別紙様式８

研 究 主 論 文 抄 録

論 文 題 目　　FAULT CLASSIFICATION OF TRANSMISSION NETWORKS THROUGH WAVELET TRANSFORMS AND ARTIFICIAL NEURAL NETWORKS
（ウェーブレット変換とニューラルネットワークを用いた送電ネットワーク事故の分類）

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主論文要旨

Transmission lines are a vital part of the electrical distribution system, as they provide the path to transfer power between generation and load. Factors like de-regulated market environment, economics, right-of-way clearance and environmental requirements have pushed utilities to operate transmission lines close to their operating limits. Any fault, if not detected, classified and isolated only the faulted section quickly will cascade into a system wide disturbance causing widespread outages for a tightly interconnected system operating close to its limits. Transmission line is a very delicate part of the electrical network and fault most likely to happen in it because it is an out-door equipment which can run to several hundreds of kilometers and is subjected to different types of short circuit faults which are the most sever such as single line to ground fault, double line to ground fault, double line fault, and three-phase fault. Transmission line is the part of power system Researches on fault analysis are very importance as a result, while fault detection and location schemes have been developed in the past, a variety of algorithms continue to be developed to perform this task more accurately and more effectively. A brief explanation of this research study thesis which consists of six chapters is explained in next paragraphs.

Chapter 1 presents the short introduction and general literature review which cover the power system transmission line fault types, fault classification concepts and methods used in fault classification. Traditional method like Fourier transform and its historical

development process to overcome its disadvantages to increase its efficiency in fault classification analysis was introduced. Wavelet transform and Artificial intelligent especially neural network as new methods were introduced with their different types, working process and there using in the power system filed. The research problem, objectives, thesis structure and author's contribution in the related area also explained in this chapter.
Chapter 2 presents the comparison between using different types of Fourier transform as traditional analysis method and new method which is wavelet transform in fault classification by analysis the input faulty phase current signal for three cycles including pre and post fault time . The Fourier Transform uses the past and future signal information to calculate the spectrum in any small time period- its process is the same so that it cannot reflect the frequency variables in time domain. The short-time Fourier Transform it maps the signal into a two-dimensional function in a time frequency plane, but depends critically on the time window. The wavelet transform overcomes the time and frequency limits. It has good frequency resolution while high frequency and good time resolution while low frequency. This feature benefits the non-stationary signal analysis such as faulty signals which discrete wavelet transform DWT can detect clearly and accurately in small time simulation. Furthermore, fast computing algorithms of the sub-band coding make it possible to implement the discrete wavelet transforms in practical work. Daubechies 4 (db4) wavelet was used as the mother wavelet, due to its good time resolution that provides an accurate detection of the fast transients this gives a very good result. Simulation of the three phase single circuit transmission line with single feeding was done to obtain the required current signal for investigation. Applying Fast Fourier transforms FFT and discrete Fourier transform DFT in simulation system cannot give any cleared analysis for any cases if the simulation time is so small. DWT which indicate a highly change at the fault period and clearly describe what happened to the signal and the beginning and end time of these sudden change occurred appeared like two spark from the first level as high frequency generated due to fault so the signal is smooth until this disturbances happened. From first level the period of fault can be known but with increasing the decomposition level some important data can be collected from low frequency scale which can describe the nature of signal.
Chapter 3 presents the proposed three feature extractions from discreet wavelet transform method to discriminate between ten different fault types using same simulated power system model used in chapter 2. Three phase current signals at normal and faulty condition were recorded and decomposed using DWT (db4 level 1) to get there maximum details coefficient, energy of these signals and then making compression of these signals and take the ratio of energy change from the first level with keeping approximation with no change because fault inception have great effect on detail coefficient as it generate a high frequency component to signal. Detail coefficient with no fault these signals are near to reach zero. During single phase to ground fault the faulty phase was the highest in detail coefficient

(greater than 0.001), energy and the change of energy ratio (higher than normal condition) so it was much cleared to detect the faulty phase. In our work and after a lot of collected cases it indicated that if the energy ratio was exceed 0.001 level this means this phase is a faulty phase. Secondly if the fault is double phase the energy ratio will be the same for these two faulty phases but the energy ratio when there is double phase to ground fault were not same.

Chapter 4 in this chapter the proposed fault classification has been achieved by using the combination between discrete wavelet transform as a feature extraction and preprocessing with a classifier from one type of artificial neural network which is feed forward neural networks FFNN. The first level discrete wavelet transform (db6) using as a mother wavelet is applied to decompose the quarter 1/4th of a post fault current cycle signals of the transmission line into a series of coefficient components (approximation and detail). The values of the approximation coefficients obtained can accurately discriminate between all types of fault in transmission line and decrease the data input to half of its original signal and taking only the 20 samples of the post fault current signals which catch important information for classification then normalized these data, between -1 and +1, to be the FFNN input. The simple proposed neural network is ten input neurons with one hidden layers which has twenty neurons hyperbolic function and four neurons in output layer with pure linear function , the target output is assigned 1 for faulty phase and 0 for healthy phase ,was found to give. The FFNN correctly classifies fault types with good performance, less error, advantages in accuracy and speed.

Chapter 5 presents the fault classification in simulated power transmission line system which compensated by series capacitor and protected by Metal-Oxide Varistor (MOV) devices used to increase transmission capabilities, decrease the generation cost and improve the security and stability of power system but during fault, the presence of compensating devices affects steady-state and transient components of current and voltage signals which create problems with relay functionality devices so it is a very challenging task. This work presents a framework for fault classification using discrete wavelet transform (DWT) using the db4 as mother wavelet and the decomposition of signals will be to the third level to prepare the feature which would be given as the input to the radial basis function neural network (RBFNN) which has high performance level especially in classification problems. The total energy used as a single feature of data classification using the summation of the energy of the detail and the energy of the approximate at decomposition level to express each signal. The energy of wavelet coefficient is varying over different scales depending on the input signals and is contained mostly in the approximation part and little in the detail part. The number of hidden neurons, the centers of the RBFs and the weights of the output layer can be obtained by using the Orthogonal Least Squares (OLS) algorithm to optimize the number of hidden neurons in large and complex system.

This work was made with ten cases of faults, with four cases of faults inception angle are (0, 45, 90, 135), and with four fault location cases from the sending end distance (25 km,100 km,175 km,250 km) before and after the series compensated so the total cases are (10*4*4=160).Quarter cycle of three phase current signals from only the sending end were decomposed using (db4level3) to get the energy then these data obtained was normalized between 0 and 1after that forward as input to the RBFNN to classify the fault type.

Targets of the outputs from RBFNN are detected with 0 if healthy and 1 when faulty. During study we notice that the fault inception angle affected the current energy although for same fault type and at same location. The energy of different phases at steady state appeared very near or almost same, these values are used as a reference to notice the effect of different faults at the signal energy value

During single line to ground fault, the energy of the effected line was increased sharply from its normal state although the other two phases slightly changed. During double line with or without ground fault the energy of the effected two lines were increased sharply from their normal state although the healthy phase slightly changed. During three line faults the energy of the three affected lines were increased from their normal state.

Although RBFNN for almost cannot detect the ground phases fault directly but should making some index or adding extra input data but in this work no need to make that as it will detect the ground directly from the inputs without adding any extra data or making any index. The proposed RBFNN for fault classification estimation in power systems is proved to be very efficient and built up in a fraction of time and performs very well.

Chapter 6 presents conclusion of the thesis and the recommendation for future work