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A novel transmission line relaying scheme for fault detection and classification using wavelet transform and linear discriminant analysis

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Abstract This paper proposes fault detection and classification scheme for transmission line protection using WT and linear discriminant analysis (LDA). Current signals of each phase are used for the detection and identification of faulty phases and zero sequence currents are used for the detection of ground. Current signals are processed using discrete wavelet transform with DB-4 wavelet up to level 3. Approximate coefficients are reconstructed using wavelet reconstruction. Performance of the proposed based scheme is tested by variations of parameters such as fault type, location, fault resistance, fault inception angle and power flow angle. The scheme is applicable for both single circuit and double circuit transmission line. All shunt faults and multi-location faults which occur in different locations at the same time are also detected and classified by the proposed scheme within one cycle time. The simulation results show that the proposed scheme is not affected by non-linear high impedance fault and CT saturation.

1. Introduction

Fast and reliable fault detection and fault classification technique is an important requirement in power transmission systems to maintain continuous power flow. Many researchers proposed different techniques for fault detection and classification. Among the various techniques reported wavelet based techniques are used for detection and classification of faults by researchers [1,2]. Different artificial intelligence techniques such as ANN, fuzzy, ANFIS, and SVM also used for detection and classification of faults. Artificial-neural-network (ANN) based approach is used for fault detection, fault phase selection and fault classification in [3–5]. ANN in combination with wavelet transform is used for detection and classification of fault in [6,7]. Combination of particle swarm optimization (PSO) and ANN is also used for classification of fault in [8]. Fuzzy logic is used for fault phase identification and classification in [9,10]. Fuzzy logic in combination with neural network called as adaptive neuro fuzzy inference system (ANFIS) based distance relaying has been used for protection of power system [11]. Support vector machines (SVM) are used for classification

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of fault in [12]. In [13] phase space based fault detection scheme for distance relaying is proposed. Fault classification and faulted phase selection schemes are also proposed based on the symmetrical components of reactive power for single-circuit transmission lines [14]. Detection and classification of faults in power transmission lines using functional analysis and computational intelligence is proposed in [15].

Moreover the reach setting or the protection range reported in all above discussed papers is much lesser than 90% of the line length i.e. if the fault occurs in between 90% and 100% of the line, these scheme will not be able to detect the fault. However if any protection scheme can provide protection to larger portion of the line length then that scheme will be beneficial for protection of transmission line. Many researchers did not mention about the fault detection time which is the most important task in transmission line relaying. Fault detection time is important because from this it can be observed that how quickly the normal flow of power can regain. Thus in this paper a protection scheme is designed using wavelet transform and linear discriminant analysis to detect the fault, identify the faulty phases and classify the type of shunt faults that may occur in power transmission lines. Instead of designing 10 modules for 10 types of fault only 4 modules are designed to identify the faulty phases and classify the faults. Only three line currents and zero sequence current measurement are sufficient to implement this technique. The number of samples given in training is quarter cycle data (5 samples) after pre-processing through discrete wavelet transform. The time taken by this method is about within one cycle (20 ms).

2. Discrete wavelet transform

Wavelets have both scale and a time aspect that is why it is used for signal analysis in power system protection [16]. Wavelet analysis represents a windowing technique with variable-sized regions which allows the use of long time intervals where more precise low-frequency information is required and shorter regions where high-frequency information is required. Advantage of wavelets is the ability to perform local analysis which analyzes a localized area of a larger signal. Wavelet analysis is capable of revealing aspects of data that other signal analysis techniques may miss. Wavelet analysis is the breaking up of a signal into shifted and scaled versions of the original wavelet to obtain a better resolution.

For analysis of power system transients, DB wavelets have been used in majority of the power system transient detection algorithms and also DB wavelets are described as best mother wavelet of choice of the power system researchers in [17]. So in the proposed work DB wavelet is taken as mother wavelet. In wavelet analysis signals divided into two parts approximations and details. The approximations are the high-scale, low-frequency components of the signal. The details are the low-scale, high-frequency components. Decomposition of a signal S up to level three is shown in Fig. 1. The decomposed signal contains the approximate and detail coefficients up to certain level. Proposed method is first designed by using different levels of decomposition of wavelet up to level 5. But the accuracy of the method remains constant after level 3. So if level higher than level 3 will be considered it will take more time for decomposition due to which processing time will increase but the accuracy will be same as level 3. So it is better to take decomposition level up to level 3 to detect fault quickly than other higher levels.

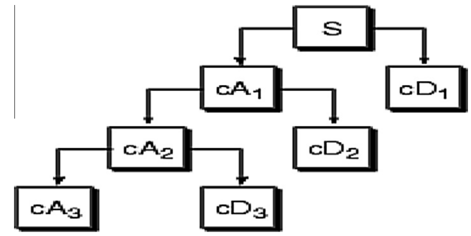

Figure 1 Wavelet analysis of signal S up to level 3.

The decomposed components can be assembled back into the original signal without loss of information which is called wavelet reconstruction, or synthesis or inverse discrete wavelet transforms (IDWT). Wavelet Reconstruction is used here for the approximate coefficients. Signals use zero padding to construct the original signal. Reconstruction process of proposed method is shown in Fig. 2. After reconstruction required numbers of samples are taken from the signal for further use in the training of LDA network.

3. Linear discriminant analysis

Linear discriminant analysis is used to study the difference between two or more groups of objects with respect to several variables simultaneously, determining whether meaningful differences exist between the groups and identifying the discriminating power of each variable [18]. Any data set contains observations with measurements on different variables called predictors and their known class labels. For new observations with predictor values, classes can be determined based on the old data set in case of classification of data [19]. The observations with known class labels are usually called the training data. Training data are used to train the LDA network. After training re-substitution error is computed to know the proportion of misclassified observations on the training set. Then the confusion matrix on the training set is computed to obtain the different sets of misclassification data. A confusion matrix contains information about known class labels and predicted class labels [20]. The element (i, j) in the confusion matrix is the number of samples whose known class label is class i and whose predicted class is j. The diagonal elements represent correctly classified observations.

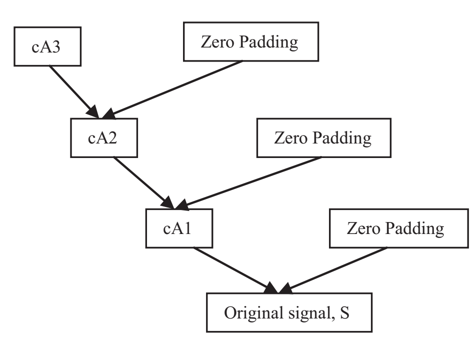

Figure 2 Wavelet coefficient reconstruction up to level 3 to get signal S.