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Support Vector Machines for classification and locating faults on transmission lines

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ABSTRACT

This paper presents a new approach to classify fault types and predict the fault location in the high-voltage power transmission lines, by using Support Vector Machines (SVM) and Wavelet Transform (WT) of the measured one-terminal voltage and current transient signals. Wavelet entropy criterion is applied to wavelet detail coefficients to reduce the size of feature vector before classification and prediction stages. The experiments performed for different kinds of faults occurred on the transmission line have proved very good accuracy of the proposed fault location algorithm. The fault classification error is below 1% for all tested fault conditions. The average error of fault location in a 380 kV–360-km transmission line is below 0.26% and the maximum error did not exceed 0.95 km.

1. Introduction

The accurate fault location is a very challenging task for power transmission line protection, since a more accurate location results in the minimization of the amount of time spent by the repair crews in searching for the fault.

There are several methods such as radial basis function neural networks, back propagation neural networks, fuzzy neural networks, WT and Kalman filtering approach based on measuring faulty current and voltage signals and a lot of study has been continued with advance in computer technology [1,2]. The above mentioned approaches require large training sets and training time. These methods are also sensitive to system frequency changes [3]. The methods based on artificial neural network (ANN) combining with WT are very encouraging for line protection applications.

In recent years, a widely used method in the classification and regression problems is SVM. In SVM technique, the original input space is mapped into a high dimensional dot product space called feature space in which the optimal hyperplane is determined to maximize the generalization ability of the classifier [3]. The optimal hyperplane is found by using optimization theory and the Statistical Learning Theory. In recent years, SVM has been widely used in many research areas, such as face recognition, signal and image processing and fault diagnosis. SVM based classifiers have better generalization properties than ANN based classifiers. The efficiency of SVM based classifier does not depend on the number of features. This property is very useful in fault diagnostics because the number of features to be chosen is not limited, which make it possible to compute directly using original data without preprocessing them to extract their features. These advantages make SVM an excellent choice for the fault detection and localization applications.

This paper presents a novel method based on Discrete Wavelet Transform (DWT) and SVM for the prediction of fault types and location. Wavelet entropy criterion is applied to wavelet detail coefficients to reduce the size of feature vector before classification and prediction stages. The advantages of WT on Fourier Transform for analyzing non-stationary signals and the good performance of SVM which has been proved in the literature for classification problems are combined in this study. The application of wavelet entropy criterion to decomposed fault signals reduces the size of feature matrix. Therefore, both training time is reduced and the performance of the proposed method is increased by using this new distinguished data set.

The proposed SVM based method works in three stages. In the first stage, the current and voltage signals which are obtained from the sending end of the transmission line are saved for different fault types and locations. In this stage, the entropy criterion which gives the disturbance level of a curve is also applied to detail coefficients of DWT to reduce the sizes of feature matrix. The data obtained from DWT are normalized between [−1, 1]. In the second stage, Multi-class Support Vector Machines (MCSVM) which consists of several binary SVM is employed for the classification task after parameter optimization. In this way, the most efficient parameters which give the best training results can be found. In the third and last stage, the fault locations are predicted by using SVM.

The results presented show that the proposed approach of fault location gives accurate results in terms of the estimated fault

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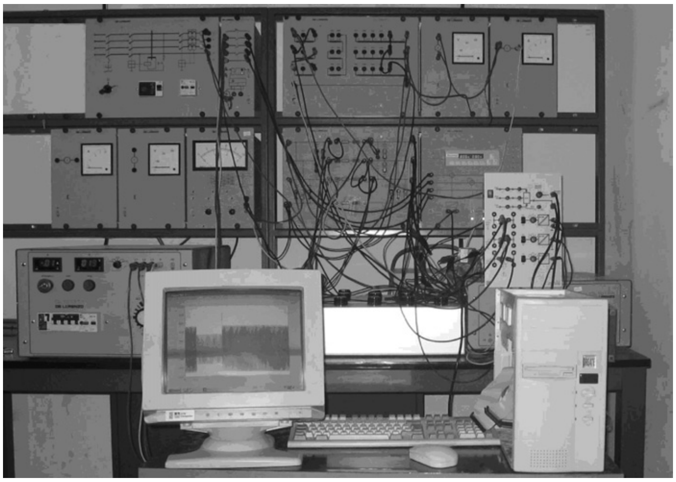

Fig. 1. Prototype power system.

location. The results also demonstrate the feasibility of applying the proposed method in fault classification and location problems.

2. Characteristics of power transmission line system

To obtain the necessary information about the fault cases, a 380 kV–360 km long transmission line model is experimented in laboratory as shown in Fig. 1. It is true that lossless lines cannot realized in practice, nevertheless the simplifications are more applicable.

In order to investigate the stationary performance a simulation using one or, if necessary, more π elements is sufficient; in this case, the quantities per unit length are added together into compound circuit elements. This simplification is sufficiently accurate for those line lengths used in actual practice. For basic considerations, which are not used for quantitative evaluations, lines transmitting high and ultra-high voltage levels can only be modeled through an inductance and capacitance. This representation is sufficient for displaying some of basic characteristics of a line in operation. At least the equivalent resistance is to be taken into account for additional considerations (e.g. determination of efficiency).

Table 1
Line parameters of 380 kV overhead transmission line.

Circuit parameters	Values
Ohmic resistance at 20 °C	0.036 Ω/km
Line inductance	0.805 mH/km
Capacitance conductor-conductor	2.78 nF/km
Capacitance conductor-ground	5.556 nF/km
Operating capacitance	13.889 nF/km
Characteristic impedance	240 Ω
Thermal limit rating	1700 MVA
Return line resistance	0.031 Ω/km
Return line inductance	0.694 mH/km

In the laboratory experiment performed in this study, this type of low-loss transmission line is simulated. The actual line on which this simulation is based has a length of 360 km overhead transmission line on braced mast, cross-section $4 \times 240/40\,\text{mm}^2$ Al/St. and the following data in Table 1.

For all fault types occurred at 50 different locations, the faulty voltage and current signals are saved by a data acquisition card. In Fig. 2, two-phase to ground fault voltage and current curves obtained from sending end of the prototype transmission line are illustrated.

The prototype power system is also simulated by using ATP/EMTP [4,5]. The one-line diagram of the studied ATP system is shown in Fig. 3. The simulation time is 500 ms with 20 µs time step. Fault type, fault location and fault inception time are changed to obtain training patterns covering a wide range of different power system conditions. In Fig. 4, the voltages and currents of a two-phase to ground fault occurred at sending end of the line and obtained from ATP simulation are shown.

3. Review of Wavelet Transform

Wavelet Transform (WT) is a mathematical technique used for many applications of signal processing [6,7]. Wavelet is much more powerful than conventional methods in processing the stochastic signals because of analyzing the waveform time-scale region. In Wavelet Transform, the band of analysis can be adjusted so that low frequency and high frequency components can be

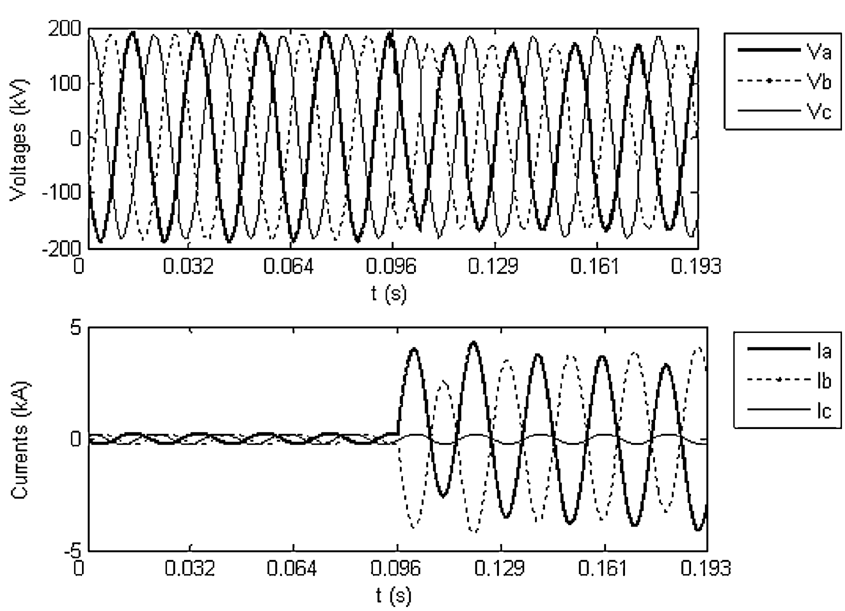

Fig. 2. Voltages and currents of a two-phase to ground fault.