AUTOMATIC FAULT DETECTION AND LOCATION IN POWER TRANSMISSION LINES USING ANN ALGORITHM WITH LabVIEW

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***Abstract*—*Transmission lines, among the other electrical power system components, suffer from unexpected failures due to various random causes. These failures interrupt the reliability of the operation of the power system. When unpredicted faults occur protective systems are required to prevent the propagation of these faults and safeguard the system against the abnormal operation resulting from them. The functions of these protective systems are to detect and classify faults as well as to determine the location of the faulty line as in the voltage and/or current line magnitudes. Then after the protective relay sends a trip signal to a circuit breaker(s) in order to disconnect (isolate) the faulty line. The features of neural networks, such as their ability to learn, generalize and parallel processing, among others, have made their applications for many systems ideal. The use of neural networks as pattern classifiers is among their most common and powerful applications. This paper presents the use of artificial neural network architecture as an alternative method for fault detection, classification and isolation in a transmission line system. The main goal is the implementation of complete scheme for distance protection of a transmission line system. In order to perform this, the distance protection task is subdivided into different neural networks for fault detection, fault identification (classification) as well as fault location in different zones. Three common faults were discussed; single phase to ground faults, double phase faults and double phase to ground faults. The result provides a reliable and an attractive alternative approach for the development of a protection relaying system for the power transmission systems.*

1. INTRODUCTION

Methods for fault detection, classification and location in transmission lines have been intensively studied over the years. With the concepts associated with smart grid attracting growing concern among researchers, the importance of building an intelligent fault monitoring and diagnosis system capable of classifying and locating different types of faults cannot be overstated.

The past 20 years has witnessed the rapid development in various fields concerning the detection, classification and location of faults in power systems. The advances in signal processing techniques, artificial intelligence and machine learning, global positioning system (GPS) and communications have enabled more and more researchers to carry out studies with high breadth and depth in that the limits of traditional fault protection techniques can be stretched. Furthermore, two major restrictions of online fault diagnosis systems are also being solved. The first restriction is the difficulty in data acquisition. In addition to traditional measurement equipment such as potential transformer, current transformer and remote terminal unit, newly developed intelligent electronic devices (IEDs) are being deployed to obtain information at multiple nodes in the grids. Self-powered non-intrusive sensors are also being developed with the potential to form sensor networks for smart online monitoring of smart grids. With more data available, researchers are able to develop intelligent fault diagnosis systems through mining knowledge from the data corresponding to different conditions. The effect of complex and varied network configurations can also be eliminated when the current and voltage signals can be collected by interspersed sensors that are plentiful in number. The second restriction is the lack of communication and computation capability. The prospective of GPS-based synchronised sampling and high-speed broadband communications for IEDs in power grids were mentioned in. The application of phasor measurement units has also gained wide attention and a brief introduction of which is found in. These technical improvements can guarantee fast response to faulty situations and the proper functioning of online monitoring systems based on sensor networks. The computational ability of computers has also increased rapidly. High-performance computing solutions such as server clusters are able to complete distributed computing tasks within very short period of time, thus allowing methods with higher computation complexity to be implemented.

In this paper, we present a comprehensive review on the methods used in fault detection, classification and location. A simplified framework for fault detection, classification and location is illustrated in Fig. 1. In the first step, current and voltage signals are sampled and the sampled points are passed to the feature extraction module. This module then extracts features used by the fault detector, the fault classifier and the fault locator. The outputs are the fault type and the fault location provided by the fault classifier and the fault locator, respectively. Some of the works cover all three aspects, while some others focus on one or two of the aspects.

2. Feature extraction and fault detection

Although the current and voltage signals contain all the information within themselves, it is extremely hard to fit the raw signals into some sets of rules and criterions capable of intelligently interpreting the underlying messages brought by the signals. This is where the feature extracting techniques come in handy, as they dig out useful information purposefully and reduce the impact of variance within the studied system. After proper feature extraction techniques are used researchers may gain a better awareness of the nature of the fault classification or location problems and thus solve them in a more coherent and efficient manner. Moreover, a reduced dimensionality of the data can sometimes boost the performance of certain algorithms used in the classifiers or locators, providing more accurate and robust results as fast as possible. In this section, methods used for feature extraction are presented together with detailed application examples. At the end of this section, a brief introduction to fault detection methods, which is highly dependent on the feature extraction process, is presented.

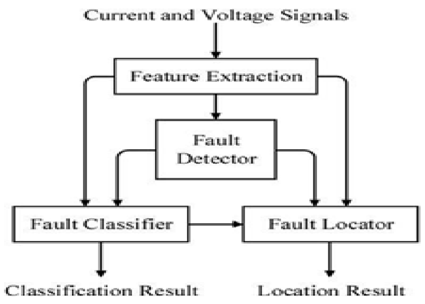
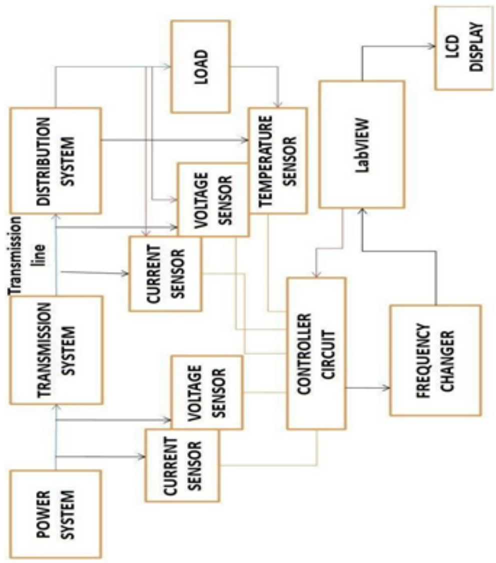


Fig.1Simplified framework for fault detection, classification and location

Fault detection based on extracted features

Generally speaking, the task of fault detection is done prior to fault-type classification and fault location. When an independent method is used for fault detection, the classifier and the locator are triggered after a fault is securely detected. This can be done easily by setting some thresholds for the extracted features. Moreover, in the case where the classifier or the locator is capable of distinguishing between faulty and non-faulty states, there is no need to implement additional fault detection methods. One scheme to perform fault detection in this case is to use an individual classifier to differentiate faulty and non-faulty states. The other scheme is to add the non-faulty state to the output categories, and a fault is detected whenever the output is other than the non- faulty state. Considering the learning abilities of the models used for classification, there is no essential difference between both schemes. Thus, for clarity, we only present here either methods that are used in some special cases or representative methods that are independent of the classification methods discussed in detail. Negative sequence components were calculated in for fault detection. For a more stable detection of faults, the authors designed a joint fault indicator by convoluting the partial differential with respect to time of negative sequence components with a triangular wave, so that the chance of issuing false alarms can be reduced. This fault detection method using the joint fault indicator also shows robustness in cases of frequency deviation and amplitude variation. In, the author proposed a wavelet-based method for real-time fault detection in transmission lines. The border effects of the sliding windows used to obtain the wavelet coefficients used for energy calculation were considered, allowing a shorter detection time than considering the transients alone.

3. Block Diagram



Power system fault detection Model

Fault-type classification

Fault-type classification plays a significant role in protection relay for transmission line systems, thus researchers have had constant interest in developing new, robust and accurate fault classification algorithms and models for decades. The majority of the classification methods adopt classifier models based on statistical learning theory, while some other works used logic flows based on experience and observation of collected data. It is noteworthy that the development of studies in this particular field has been highly relevant to the development of pattern recognition and machine learning (more specifically, supervised leaning algorithms for classification). In this section, a detailed review of methods for fault-type classification is provided in a developmental and comprehensive point of view.

A. Fault classification based on logic flow

If no machine learning or artificial intelligence based algorithms are implemented, usually a tree-like logic flow with multiple criterions is used. In, authors compared the values of four extracted features for three phases and ground to pre-set thresholds. If any one of the values exceeds its threshold, the corresponding phase (or ground) is involved in the fault. Researchers in extracted the features using WMA and generated logic flows based on observations of the characteristics of the features. At each node in the logic flow, certain comparisons were made between feature values or between a feature value and a threshold. CT was used in to produce fault detection indexes for each phase. Thresholds were then added to complete the classification task. In, Karrenbauer transformation and WT were used. Modulus maxima of the WT were then fed to the logic flow to decide the fault type. WT and Shannon entropy were used in to produce features. In, where the authors used the WSE method, logic flows were implemented after the features related to the entropies were calculated.

B. Artificial neural network

Artificial neural networks (ANNs) are a family of non-linear statistical models and learning algorithms with the intention to imitate behaviours of connected neurons within biological neural systems, which has developed and evolved over a long period of time. Different ANN models have been used for applications in various fields, including fault classification in transmission lines and distribution systems. Of all the ANN models, one may find a feed forward neural network (FNN) the simplest in configuration, which can be characterised as single-layer or multi-layer perceptrons. A FNN often has an input layer, an output layer and at least one hidden layer. Generally, the nodes (or neurons) in adjacent layers are fully connected, and the parameters (weights assigned for the connections and biases for the nodes) decide the output of the network given an input. To put it simply, the so-said learning process is carried out by adjusting the parameters of the network, so that the output would satisfy certain conditions, such as estimating a function accurately.

Fault location

A considerable number of studies have focused on fault location in that accurate location of faults in transmission lines and distribution systems can greatly reduce the time to recovery. A comprehensive review of fault location in power systems. In, where a smart fault location method was proposed, the background knowledge for fault location was also provided. Thus, in this paper, on the basis of existing review studies, we present the fundamentals and some new progress in fault location techniques. For transmission lines, conventional fault location methods can be divided into impedance focused methods (phasor or time-domain based) and travelling wave based methods. Depending on the source of data, fault location methods may be further categorised as single-end methods, double-end methods, multi-end methods and wide- area methods. In this paper, however, we present fault location methods in a different manner as we only focus on some special portions of them. Due to the fast development of wide-area methods and the need of building reliable large- scale smart grids, we take wide-area methods into account. Similarly, we take fault location methods of series- compensated transmission lines and hybrid transmission lines into consideration because of their special properties that distinguish them from normal transmission lines. At the same time, we take modern artificial intelligent methods into account because of their good performance on fault location and broad application prospects. Consequently, the following fault location algorithms to be discussed mainly concentrate on wide-area fault location algorithms, series-compensated transmission lines fault location algorithms, hybrid transmission lines fault location algorithms and artificial intelligence based fault location algorithms.

4. CONCLUSIONS

This paper presents a review on the methods used for fault detection, fault classification and fault location in transmission lines and distribution systems. A variety of methods are introduced and representative works are presented in detail. Prior to introducing the methods directly used in the three topics, we first give an overall review on the methods used for feature extraction, which lays the foundation for other fault diagnosis tasks. Different types of transforms as well as dimensionality reduction methods are presented. We can see that information across the low- frequency ranges and high-frequency ranges is fully exploited, and researchers are more purposeful when choosing the feature extraction techniques as well as selecting the extracted features. Fault detection is presented on top of the feature extraction methods, as the detection techniques are highly dependent on feature extraction. Still, some noteworthy aspects and newly developed ideas regarding to fault detection are presented.

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