# A Comprehensive Study of Faulted Section Estimation Methods in Electric Distribution System

Yogendra Kumar

*Electrical Engineering Department*
*Maulana Azad National Institute Technology*
*Bhopal. Email:ykmact@yahoo.co.in*

## ABSTRACT

**The comparative study in this paper addresses the problem of fault section estimation following the occurrence of fault in electric distribution system. The operator & decision support for fault section estimation is an active research area. It is important for operator to locate the faulted section as quickly and accurate as possible so that restoration plan may be implemented as soon as possible to enhance the supply continuity and achieving better efficiency. This paper provides a comprehensive survey of the conceptual aspects as well as recent algorithmic developments to identify the fault location in distribution system. Several fundamentally different approaches are discussed in the paper together with strength, weakness of faulted section estimation schemes as currently practiced and recently reported. Fault section estimation is classified broadly in three categories , viz., Artificial Nueral Network Expert system, Genetic Algorithm. Different methods developed in each category along with further scope of research are also briefly discussed.**

## I. INTRODUCTION

A continuous and reliable electric energy supply is the objective of any power system operation. Nevertheless, faults do occur in power system, The faults take place more frequently in distribution system than transmission line. Following the occurrence of a fault in distribution system, the maintenance crew must find and fix the problem to restore the service as quickly as possible. Rapid restoration of the service reduces the outage time and loss of revenue. Therefore the accurate fault location under a variety of fault conditions is an important requirement. A fault in a power system can trigger cascaded events, leading to major outage if the fault is not isolated quickly and accurately. Over the last three decades due to technological progress in computers and electronics, power system have been equipped
with digital relays. Power system components includes bus bars, lines, transformers switches relays and communication devices. Due to complexity, a fault on one component can trigger numerous other events. Alarm messages are recorded at sub-stations by sequence of event recorder. Remote terminal units can also transmit analog and status data to the control centre through the supervisory control and data acquisition (SCADA) systems. For complex fault or malfunction scenarios identification of the fault location, type and malfunctioning devices may require extensive knowledge about the power system and its protective devices.

Traditionally, fault diagnosis is performed off line by experienced engineers. However, software tools for fault location have emerged in recent years. To improve the accuracy and speed of fault location the information is stored in a database and intelligent systems in a control center can access the database for diagnosis of a fault event [1]. In [2]-[4], the authors proposed Knowledge Based System (KBSs) that compares actual events messages with simulated messages. Most of their work focused on the development of an inference engine that access knowledge modules to perform fault location. A Model Based System (MBS) uses models that represents physical relations between event messages and power system components [5],[6]. In [5], the author use logic gets to determine the correct module that explains the cause of transformer alarms. The accuracy of fault location in KBS or a MBS relies to information in the knowledge modules and models. To deal with a complex scenario, the time required to diagnose an event would increase with amount of their information. To solve this issue, LBSs have been developed for fault location. The expected behavior of protective devices (e.g. relays and breakers) in response to a fault is formulated into a set of logic formulas that can be used to derive the fault/malfunction events [7],[8] -An Logic Base Systems does not require a search engine for informing (While KBSs do).

The adductive inference technique is proposed for identification of fault location [10]. The accuracy of fault diagnosis depends on the completeness of event messages. Completeness can be divided by type of protective and communication devices that vary from power system to another. The most common information for fault diagnosis is the status of breaker. In [11] the authors use a set of current transformers with Kirchhoffs law to identify a fault location. To identify the exact fault location rather than a wider fault zone, voltage and current wave forms recorded by digital fault recorder have been used in power systems to record the relay and breaker operation [8],[13],[14].

None of the fault diagnosis systems introduced above considers malfunctions of the protective devices, communication devices and/or recorders especially, malfunctioning of communication devices/recorders can significantly affect the accuracy of diagnostic results. For some power systems, event recorder are not available at all substations. As a result, detailed event information from the protective devices may be unavailable. These considerations must be taken into account to achieve a practical fault diagnosis system.

## II. ARTIFICIAL NEURAL NETWORK

Artificial neural networks have been successfully applied to many power system planning and operation problems in recent years [16],[18]. ANNs may be able to provide a better solution to the analysis of alarms in control centers to identify the faults due to their special properties [19]. Such as their ability to learn from examples, without extra effort required in defining rules, their ability to function with noisy inputs (malfunction of relays, etc) their ability to identify faults in a short time and ease with which they can be adopted by the various utilities. ANNs are fault tolerant and once trained, present very short execution times. Besides, they present generalization capability during real time inferences, which means that they are able to perform satisfactorily even for unseen alarm patterns.

The idea of using a neural network for fault diagnosis is first described in [6] where a back-propagation is used to study the fault diagnosis of a power system. A hybrid system, a rule based system and a back propagation based neural network model, for alarm processing is described in [20]. Some ANNs based method have been proposed for fault location. In [21],[22] the use of only one ANN for monitoring the whole power system makes its application very difficult for real size power systems, as the number of input variables would be extremely large. The application of different ANN for different system configurations have been proposed in [23]-[25]. These methods assume that the protection system without fail and that all alarms and messages will be always available at the control centre. This situation may not occur for real power systems. In [26] the application of device specific ANNs have been proposed. Following the occurrence of a fault, some ANNs are executed and each ANN output serves as input to other ANNs. The result is an iterative process in which a final diagnosis is obtained only after all activated ANNs stabilize their individual diagnosis. However, in case of protection device failures, the available information may not be sufficient to obtain correct diagnosis through the tested ANNs and an accurate final diagnosis may not be achieved. Recently, an ANN approach through the use of local neural classifiers has been investigated [27] test with small system showed that the .method can produces good results even under different situation such as data loss and protective device failures. In [28] the method explores the fact that the identification of a faulted component requires only information from alarms coming from a restricted area in the system. A load strategy is proposed to tackle the problem of dimension. Several neural classifiers are employed each of them being responsible for monitoring a limited number of system components. Decision rules are presented in order to achieve accurate final diagnosis from the analysis of the ANNs classifications. Correct diagnosis is obtained even in case of protection devices failure data loss, noisy data etc. There is no doubt that fault location using ANN techniques is very fast and gives result without taking any time. But it is seen that the accuracy is very poor in comparison of other techniques. So in ANN technique more research is required to improve the accuracy.

## III. EXPERT SYSTEM

During last few decades, many expert systems have been proposed to cope with various operational problems in power systems fault diagnosis alarm processing and restoration etc. for the eventual dream of the fully automated reliable power systems. Regarding the fault diagnosis or fault section estimation problem, Fukes [29] and others [30],[31] have proposed the expert system approaches to diagnose the faults in a transmission network. Regarding the substations, since the substation automation has become a major uses, many fault diagnosis system [32]-[37] have been proposed. Protopapos [32] proposed an interactive expert system for non experts using PC-SCADA. Venkata [5] proposed a basic expert system approach on the ICPS (Integrated Control and Protection system). Japanese power companies have announced many prototype or practical system through[6]-[9] for a substation. Kansari Power company has developed one for a 500 KV substation [6]and another one for a 275 KV substation [35]. Tokyo. Electric power company has developed a supervisory system [36] and Chabu power company presented a frame based expert system [37]. A practiced expert system [38] for the fault diagnosis for multiple distribution substations combined with a SCADA. Like many countries, the Kaream power system has applied the hierarchical distributive control structure, which comprised of one MCC (main control centre) at the top level a few RCCs (Regional Control Centres) at the medium level, and many LCC (Local control centres) as the subsidiaries of RCCs. The major functions of a LCC are monitoring and control of affiliated distribution substations. Ninty percent of the substations are unmanned by now. The expert system [38] was installed as a part of the intelligent guidance system in a LCC in Korca, and is functioning since 1994. This system has all advanced functions such as the fault diagnosis in multiple substations with multiple faults, in exact reasoning and hypothesis generation (explaination function) including the discrimination of the false or non operation of the protective devices. Another special feature of this system is the utilization of knowledge to describe the general topological information [39]. This feature contributes to the compact and efficient structure of the integrated guidance system and enhancement of the overall performance.

The four years operating experience and over 60 case studies on the past faults history of the red power system have proved the 100% diagnostic performance of this expert system, which means that the real fault sections have, been exactly estimated by the most possible solution generated by the system for all the cases.

## IV. GENETIC ALGORITHM TECHNIQUE

In this paper, so far it has been told that several methods have been reported, such as logic based method [40], expert systems [41 ],[ 42] and artificial neural network [43], [44] for faulted section estimation. But the expert system based method is the most successful. Upto now many kinds of expert systems have been developed using the conventional knowledge representation and inference procedure such as rule based [41] and model based [42] approaches. In order to achieve precise inference especially in the complex fault cases, the expert system based on production rules must involve a great number of rules describing the complex protection system behaviors. Maintenance of the large knowledge base becomes very difficult. On the other hand, the model based system is easy to maintain, but the inference process is time consuming. The application of artificial neural networks (ANN) to the fault section estimation has been an active research area. ANNs methods can be planned into two categories. The first kind is to treat the fault section estimation problem as a classification problem, and use the appropriate ANNs such as the Back propagation model or the Kohenon model to train and estimate [43]. It is very difficult to reasonably specify a sample set, so the correctness of the estimation result can not be guaranteed theoretically. The second kind is to formulate the fault section estimation problems as 0-1 integer programming problem and uses the appropriate, ANNs such as the Boltmann machines to solve it for example [44]. The 0-1 integer programming model of the fault section estimation problem using information from protective relays and circuit breakers [45],[46] have been developed and three methods i.e. Simulated Molecular Evaluation [45], Simple Genetic Algorithm and Simulated Annealing method [46] have been presented to solve 0-1 programming problem. It is shown by many simulation results that the developed mathematical model is correct and the proposed three methods are suitable and efficiel1t, and can find multiple global optimal solutions directly in a single run, and are of great promise for on line fault diagnosis. Of these three methods, Simple Genetic Algorithm appears to be the best in terms of computational efficiency and storage requirement. The research work presented in [45],[46] has been extended in [40] in following three aspects:

a. The mathematical model of the fault section estimation problem by using the time sequence information of the tripped circuit breakers at the actuating time zones of any protective relay is proposed for the first time. The objective in developing such a mathematical model is to seek a fault section estimation method for some power systems in which the information of the protective relays is not available or is incomplete. In many power systems of some developing countries, the information of protective relays cannot be obtained on-line at the dispatching centers, so it is necessary to develop a fault diagnosis method by using the real time information of circuit breakers only. Method [40] is the first attempt to solve this problem.

b. An efficient method to identify subnetworks which include all possible faulty sections is developed by using a real-time network configuration determination method. When faults occur in a power system, the protective relays corresponding to the faulty sections should actuate and isolate the faulty sections out of operation. In other words, the faulty sections will be disconnected from the healthy part of the power system of the operation of the corresponding protective relays and circuit breakers. Thus, some isolated subnetworks will be formed which include all faulty section and have no generators, and we can restrict the fault section estimation problem to these subnetworks only. In this way, the size of the problem can be greatly reduced, and very fast computation can be achieved, quickly.

c. Several schemes of Refined Genetic Algorithms (RGA) are adopted to solve the fault section estimation problem, and the simulation results of three sample power systems show that RGA can be more efficient than SGA and can find multiple optimal solutions directly and efficiently in a single run.

## V. CONCLUSION

In this paper 46 papers are reviewed and rest are taken as reference, based on which following is concluded.

On occurrence of fault in distribution system, the attempt is always made to find the fault quickly and accuratly as possible. The methods used for fault section estimation are classified in three major categories (l)Artificial Neural Network (2)Expert system (3)Genetic Algorithm.

ANNs may be able to provide a better solution to the analysis of alarms in control centers to identify the faults due to their special properties. Such as their ability to learn from examples, without extra effort required in defining rules, their ability to function with noisy inputs (malfunction of relays, etc) their ability to identify faults in a short time and ease with which they can be adopted by the various utilities. ANNs are fault tolerant and once trained, present very short execution times. But accuracy of ANN in fault location is found poor in comparison to others. It is very difficult to reasonably specify a sample set, so the correctness of estimation result cannot be guaranteed theoretically. A significant research work is required in ANN to improve the accuracy. The expert systems developed to identify the fault location are doing well. These expert systems are developed on knowledge base or model base. Such experts system have also been developed whose 100% accuracy is found. But time consumed to give the result is found more in comparison to others. Moreover, in order to achieve precise inference especially in the complex fault cases, the expert system based on production rules must involve a great number of rules describing the complex protection system behaviors. Maintenance of the large knowledge base becomes very difficult. On the other hand, the model-based system is easy to maintain, but the inference process is time consuming.

The main contribution of Genetic Algorithm technique developed to locate the fault in distribution system are:

1) A mathematical model of fault section estimation problem by using time sequence information of circuit breakers only is developed for the first time.
2) An efficient method to identify the faults, sub-networks is presented, and in this way the fault section estimation problem can be confined to these sub networks and very fast fault diagnosis can be implemented in line for large scale power systems.
3) A simple Genetic Algorithm and several schemes of Refined Genetic

Algorithms have been adopted to solve the fault section estimation problem and many simulation results have shown that these methods can find multiple optimal solutions directly and efficiently in single run. More research work is required to make Genetic Algorithm more efficient and to improve the accuracy.

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