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PII: S2314-7172(17)30006-5
DOI: http://dx.doi.org/doi:10.1016/j.jesit.2017.01.004
Reference: JESIT 151

To appear in:

Received date: 13-4-2015
Revised date: 11-10-2016
Accepted date: 10-1-2017

Please cite this article as: Avagaddi Prasad, J.Belwin Edward, K.Ravi, A Review on Fault Classification Methodologies in Power Transmission Systems: Part – I, http://dx.doi.org/10.1016/j.jesit.2017.01.004

A Review on Fault Classification Methodologies in Power Transmission Systems: Part – I

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Abstract **–**This paper presents a survey on different fault classification methodologies in transmission lines. Efforts have been made to include almost all the techniques and philosophies of transmission lines reported in the literature. Fault classification is necessary for reliable and high speed protective relaying followed by digital distance protection. Hence, a suitable review of these methods is needed. The contribution consists of two parts. This is part 1 of the series of two parts. Part 1, it is a review on brief introduction on faults in transmission lines and the scope of various old approaches in this field are reviewed. Part 2 will focus and present a newly developed approaches in this field.

Index Terms- Fault; Fault Classification; Protection; Soft Computing Techniques; Transmission Lines.

I. INTRODUCTION

Here transmission lines shield against uncovered deficiency is the most basic errand in the assurance of power system. Faults in overhead lines are an unusual condition, brought on by climate conditions, human mistakes, smoke of flames, hardware letdowns, for example, pivoting machines and transformers, and so on. These issues cause intrusion to electric streams, hardware harms and even cause passing of people, winged creatures, and creatures. These issues are hazard to the congruity of power supply. Fault is nothing but an abnormal condition. For easy to understand, this paper comparing transmission system faults with human diseases. For example, a healthy person in his day to day life disturbs whenever he faces any abnormal condition, here abnormal condition in the sense nothing but diseases like cold, cough, fever, heart attack, cancer etc. In a similar way in power transmission systems the system quantities (voltage, current, phase angle etc.) exceeds its threshold values whenever the system faces an abnormal condition, this is called as a fault. The maximum part of the overhead transmission line exposed to atmospheric condition, so the chances of occurrence of faults in overhead transmission lines were more when compared to underground cables. Faults in overhead transmission system can be classified into two types, i.e. series (open conductor) faults, and shunt (short circuit) faults. Series faults can be identified easily by observing the each phase voltage. If the voltage values increases, it indicates that open conductor fault is occurred. These faults are classified into two types, i.e. one open conductor faults, and two open conductor faults. These faults are very rarely occurred faults. Short circuit faults can be identified easily by observing the each phase current. If the current values increases, it indicates short circuit fault is occurred. Short circuit faults are divided into two types, i.e. asymmetrical faults, and symmetrical faults. Asymmetrical faults line to ground (LG), line to line (LL), and double line to ground (LLG), and symmetrical faults are triple line (LLL) and triple line to ground (LLLG) faults. The Fig. 1. shows the classification of faults in overhead transmission system, in this figure A, B, C, and G indicate phase A, phase B, phase C, and ground respectively.

The frequency of occurrence and severity of the faults are going to be compared again with human diseases. The most commonly occurring fault is LG fault and the most commonly occurring diseases are headache,

cold. As we know, headache and cold are less severe compared to other diseases, in the same way, LG fault also less severe compared to other faults. The next fault in severity wise and occurrence wise is LL fault. It can be compared with diseases like fever and LLG fault with viral fever and 3- phase (LLL and LLLG) faults can be compared with big disease like heart attack, it means if 3-phase fault is occurred, the total system will be collapsed, so it was compared with big diseases like heart attack. So protection scheme needs to detect the fault and classify nature of the fault and location of the fault within less time to avoid the major damages. For this up till now, so many methods are invented, each method has their own advantages and disadvantages. So selecting a fault classification method is a big task for users. Hence, it is required to make a review that covers all the efficient and effective fault classification methods proposed. Several fault classification methods together with their execution are described in the literature. In this review article, an attempt has also been made to relate the fault classification methods on the basis of their techniques, simulation tools used in that corresponding approach. This review article tries to deliver a survey on maximum of the reported fault classification methods. Part 1 of this paper presents a review on popular and hybrid techniques and Part 2 of this paper discusses the newly developed fault classification approaches. This Part 1of this article is prepared as follows. First, Section 1, describes the brief introduction on fault and fault classification in transmission lines. In Section II, fault classification methods taken out from an enormous collected works are presented. Section III describes comparison of fault classification techniques in transmission lines and the concluding explanations of Part 1, and it introduces the topics that have been discussed in Part 2.

II. SURVEY ON FAULT CLASSIFICATION METHODS

Classification is a general procedure related with categorization, the procedure in which thoughts and items are perceived and separated. Classification permits us to see connections between things that may not be clear when taking a gander at them in general. Classifying things likewise makes it less demanding for us to make subjective judgments about the value of various things. Classification required mainly for business, science, mathematics, media, associations, financial aspects, industries, security arrangement, etc. In power system, overhead lines are most effortless to analyze since the issue is normally self-evident, e.g., a tree has fallen over the line, or a utility shaft is broken and the conductors are lying on the ground. The exactness about its fault recognition and classification are the most vital elements for protection of overhead line. The association of new generating stations to fulfill this quick increment sought after requires growing transmission and distribution facilities. The subsequent lower dependability limits make it imperative to clear the transmission faults quick utilizing fast protection strategies. This has produced another enthusiasm for the transient based protection techniques. Due to so many techniques developed for fault classification, the user may get confusion to select the appropriate technique. To understand easily this review divided the widely used fault classification techniques into 3 types as follows:

A. Prominent Techniques
B. Hybrid Techniques
C. Modern techniques

The Fig. 2. shows the tree diagram of the existing fault classification methods in fault analysis.

A. Prominent Techniques

Prominent techniques are well-known techniques, commonly used for fault classification in transmission lines. These Techniques are classified into 3 types. They are

A.1 Wavelet Approach
A.2 Artificial Neural Network Approach
A.3 Fuzzy Logic Approach

The explanation of each technique is given below. The Fig. 3. shows the single line diagram of typical power system considered for the simulation.

A.1 Wavelet Approach

Wavelets are a numerical tool for signal preparing. The fundamental thought in wavelet transform (WT) is to choose a reasonable wavelet function as "mother wavelet" and afterward execute examination utilizing moved and enlarged adaptations of this wavelet. Wavelet can be picked with exceptionally attractive recurrence and time attributes when contrasted with Fourier procedures. The Fourier extension has just frequency determination and no time determination. This implies it decides every one of the frequencies present in the signal however it doesn't tell at what time they introduce. To conquer this issue WT is proposed. WT gives time and frequency data all the while. WT can split signals into different frequency bands with the help of multi resolution analysis (MRA). It can be used in detecting faults and to estimate the phasors of the current and voltage signals, which are important for the protection of transmission lines. WT can split signals into different frequency bands with the help of multi resolution analysis (MRA). MRA is used for fault analysis in the protection of overhead lines. In the technique [1], the system was simulated using electromagnetic transients program (EMTP), and in which the distributed parameters model was used to simulate the transmission line, then lumped impedances model was used to simulate the local and remote end sources. In this work the simulation data used as input to classify the nature of fault [1], [2]. An approach has been implemented using wavelet technique for fault analysis with the help of wavelet entropy principle. In which the PSCAD/EMTDC used to simulate the power system presented by S. El Safty, and A. El-Zonkoly [3]. A novel approach proposed by F. B. Costa et al., shows the capability to find the faults. According to F. B. Costa et al., disturbance diagnostic method contains two modules, a fault has been identified in the first module and fault classification attains in the second module. The advantage of this approach is able to classify the cross country faults [4]. Using mexican hat and coif let as mother wavelet, an algorithm was implemented by B. Ravindhranath Reddy et al., for classifying the fault and computing the fault distance within half cycle after the fault initiation [5]. Wavelet coefficient energies of the fault-induced transients were used for fault analysis in power transmission systems. The key benefit of this recommended technique was to find the faults in real-time [6]. The Fig. 4. shows the decomposition of a signal ‘S’. In this figure, A and D indicates approximation coefficients and detail coefficients respectively.

V. Ashok et al., proposed the discrete wavelet transform for classification of faults in transmission systems. In this approach percentage of energy levels used to detect faulted phases and nature of faults were furthermore classified [7]. A solution for protection of three-terminal transmission system using discrete wavelet transform (DWT) for fault classification was presented by A. Dileep kumar et al., It helped to detect the nature of fault [8]. The energy of the signal, maximum detail coefficient and the ratio of energy change of each phase currents are calculated from the transients produced by each phase due to faults using discrete wavelet transform (DWT) and thus detecting and classifying transmission system faults. A wavelet based current signature analysis technique is used to detect and classify the nature of the fault [9]. B. Lakshmana Nayak implemented a discrete wavelet transformer (DWT) approach for fault classification, once the fault currents are known in a particular location. Phase currents in two ends of a transmission line utilized to classify the nature of fault with the help of daubechies eight (D-8) wavelet transform [10]. Avagaddi Prasad et al., has implemented a new method using currents at one end of the overhead line with the help of DWT [11]. A. R. Shahzad has proposed a method using MATLAB wavelet toolbox to detect and to classify the type of faults. Fault data generated by workspace on MATLAB simulation model has been used for fault analysis [12].

A.2 Artificial Neural Network Approach

Artificial neural network (ANN) show qualities, for example, design affiliation or mapping capacities, adaptation to internal failure, strength, speculation and fast data preparing. Neural systems can be learned by illustrations. They can in this manner be prepared with known case of an issue to obtain information about it. Once suitably prepared, the system can be put to powerful use in understanding "untrained" or " unknown" case of the problem. The essential structure of simulated neuron model appears in Fig. 5.

Thomas Dalstein and Bemd Kulicke have proposed a method based on multi-neural network for fault analysis of high speed protective relaying systems. This scheme uses digital signal processing implementation and neural network architecture concept for fault classification [13]. M Oleskovicz et al., has presented artificial neural network method as another technique for classification of faults and fault location tasks for transmission system protection scheme explored in this method. The approach uses voltage and current samples as inputs and it helps to find all types of faults [14]. M. Sanaye-Pasand et al., has proposed an approach to use current signals to study the hidden connection in the input patterns, for fault identification, classification and location could be achieved within quarter cycle. This approach shows that it is capable to achieve results accurately for different combinations of fault conditions [15]. Tahar Bouthiba has implemented a technique for extra high voltage (EHV) transmission lines for fault identification and location using terminal line data for high speed protection with the application of ANN [16]. Classification of faults in overhead lines with the help of artificial neural networks by using pre and post-fault data of power system model were presented by M.Tarafadr Hagh et al., in [17]. A distributed & hierarchical neural network (DHNN) system based on architecture of the hierarchy and integrated module is presented by Xiangning Lin et al., [18]. The DHNN system effectively uses the influential function of artificial neural networks at features of pattern identification, nonlinear approaching, associative memory et al., Its information handling mechanism matches with the processing law of classification sketchiness-accuracy in human biologic neural network system.

Anamika Jain et al., has proposed a technique for fault identification and classification for the double circuit overhead line with double end in feed by using only current signals measured at local ends [19]. Muntaser Abdulwahid Salman et al., has presented a protective relaying pattern classifier algorithm with the help of artificial neural networks. This methodology demonstrates that severe three phase trips are simulated on four discretionary areas of uncontrolled overhead lines [20]. In present days, the need of high phase order transmission system increases due to the consumption of power increasing continuously. Six phase transmission lines will be able to transmit extra power for same phase to phase voltage with the same right of way economically. It's a big challenging task to protect six phase transmission lines. Ebha Koley et al., has demonstrated a methodology for fault analysis in six phase transmission system with the assistance of artificial neural networks [21]. A novel approach for double line to ground faults in teed transmission lines using neural networks was presented by Prarthana Warlyani et al., in [22]. In this method, double line to ground faults were identified with the help of the voltage and current signals at one end of the teed circuit. Anamika Yadav et al., has proposed an adaptive protection technique for doubly fed transmission lines shows that line-to-ground faults (both forward and reverse) [23]. This procedure uses the fundamental components of phase voltage and phase current measured at one end only. This method gives the automatic determination of fault direction (forward or reverse) and location of fault after one cycle from the inception of fault.

Eisa Bashier et al., has actualized the utilization of back-propagation (BP) neural system design as an option strategy for fault examination. In this work, the distance protection plan is subdivided into various neural systems for classification of faults in different regions [24], [25]. N. Saravanan et al., has presented a comparative study of fault analysis of double circuit transmission line based on artificial neural networks. It is a new presentation of neural network with three different feed forward neural networks, those are cascaded

correlation feed forward network (CFBPN), radial basis function (RBF) network and back propagation algorithm (BPN) presented in [26]. Suman Kumar Saha et al., developed a relay for identification of faults in overhead lines based on ANN [27]. Moez Ben Hessine et al., has developed a technique using current and voltage of each phase. The outputs of the artificial neural network indicate the fault presence and its nature. The strategy approaches information of current and voltage tests of every stage on a terminal like contribution at the relating ANN for classifying the nature of the fault [28]. Sanjay Kumar K et al., has proposed another technique for classification and isolation of faults in overhead lines using back-propagation (BP) neural network architecture. This work highlights phase RMS values of voltage and current used as inputs for fault classification [29]. Smriti Kesharwani et al., has developed a technique based on MATLAB software to notice the fault on transmission lines. The output of the Simulink model is used to train the ANN to find the faults in transmission systems [30].

A.3 Fuzzy Logic Approach

The utilization of fuzzy logic has gotten a great deal of consideration as of late on account of its adequacy in diminishing the requirement for complex scientific models in critical thinking. Fuzzy logic utilizes linguistic terms, which manage the easygoing relationship amongst input and output variables. Hence, fuzzy logic technique makes it simpler to control and to take care of numerous issues, especially where the numerical model is not unequivocally known, or is hard to settle. Fuzzy logic gives not just a capable representation for estimation of instabilities additionally an imperative representation for vague ideas expressed in natural language. It is a scientific hypothesis, which incorporates the piece of information of ambiguity while portraying an importance or idea. Fuzziness is fundamentally one method for portraying uncertainty. Such ideas are valuable in issue order. The general procedure performed in a fuzzy logic methodology appears in Fig. 6. where S1, S2, and S3 are three inputs to the fuzzy classifier, used to characterize fault type.

Alessandro Ferrero et al., has proposed a method to classify the fault in transmission lines utilizing fuzzy set methodology. The beauty of the proposed approach was to calculate the symmetrical components properly in the existence of harmonic distortion and exponential decaying components [31]. A technique for the safeguard of EHV transmission lines based on travelling waves and fuzzy logic method has been presented by Parmod Kumar et al., in [32]. To estimates the frequency, fault voltage and current signals at one end of the transmission line were used. This technique can calculate the distance between them by using time taken by wave from fault location to relay end [32]. Biswarup Das et al., has established a technique to identify the nature of faults based on fuzzy-logic-algorithm. This method was able to classify exactly the phase(s) involved in all ten kinds of shunt faults that may possibly happen in a transmission line under different inception angle, fault resistances and loading levels. It needs only three line current measurements to perform the method [33]. The general structure of fuzzy inference system (FIS) utilized as a part of this strategy appears in Fig. 7.

R.N. Mahanty et al., has built up a methodology for fault analysis utilizing current samples with the help of fuzzy logic. In this technique, only one end of three phase current samples was considered to achieve the fault classification [34]. Carlo cecati et al., utilized fuzzy-logic method to increase the exactness in fault classification for both single and double-circuit transmission lines. This technique can find both symmetrical and asymmetrical faults. The benefit of this methodology is, it can separate the faulty and non-faulty phases [35]. Shashi R et al., has developed a scheme to detect the line to ground fault by using fuzzy logic. The developed method needs post fault current samples at one side of the transmission line only. Simulation studies are carried out in PSCAD/EMTDC on 400 kV, 300 Km transmission line model designed for different types of single phase to ground faults [36]. Avagaddi Prasad et al., has been implemented a new approach using two fuzzy rule systems. One is for ground faults and other is for phase faults [37]. S.R. Samantaray

has developed a new strategy to investigate the faults in overhead lines based on fuzzy system, which was superior to any heuristic fuzzy rule-based technique. In this work a comparison was also made between s-transform and wavelet transform. Finally, they conclude that s-transform based decision tree (DT)-fuzzy delivers accurate fault classification [38].

B. Hybrid Techniques

Hybrid techniques discuss the integration of the three techniques, namely wavelet approach, ANN approach, and fuzzy logic approach. Hybridization has been to overcome the drawbacks in one approach during its application, with the strengths of the other by appropriately integrating them. These are the combination of one or two prominent techniques. These techniques are classified into 4 types. They are

B.1 Neuro-Fuzzy Technique.
B.2 Wavelet and ANN Technique
B.3 Wavelet and Fuzzy-Logic Technique
B.4 Wavelet and Neuro-Fuzzy Technique

B.1 Neuro-Fuzzy Technique

This is one of the most researched forms of hybrid systems and has resulted in a stupendous quantity of publications and research results. Neural systems that perceive designs and adjust to adapt to evolving situations, fuzzy inference systems that join human learning and perform approaches, together with certain subordinate – free enhancement strategies, brings about another procedure called neuro and fuzzy or adaptive neuro fuzzy inference system (ANFIS). Huisheng Wang et al., has developed a different methodology to real-time classification of faults with the help of neuro-fuzzy approach. In this method sequence components and three line currents were used to detect the nature of fault such as phase faults and phase to earth faults [39]. A new approach using fuzzy neural network (FNN) to distance relaying was presented by P. K. Dash et al., in [40]. In this work a neural network was used for training and a fuzzy view point was applied to gain insight into the system and to reduce the complexity of system [40]. Fault classification achieved by using only the current signals, with fuzzy-neuro methods was presented by W. W. L. Keerthipala et al., the symmetrical components and three line currents were utilized to identify fault types [41].

Adel A. Elbaset has presented an application of ANFIS for automated fault analysis in transmission lines using only data at one end. This application of ANFIS aimed at high-speed processing which can offer real-time identification of faults. This ANFIS was proposed not only to detect all shunt faults but also to classify the nature of faults for distance protection system. This method can correctly detect the faulty phases in a transmission line [42]. T. S. Kamel et al., has presented a protection method using multiple classified ANFIS networks for long transmission lines. In this work, input data of the ANFIS identification units initially calculated from the fundamental measurements of the current and voltage [43]. El Sayed Mohamed Tag Eldin has developed a fault location technique for a series compensated transmission system based on WT and ANFIS. This scheme used both end line currents to obtain wavelet multi resolution analysis for fault recognition. Directions and magnitudes of spikes in the wavelet coefficients were used for detection and classification of faults. After finding the faulty sections, the summation of the sixth level MRA coefficients of the currents was fed to ANFIS to obtain the correct location of fault [44].

B.2 Wavelet and ANN Technique

Wavelet and ANN Technique attempt to combine the best features of a wavelet approach and artificial neural network approach to give better results in fault classification. A different fault classification method using current signals for thyristor controlled series compensated transmission systems by integrating both the DWT and ANN algorithm together achieved, this technique has been presented by W. J. Cheong & R. K. Aggarwal [45]. This modular approach employs firstly a fault-classifying network based on simple

standard back propagation (SBP) learning algorithm and secondly a network for discriminating the fault location based on Self- Organizing Maps (SOM) network [45]. The combination of both ANN and WT to solve fault classification problem was developed by F. B. Costa et al., in [46]. In this work the input patterns for a simple multi-layer perceptron network (MLP) are wavelet coefficients of the currents. C++ language used to develop this technique.

The location, estimation of faults in high voltage transmission systems and the relative study of the behavior of Fourier and WT methods combined with Neural Network (NN) were proposed [47] by A. Abdollahi et al., According to this approach DWT is best for detecting phase to ground faults and DFT performs better for other faults. Soumyadip Jana et al., has developed a fault classification technique in transmission systems depends on wavelet entropy and neural network. It was found that only three level of decomposition of the voltage signal was sufficient for classification of faults. The proposed system was verified with various types of faults, such as symmetrical and asymmetrical faults for different locations and resistances [48]. High speed and accurate fault classification technique of transmission line based on new feature selection of wavelet transform and probabilistic neural network (PNN) presented by M. Mollanezhad Heydar-Abadi and A. Akbari Foroud [49]. In this algorithm, three PNNs and one ground detector (GD) have been used for fault classification. Each of the three PNNs (PNN_a, PNN_b, and PNN_c) is used to classify the faults and the ground detector (GD) is used to calculate the contribution of the ground in fault. The output of each PNN, the value '1' and '0' denotes the occurrence or nonappearance of the fault, correspondingly. The Fig. 8. explains the working procedure of wavelet and ANN method.

A novel methodology to classify the faults occurring in High Voltage transmission line was developed [50] by M. A. Beg et al., and they simulated 400 KV MSETCL system in PSCAD with actual line parameters. Majid Jamil et al., has proposed a study based on the application of wavelet technique in combination with neural network to locate the fault distance from the sending end, the analysis produces very accurate fault location results and it is observed that the mean relative error is around 3.2 % including all cases of phase and ground faults for an extensive difference of fault working situations [51]. Mayuresh Rao & R. P. Hasabe has presented neural network and DWT method for fault analysis. In this approach detection of faults using DWT and neural networks were used to find the nature of fault [52]. Fault classification in 220 kV overhead line using WT and ANN, has been presented by R. P. Hasabe and A. P. Vaidya. This approach depends on energy of the detail coefficients of the phase signals [53], [54]. Ravi Kumar et al., has implemented a fault classification technique for line to line faults in six phase transmission line using haar wavelet and ANN. The algorithm uses the standard deviation of approximated coefficients of instantaneous voltages and currents recorded at one end only [55]. V. T. Raikwar et al., has developed an approach using DWT-ANN for classification of faults in 765kv Transmission line [56].

B.3 Wavelet and Fuzzy-Logic Technique

In this technique, wavelet transform is used for decomposition of the output signals of simulated power system network. It decompose the output signals to required level and detail coefficients at that required level used as input to the fuzzy logic tool box. Fuzzy logic tool box based on the rules used in that particular fuzzy inference system gives fault type as output. Omar A. S. has developed a new technique for fault classification with the help of fuzzy inference system. Only the three line currents were utilized to identify nature of the fault such as phase faults and phase to ground faults and then to define the faulty phase [57]. M. Jayabharata Reddy et al., extended this approach to fault location in transmission lines [58]. Atthapol Ngaopitakkul et al., has developed a method using combination of DWT and fuzzy logic in order to classify the fault. In this approach, mother wavelet is Daubechies4 (db4). Moreover, the structure of the decision procedure is definite and executed with several case readings taking into account thailand power transmission systems [59].

B.4 Wavelet and Neuro-Fuzzy Technique

The combination of both Wavelet and Neuro-fuzzy based fault location technique has been developed by C.K. Jung et al., for transmission systems [60]. Location of faults for a series compensated transmission system using WT and ANFIS has been developed by El Sayed Mohamed Tag Eldin [61]. In this approach, fault detection and classification are done by using wavelet MRA Coefficients only. In this work, wavelet transforms are connected to the three phase currents at both closures of the transmission line. Directions and magnitudes of spikes in the wavelet coefficients are utilized for fault analysis. A wide range of faults with various beginning points, distinctive locations and distinctive fault resistances in both sections of the series compensated transmission line are simulated to assess the execution of the proposed issue area calculation and the legitimacy of the calculation to identify and classify faults is tried. The legitimacy to separate amongst inner and outer faults is moreover tried. The key benefit of this scheme is its adaptability with uproarious information and its principle downside is long time required training feed forward network with backpropagation training algorithm, particularly when the dimension of power network is high. The complexity of the scheme is more compare other methods.

III. COMPARISION and CONCLUSION

Comparison

The following Table. 1 gives the clear idea about the review on fault classification techniques in transmission lines based on techniques used in that approach, simulation tools used and complexity level. Complexity level is classified into 3 types i.e. simple, medium and complex, based on considering the factors; simulation time, number of inputs and rules involved in that corresponding approach etc.

Conclusion

The part 1 of the series of two papers describes a classification of available fault classification techniques in prominent and hybrid techniques, which are useful to know the initial methods and combination of different methods used earlier for the protection of power transmission systems. This review first time has classified the methods based on the approach used for fault classification i.e. prominent, hybrid and modern techniques. It also gives a brief review on all existing prominent and hybrid methods in this part 1. The part 2 of the article will present the necessity of the advanced methods for fault classification and will give a brief review on newly developed fault classification methodologies by various researchers.

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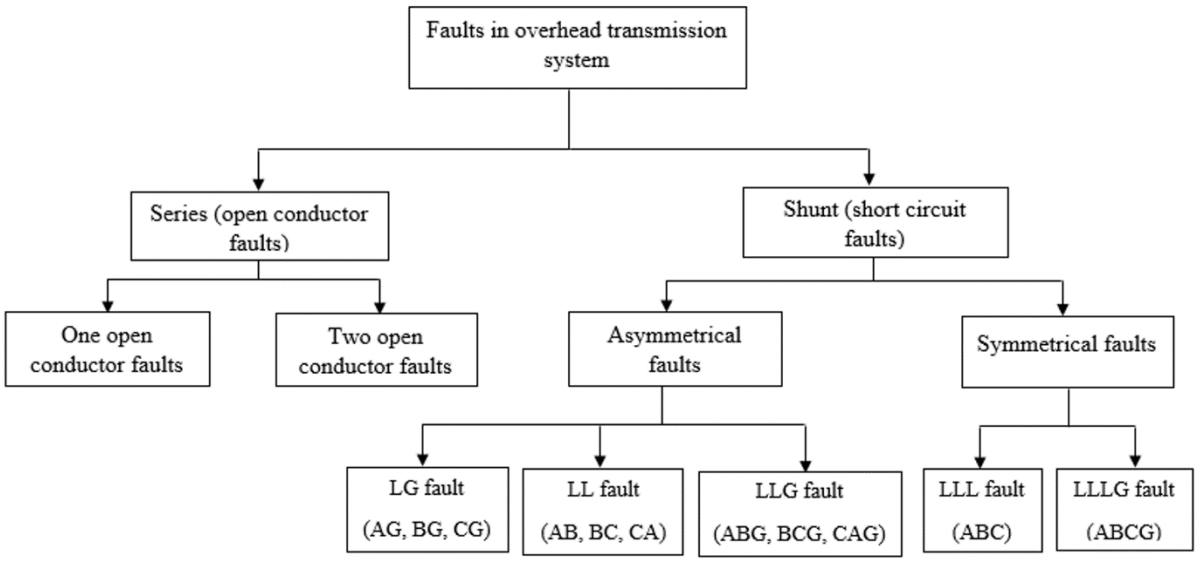


Fig. 1. Classification of faults

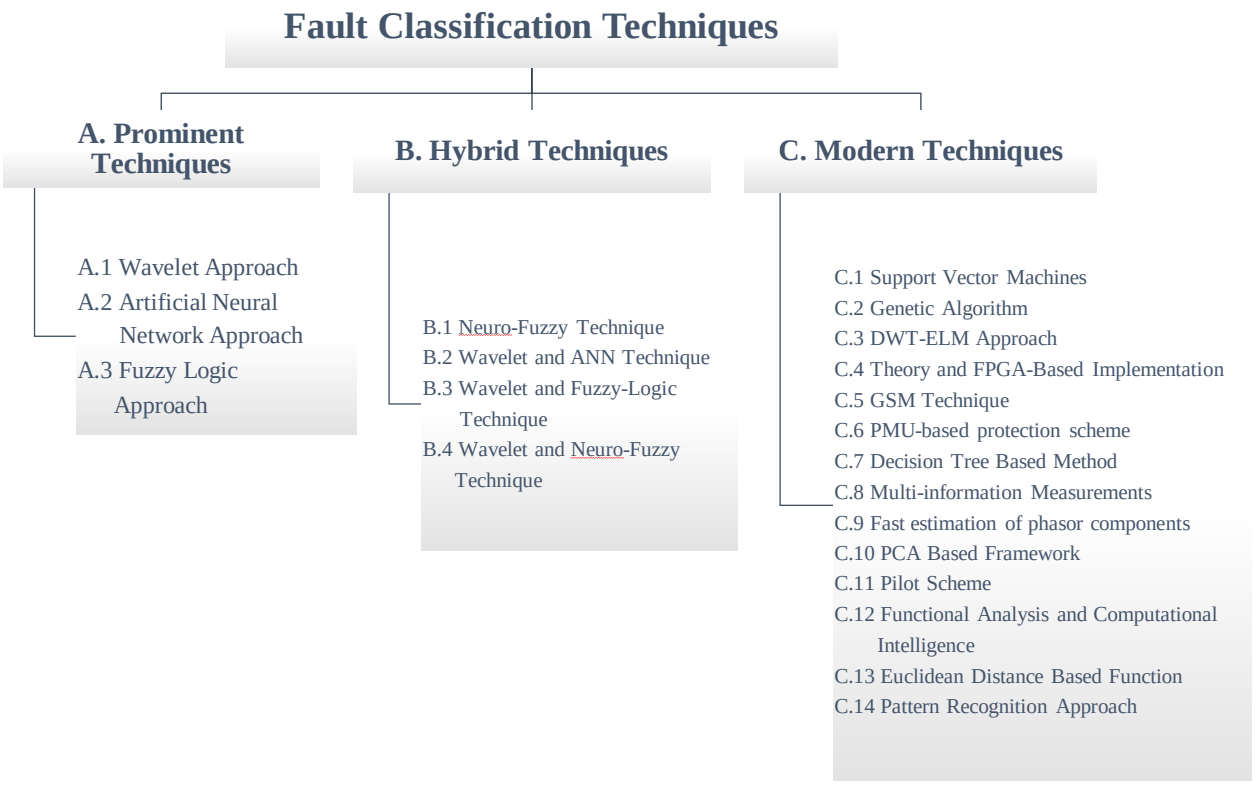


Fig. 2. Tree diagram of fault classification techniques

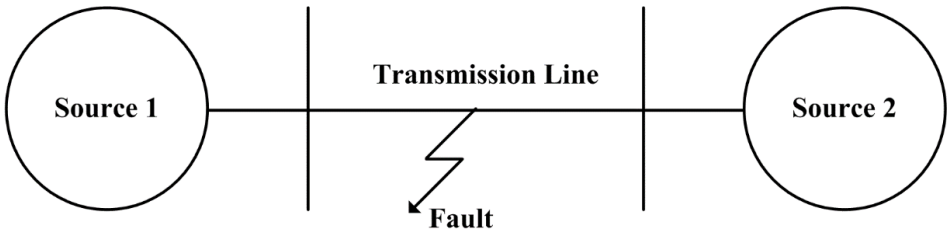
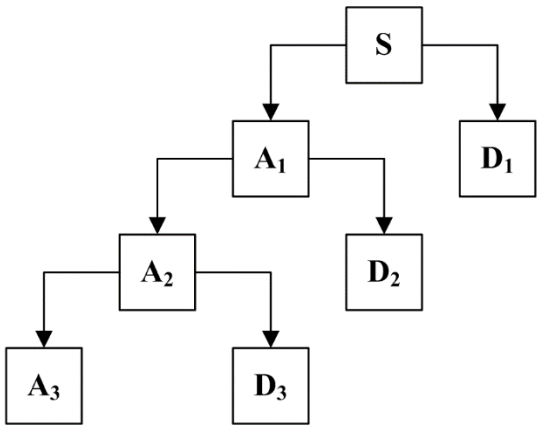


Fig. 3. Power system model



$$S = A_1 + D_1$$
$$= A_2 + D_2 + D_1$$
$$= A_3 + D_3 + D_2 + D_1$$

Fig. 4. Three-level decomposition of a signal ‘S’

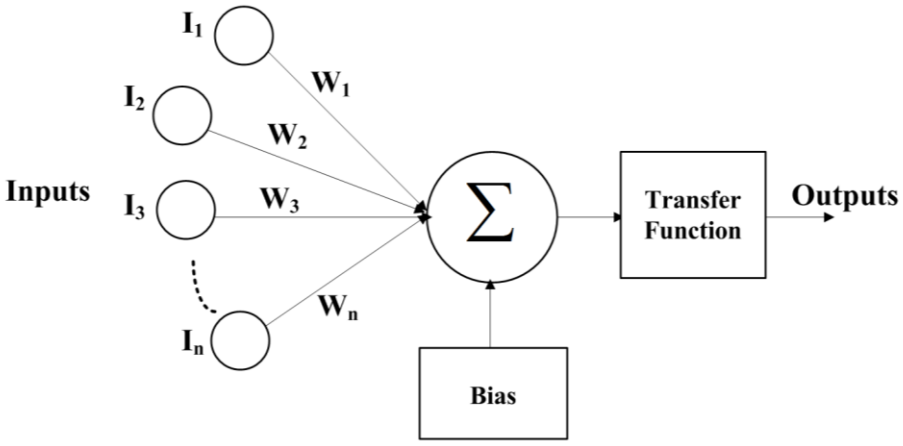


Fig. 5. Artificial Neuron Model

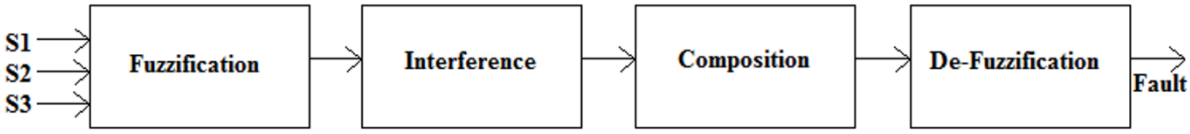


Fig. 6. Fuzzy system

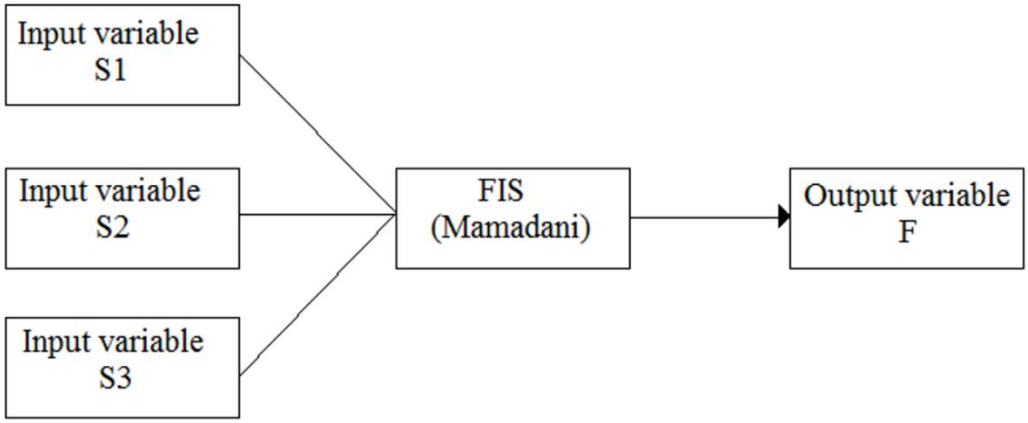


Fig. 7. Fuzzy inference system

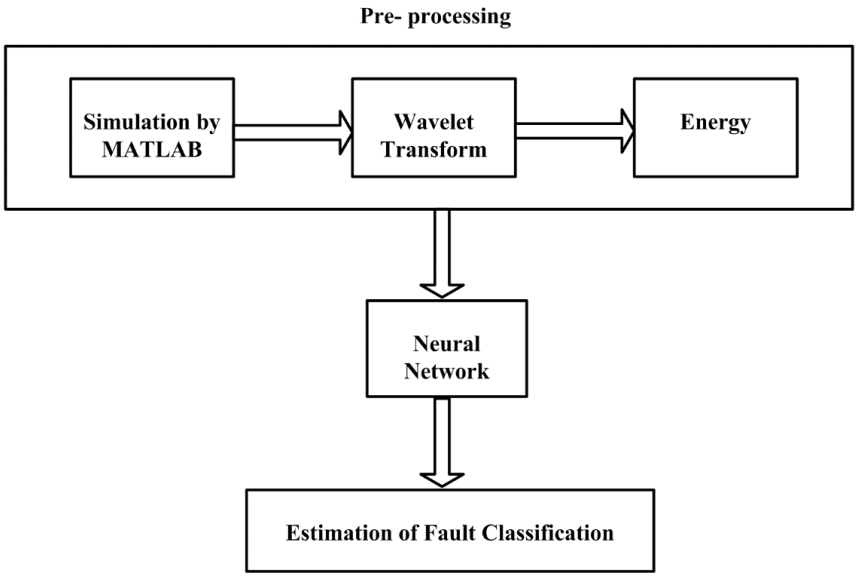


Fig. 8. Fault classification technique using WT and ANN technique

Table. 1 Comparison of fault classification techniques

No.	Name of the Approach	Reference Number	Techniques used	Simulation Tools Used	Complexity Level
A. Prominent Techniques					
A1	Wavelet Approach	[1]-[12]	Wavelet transform, DWT	EMTP, PSCAD/EMTDC, MATLAB/Simulink, ATP, MATLAB wavelet toolbox	Medium
A2	Artificial Neural Network Approach	[13]-[30]	ANN, distributed & hierarchical NN (DHNN), back-propagation (BP)	MATLAB NN tool box, EMTP, ATP	Complex
A3	Fuzzy Logic Approach	[31]-[38]	Fuzzy-set approach	MATLAB Fuzzy- logic tool box	Simple
B. Hybrid Techniques					
B1	Neuro-Fuzzy technique	[39]-[44]	Neural networks, fuzzy logic, fuzzy neural network (FNN), ANFIS	MATLAB NN & fuzzy-logic tool boxes, MATLAB ANFIS tool box	Complex
B2	Wavelet and ANN Technique	[45]-[56]	DWT, CWT, ANN	MATLAB wavelet toolbox, C++, MATLAB NN tool box, PSCAD	Medium
B3	Wavelet and Fuzzy-Logic Technique	[57]-[59]	Fuzzy-set approach, NN	MATLAB fuzzy- logic tool box, MATLAB wavelet toolbox	Simple
B4	Wavelet and Neuro-Fuzzy Technique	[60]-[61]	Neural networks, fuzzy logic, wavelet transform.	MATLAB wavelet, NN & fuzzy-logic tool boxes. MATLAB ANFIS tool box.	Complex