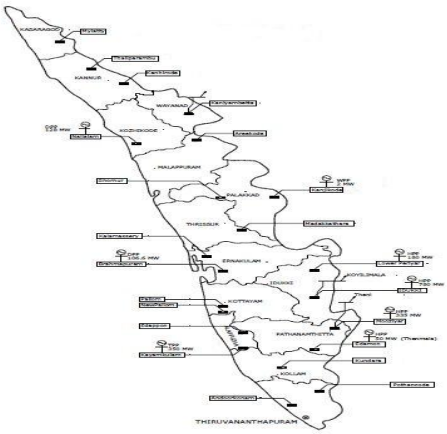

Fig 1. Kerala grid map of 220KV substations

A. Fault Tree Analysis

Fault Tree Analysis (FTA) is a technique for reliability and safety analysis. Fault tree can be applied to complex or multi element systems. It is mainly used for finding the faults and its root causes. Fault tree helps to identify how the system may fail to function. The undesired state of the system, which is identified at the beginning of the fault tree analysis, is usually a state that is critical from a safety or reliability standpoint and is identified as the top event. The probability of the undesired event can be evaluated using the numerical probabilities of occurrence. FT consists of gates which serve to permit or inhibit the passage of fault logic up the tree [8]. Primary or basic events are the termination points of the analysis. For a quantitative model, it is necessary to assign values (probability or frequencies) to these events. Logical relationships like union and intersection between events constitute the gates of the fault tree. The most commonly used logic gates are AND gate and OR gates. AND gate represents a condition the output event will occur only if all of the input events exist simultaneously. OR gate represents that the event will occur if only one or any combination of the input events exists. Symbols are used to represent various events and there are five types of event symbols:

- Rectangle - The rectangle is the main building block for the analytical tree. It represents the negative event and is located at the top of the tree and can be located throughout the tree to indicate other events capable of being broken down further.
- Circle - Circle represents a base event in the tree. There are no gates or events below the base event.
- Diamond - The diamond identifies an undeveloped terminal event
- Oval - An oval symbol represents a special situation that can only happen if certain circumstances occur.
- Triangle - The triangle signifies a transfer of a fault tree branch to another location within the tree [9].

Here the RAM Commander Software was used for drawing the Fault tree diagram. Fig. 3 shows the fault tree diagram of the system done using RAM Commander software.

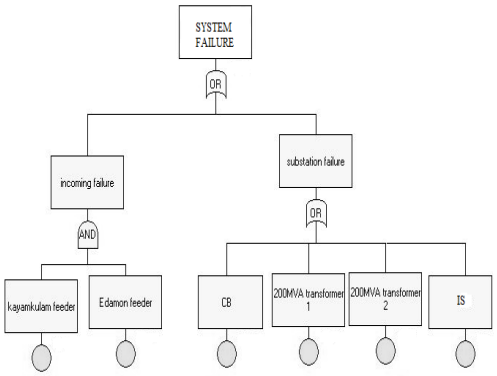

Fig 3. Fault Tree Diagram

B. Event Tree Analysis

An event tree is a pictorial representation of all the events which can occur in a system. Event Tree Analysis (ETA) is the technique used to determine potential accident sequences associated with a particular initiating event or set of initiating events. The event tree is a standard tool in probabilistic risk. Event tree analysis provides an inductive approach to reliability assessment as they are constructed using forward logic.

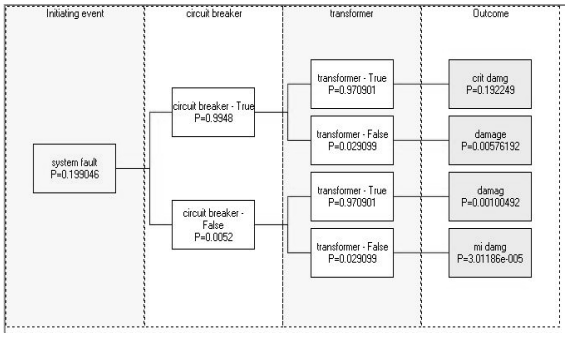

Fig. 4. Event Tree Diagram

Event tree analysis was done using RAM Commander software. Initiating event considered here is an accidental event and their probabilities are defined first. We have to add its success and failure branches resulting in different outcomes. From this the probability values of different outcomes were obtained. Fig. 4 shows the event tree diagram of the system done using RAM Commander software.

III. RELIABILITY PREDICTION

Reliability estimation and prediction are very important in power system. Reliability prediction is commonly used for

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various purposes like maintenance planning, fault detection, risk evaluation etc. Here the reliability prediction was done using Neural Network. The weight optimization of the network was done using Genetic Algorithm. In this paper, the prediction was done using the software called neural lab. Neural network architecture was presented here for the prediction of reliability of 220 kV Kerala power systems. Artificial Neural network is an artificial intelligence technique whose processing is based on biological neural network. Neural network only requires failure history as input and it can predict the future failure values [10]. Here the weight optimization was done using genetic algorithm for more accurate performance. Fig. 5 shows the Neural Lab window with the help of which the reliability predication was done.

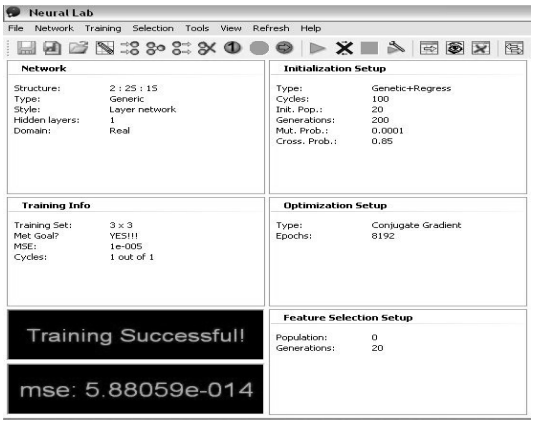

Fig. 5. Neural Lab window

IV. DATA ANALYSIS

In this paper, we have collected the outage details of the Kerala power system. Failure rate, Repair rate, unavailability and availability of Kerala power system was calculated using the outage data of five years from 2008 to 2012. In power system, there are two types of interruptions- planned and unplanned interruptions. Planned or scheduled interruptions are those which happen purposefully for maintenance or other permit works. Unplanned interruptions are the unexpected ones. Failure rates are useful for estimating the maintenance costs but we can't say whether the device is available or not. Availability and unavailability are expressed as probability and its sum is taken as one. Unavailability is the fraction of time a device cannot perform.

V. RESULT SUMMARY

The failure data of five years that is operating period 2008-2012 was collected. Reliability parameters were calculated for the reliability analysis using these data. The reliability parameters include failure rate, repair rate, unavailability and reliability. Different plots of these parameters with respect to corresponding years are shown here. The plots of failure rate, repair rate, unavailability and reliability was shown in the Fig. 5 to Fig. 8 respectively.

Fig.5. Failure rate of 220 KV System

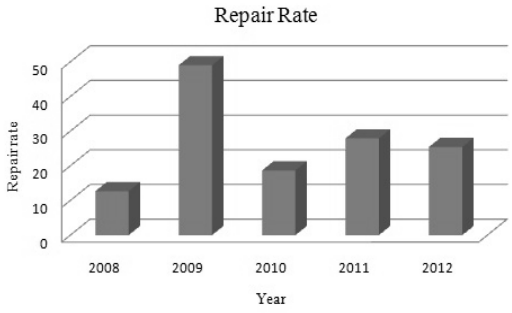

Fig. 6. Repair rate of 220 KV System

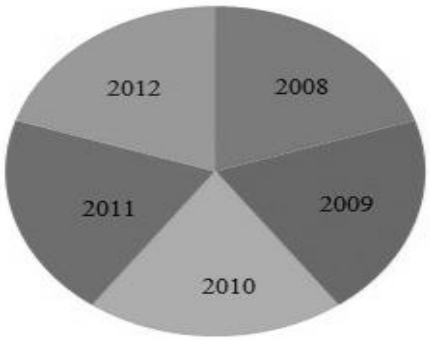

Fig 7. Unavailability of 220 KV System

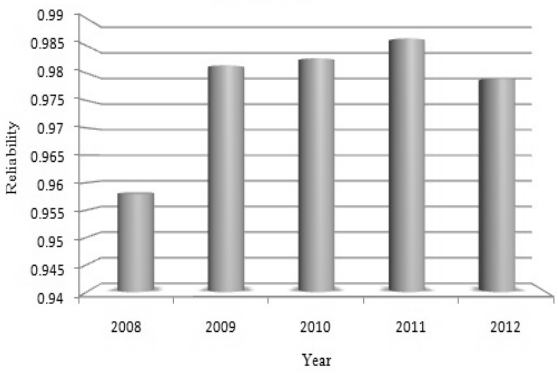

Fig. 8. Reliability of 220 KV System

Fault tree was done using RAM Commander software. From the Fault tree, the probability of failure of substation was obtained. In this fault tree there are six primary events. In

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the fault tree drawn there are five minimal cutsets. Also they listed the failure contribution and importance analysis of the tree. The probability of top event is 1.990462E-001. Table II shows the details of primary events and its failure probability.

TABLE II PRIMARY EVENT ANALYSIS

Event	Failure contribution	Importance
CB	5.20E-03	2.61%
IS	6.10E-03	3.06%
Edamon	4.00E-04	0.20%
Kayamkulam	4.00E-04	0.20%
Transformer1	3.56E-02	17.88%
Transformer2	1.60E-01	80.23%

Event tree was drawn using RAM commander software. Here the initiating event taken is the system fault. After giving the probability value of initiating event, we get different outcomes with different probability values. Using those probability values, the consequences of the system can be analyzed. Reliability prediction was done using Neural lab software. The reliability values calculated for the five years were given as the input. The reliability value of next year was obtained after training of neural network.

VI. CONCLUSION

The paper helps for the evaluation of reliability of 220kV Kerala power system. Reliability assessment methods used in this paper were fault tree analysis and event tree analysis. Failure probabilities of the system and its different consequences were obtained with the help of RAM Commander software. Different plots of reliability parameters helps to understand the area where the majority of failures occur. Reliability can be improved by the proper maintenance of the components within the system. From the analysis we can understand the various reasons for the failure of system. Reliability parameters were calculated for the analysis. The reliability parameters include failure rate, repair rate, unavailability and reliability. The reliability and failure rate value for the next year was predicted using neural network. This helps in the improvement of system performance and power system protection.

VII. ACKNOWLEDGMENT

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Prof. Abdul Jaleel. J received the Bachelor degree in Electrical Engineering from University of Kerala, India in 1994. He received the M.Tech degree in Energetics from Regional Engineering College Calicut, Kerala, India in 2002, and PhD from WIU, USA in 2006. He joined the EEE department of TKM College of Engineering as faculty member in 1990. He was with Saudi Aramco in 1996 to 1998 and worked in the field of power generation, transmission, distribution and instrumentation in the Oil and Gas sector of Saudi Arabia. He was with Water Supply department of Sultanate of Oman in 1985 to 1986 and worked with the maintenance of Submersible bore-well pumps and power supplies. He was with Saudi Electricity Company in 1979 to 1985 and worked in the Generation, Transmission and distribution fields. He worked with project management, Quality Management and he is a certified Value Engineer and Auditor for QMS. He is a consultant for Oztern_Microsoft, Technopark, Kerala and Consultant for Educational Projects of KISAT and MARK Research and Education Foundation. Currently he is a P.G. Coordinator of M. Tech Programme in the TKM College of Engineering under University of Kerala and Director of Kerala Institute of Science and Technology. His areas of interest are power system Control and optimization, power system reliability, voltage stability, computer aided design and analysis.

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