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A review on fault classification methodologies in power transmission systems: Part-II

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Abstract

The countless extent of power systems and applications requires the improvement in suitable techniques for the fault classification in power transmission systems, to increase the efficiency of the systems and to avoid major damages. For this purpose, the technical literature proposes a large number of methods. The paper analyzes the technical literature, summarizing the most important methods that can be applied to fault classification methodologies in power transmission systems.

The part 2 of the article is named "A review on fault classification methodologies in power transmission systems". In this part 2 we discussed the advanced technologies developed by various researchers for fault classification in power transmission systems.

Keywords: Transmission line protection; Protective relaying; Soft computing techniques

Contents

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1. Introduction

Transmission lines safeguard against exposed fault is the most critical task in the protection of power system. The purpose of a protective relaying is to identify the abnormal signals representing faults on a power transmission system. For high speed protective relaying, fast and accurate fault classification and the key essential in a transmission line. Recent technological advancement in soft computing techniques creates an interest to engineers to do research in this area. Earlier various researchers have proposed different schemes for fault classification. The problem is raised, whenever a new user starts his research in this area, he/she may get confusion to select the method to classify the nature of the fault. Because, so many researchers have already developed different methods but each method have their own advantages and disadvantages. So this review article will give the clear idea about all the existing methods in fault classification by selecting papers from reputed journals. The simulation process can be done in so many softwares. The user may not be aware of all the softwares. This review also gives details in the comparison table, about which software tool is used for simulation in that particular technique. Part 1 explains introduction of faults and necessity to do a review in this area and explanation of prominent and hybrid techniques.

This part 2 of this article is prepared as follows. First, Section 2 mainly focused on explanation of selected papers in different newly existed approaches. Second, Section 3, focused on the comparison of modern fault classification techniques in transmission lines and the concluding explanations of part 2.

2. Survey on fault classification methods

The prominent and hybrid techniques are explained in part 1 of the article. Now the explanation of modern techniques is as follows:

C. Modern techniques

Nowadays, these modern techniques are being implemented for fault analysis in power transmission systems. The various recently developed techniques are explained below.

C.1 Support vector machine

A novel technique for learning separating functions in classification (pattern recognition) tasks or for performing functional estimation in regression problems is support vector machine (SVM). It is a computational learning technique based on the statistical learning theory. In this the input vectors are nonlinearly mapped into a high dimensional feature space. It has been effectively applied to many classification problems. The explanations of papers based on SVM are given below.

Malathi and Marimuthu (2008), has presented a method for the classification of faults using multi-class support vector machine (SVM) in power transmission systems. This method uses data from the wavelet decomposition of post fault currents as input to support vector machine for classification of faults in transmission system. The specialty of this approach is SVM trained to become optimized classifier and with less amount of training samples.

A different approach for location of faults based on support vector machines (SVM) in power transmission systems was presented by Wang and Zhao (2009). This technique also used fuzzy set theory for solving uncertainty linear division relations. The error rates of SVM models low compared to multilayer perceptions (MLP) for the steady-state information.

Youssef (2009) has developed a novel technique to real-time fault analysis using support-vector-machines in transmission lines. Classification of faults in this approach depends on phase angles between the line currents and offline nonlinearly separable limitations between these angles generated by the SVM through training.

Tripathi et al. (2011), have implemented a technique for accurate fault classification scheme in thyristor controlled series compensator (TCSC) compensated transmission line with the help of SVM. In this approach one SVM is trained for classification of faults and its input is independent of firing angle. Thus it does not need wavelet transform, communication setup and calculation of zero-sequence-current component etc.

Singh et al. (2011), have proposed a novel approach that is combination of SVM and wavelet techniques. This is used to detect and classify the types of the faults.

C.2 Genetic algorithm

Genetic algorithms (GA) work with a coding of variables. The major difference between genetic algorithms and traditional optimization methods is that GA uses a population of points at one time in contrast to the single point approach by traditional optimization methods. This means that GA processes a number of designs at the same time. The explanation of following papers shows the classification of faults in transmission lines based on GA.

Song (1997) proposed a novel technique using genetic algorithm based neural networks (GANN) for classification of faults in transmission lines. This paper has also made comparison between a genetic algorithm based neural network and a BP (Back Propagation) network based scheme.

A novel method for classifying different types of transmission line faults by merging wavelet transform (WT) and genetic algorithm (GA) has been presented by Upendar et al. (2008). The proposed method contains a preprocessing unit depends on both DWT and GA, in which DWT has been used to extract characteristic features from the input current signal collected at source end. The data is given as an input to GA for fault classification.

C.3 DWT-ELM approach

This approach presents an accurate hybrid technique for classification of faults in a series compensated transmission system. The combination of discrete wavelet transform (DWT) and extreme learning machine (ELM) are used for fault classification. A comparison of the proposed fault classifier is made with DWT-ANN fault classifier and it is observed that the presented classifier gives high accuracy and small learning time compared to the other one (Ray et al., 2012).

C.4 Theory and FPGA-based implementation

Recent developments in FPGA technology at both hardware and software levels, as well as the rapidly reducing cost, increases the usage of FPGA in the field of power systems.

Valsan and Shanti Swarup (2009), have presented a better hardware-efficient logic using a field-programmable gate array (FPGA) for fault analysis in transmission lines. The application of an FPGA is a recently emerging method in the field of power systems for fault classification.

C.5 GSM technique

Sujatha and Vijay Kumar (2011), have developed a global system for mobile communication (GSM) method, it can be effectively applied to the previous established special protection systems to increase its reliability during network interruptions. In this approach a powerful GSM is considered to send data from a network to other network, any variation in parameters of transmission is detected to protect the whole transmission and distribution.

C.6 PMU-based protection scheme

A PMU-based protection system was proposed by Jiang et al. (2002, 2003). It presented an adaptive protection technique for transmission systems using synchronized phasor measurements. The phasor measurement unit

(PMU) protection scheme consisted of fault detection, classification and direction discrimination. This scheme used synchronized phasor quantities to enterprise a multi-function protection relay to reach the entire line protection.

Rahideh et al. (2013), have presented a model for location of faults for two-terminal multi section compound transmission lines, which was the combination of overhead lines and underground power cables, using synchronized phasor measurements.

C.7 Decision tree based method

The decision tree mechanism is transparent and we can follow a tree structure easily to explain how a decision is made. It is perhaps the most highly developed technique for partitioning sample data into a collection of decision rules. Decision trees for classification problems are often called classification trees. The following papers show how the decision tree mechanism helps in classification of faults.

Shahrtash and Jamehbozorg (2008), have developed a decision tree technique. It is implemented for fault classification in power transmission system. It determines the exact fault inception time using traveling waves initiated by the fault and fault detector. For this method, data of one side of the protected line is required and decision making has been performed in just 2 ms, which is the best time among earlier approaches. These authors extended their work to double circuit transmission lines in Jamehbozorg and Shahrtash (2010). Fig. 1 shows the schematic diagram of decision tree based method algorithm.

A new method for faulty region detection and classification for thyristor controlled series compensator (TCSC) and unified power flow controller (UPFC) line using decision tree (DT) is developed by Samantaray (2009). The decision tree based procedure uses one cycle data from fault inception of three phase currents along with zero-sequence voltage and current to constructs the optimal decision tree for fault analysis in transmission lines.

C.8 Multi-information measurements

Ling et al. (2009), have presented a novel procedure using multi-information measurements of fault transients with the help of information entropy measurement and complexity measurement for fault classification. This method can work under different transient components.

C.9 Fast estimation of phasor components

Saha et al. (2010a,b), has proposed a new method for transmission system to identify the faulty phases. The suggested algorithm is based on readings of phase currents and fast estimation of phasor components in relatively short data window. The key selection technique utilizes the relations among magnitudes of current for different possible fault loops. This method can differentiate grounded and ungrounded faults with the help of the neutral and phase currents.

C.10 PCA based framework

A novel fault classification method has been proposed by Alsafasfeh et al. (2010). This work is based on phase currents during the first (¼)th of a cycle in an combined technique that gives better results using symmetrical components method and principal component analysis (PCA). The advantage of this algorithm is used at any end of a transmission line, so data communication devices are not necessary.

C.11 Pilot scheme

Mahamedi (2011) has presented a novel fault classification technique utilizing reactive power under normal and fault conditions. A pilot method needs to relate the sign of reactive power measured by one relay to other relay. The key benefit of this technique is that it does not need any setting. The relay is not needed to set a threshold for any parameter. Thus, this technique is also called as setting free. This technique is independent on inception time and location of fault.

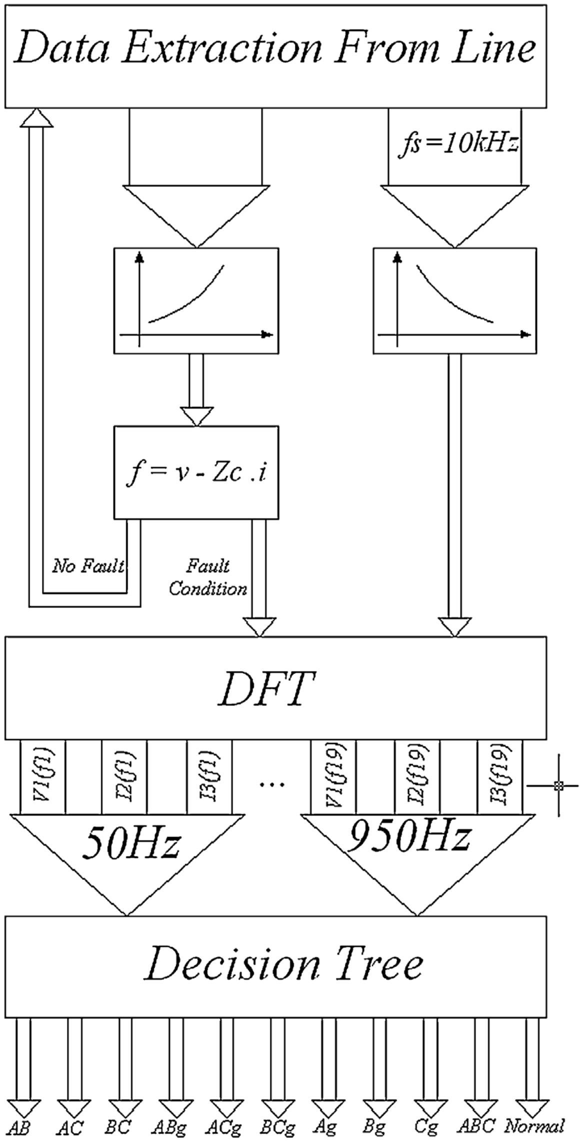

Fig. 1. Schematic diagram of decision tree based method algorithm (Shahrtash and Jamehbozorg, 2008).

C.12 Functional analysis and computational intelligence

A new model functionally represent the phases of a transmission line is presented in de Souza Gomes et al. (2013). The detection and classification strategy are developed from the analysis of the model parameters and are evaluated using a set of simulated faults and a real database. The presented mathematical model includes stochastic components which account for current and voltage stochastic deviations, or noises, under normal operating conditions. So it provides novel stochastic representation of the transmission lines, which enables faster detection of anomalous behaviors, or faults.

C.13 Euclidean distance based function

A new fault detection technique is proposed for transmission line protection using Euclidean distance between successive current samples (Prasad and Prasad, 2014). This technique is then extended to identify faulty phase. The relative performance of the procedure is considered with signals containing load change, noise, frequency deviation, spike and faults at different situations of the power system.

C.14 Pattern recognition approach

Srinivasa Rao and Baddu Naik (2013) have presented a better procedure for classification of faults in transmission lines using MATLAB/SIMULINK. Their work shows a discrimination of faults using current and voltage waveforms measured when fault occurs in the power transmission systems.

3. Comparison and conclusion

3.1. 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.

Table 1
Comparison of fault classification techniques.

No.	Name of the approach	Reference number	Techniques used	Simulation tools used	Complexity level
C. Modern techniques					
C.1	Support vector machines	Malathi and Marimuthu (2008); Wang and Zhao (2009); Youssef (2009); Tripathi et al. (2011); Singh et al. (2011)	SVM classifier, wavelet	MATLAB SVM toolbox, EMTP, MATLAB/SIMULINK, ATP	Complex
C.2	Genetic algorithm	Song (1997); Upendar et al. (2008)	GA, NN	EMTP, MATLAB	Complex
C.3	DWT-ELM approach	Ray et al. (2012)	DWT, ELM	MATLAB/SIMULINK	Medium
C.4	Theory and FPGA-based implementation	Valsan and Shanti Swarup (2009)	Field-programmable gate array (FPGA)	Real time windows target toolbox of MATLAB	Medium
C.5	GSM technique	Sujatha and Vijay Kumar (2011)	Global system for mobile communication (GSM)	Embedded based hardware design	Simple
C.6	PMU-based protection scheme	Jiang et al. (2002, 2003); Rahideh et al. (2013)	Phasor measurement unit	EMTP/ATP	Simple
C.7	Decision tree based method	Mahanty and Dutta Gupta (2004); Shahrtash and Jamehbozorg (2008); Jamehbozorg and Shahrtash (2010); Samantaray (2009)	Discrete Fourier transform	EMTDC/PSCAD	Complex
C.8	Multi-information measurements	Ling et al. (2009)	Multi-information measurements	MATLAB	Medium
C.9	Fast estimation of phasor components	Saha et al. (2010a,b)	Zero-component current phasors	ATP-EMTP	Medium
C.10	PCA based framework	Alsafasfeh et al. (2010)	Principal component analysis	PSCAD	Medium
C.11	Pilot scheme	Mahamedi (2011)	Pilot scheme	MATLAB	Complex
C.12	Functional analysis and computational intelligence	de Souza Gomes et al. (2013)	Wavelet transform	MATLAB	Complex
C.13	Euclidean distance based function	Prasad and Prasad (2014)	DWT	MATLAB/SIMULINK	Medium
C.14	Pattern recognition approach	Srinivasa Rao and Baddu Naik (2013)	Multi resolution analysis	MATLAB/SIMULINK	Complex

3.2. Conclusion

This work has included many recent fault classification techniques along with their key features. All these techniques have their own features and researches are still going on to obtain lesser operating time of relay at high speed. So there is a necessity for developing new algorithms using advanced optimization techniques and flexible alternating current transmission systems (FACTS) devices that have higher computational effectiveness and suitability for real time applications. Finally the entire article including part 1 and part 2 is expected to be useful for fault analysis users and designers of power system protection.

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