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A rough membership neural network approach for fault classification in transmission lines ☆

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ABSTRACT

Objective: This paper presents a new approach for fault classification in extra high voltage (EHV) transmission line using a rough membership neural network (RMNN) classifier.
Methods: Wavelet transform is used for the decomposition of measured current signals and for extraction of ten significant time–frequency domain features (TFDF), as well as three distinctive time domain features (TDF) particularly in terms of getting better classification performance. After extracting useful features from the measured signals, a decision of fault type of a transmission line is carried out using ten RMNN classifiers. Furthermore, to reduce the training times of the neural network, the rough neurons are used as input layer neurons, and the fuzzy neurons are utilized in hidden and output layer in each RMNN. And the Back Propagation (BP) algorithm is employed for determining the optimal connection weights between neurons of the different layers in the RMNN.
Results and Conclusions: To verify the effectiveness of the proposed scheme, extensive simulations have been carried out under different fault conditions with wide variations in fault type, fault resistance, fault location and fault inception angle. Simulations results show that the proposed scheme is faster and more accurate than the back-propagation neural network (BPNN), and it is proved to be a robust classifier for digital protection.

Introduction

Power systems transmission line fault identification is very important to ensure quality performance of the power system. Accurate and fast fault classification will help to facilitate quicker repair, improve system availability, and reduce operating costs [1–3].

Generally, the transmission line fault types classification is a typical pattern recognition problem. Numerous methods available for transmission lines fault classification have been proposed in the past. All of them can be attributed to two steps basically. The features in the current and/or voltage waveforms are extracted firstly, and then an appropriate classifier is utilized to identify different faults using the extracted features.

The features of the steady-state components have been used in the traditional fault classification scheme [4–6]. However, the steady-state components of fault current and voltage are easily impacted by many factors, such as fault type, fault inception time, and specially fault resistance. Hence, the result of transmission line fault classification is unsatisfactory. Fortunately, a lot of researches have indicated that the fault-generated transient components contain abundant fault information and are immune to the system's inconstancy. Although the fault-generated transient currents and/or voltages are utilized for transmission lines fault classification in many literatures [7–9], how to extract the effective features from the original fault transient signal is the most essential issue in these algorithms. Wavelet transform (WT), which has the perfect time–frequency localization ability, has been chosen as an effective tool for analyzing the fault transients [3,10–17]. WT was used in Ref. [11] to capture the high-frequency traveling waves for fault detection, classification, and phase selection of faults, while [12] took the discrete wavelet transform (DWT) as the fault feature extractor for the boundary protection of series-compensated transmission lines. Wavelet multi-resolution analysis (MRA) is the computing algorithm used by DWT with the automatically adjusted window to extract sub-band information from fault transients [14]. Thus it has been proved as an effective tool in analyzing fault transients. Such as, Ref. [15] presented a methodology for fault classification based on MRA and [16] presented a MRA based method for disturbance detection and classification. Moreover, wavelet entropy criterion is applied

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to wavelet detail coefficients to reduce the size of feature vector before classification stages [18–21], although it has higher computational complexity.

On the other hand, a significant amount of research work has been directed to address the problem of an accurate fault classification scheme. Different attempts have been made for fault classification, including approaches based on, fuzzy logic [5,17,22], support vector machine [4,6,23,24], neural networks [2,8,9,13,26–33], and the fusion of different artificial intelligence techniques [10,33–35]. In all of these, artificial neural network (ANN), which is one of the best intelligent classifiers, has been employed for fault classification in transmission lines successfully. A typical back-propagation neural network (BPNN) is a nonlinear regression technique which attempts to minimize the global error, and the sigmoid activation function is used frequently. The BPNN can yield very compact distributed expressions of complex data sets [25]. However, it is limited partly by low learning efficiency and local extremum [13]. Thus, a fault classification method based on a radial basis function (RBF) neural network was proposed in [26,28]. Furthermore, Ref. [29] presented a novel approach for fault classification based on finite impulse response artificial neural network (FIRANN) for high-voltage transmission lines. And an advanced pattern recognition algorithm based on adaptive resonance theory (ART) neural network was also used for fault classification to resolve the instabilities inherent in the BPNN [13,30]. In addition, the classification method based on probabilistic neural network (PNN) was utilized for identifying the type of transmission lines fault [9,31,32] because of the key advantage of its fast training process.

This paper aims at using a combination of wavelet multi-resolution analysis (MRA) and novel artificial neural network (ANN) to classify transmission lines faults in electric power systems. A typical 50 Hz 500 kV power transmission system with actual line parameters has been used as object of study. The fault conditions are simulated using electromagnetic transient program (EMTP). Post-fault current signals in each case are decomposed to several scales on the wavelet transforms, and then certain selected time–frequency domain features (TFDF) and time domain features (TDF) of the wavelet transformed signals are used as inputs for a training process on the neural networks. A rough membership neural network (RMNN) is exploited as the fault classifier, in which the rough membership neurons and fuzzy neurons are used. The main purpose of the approach is to classify the fault, where the fault types that can be identified as single phase to ground faults (Ag, Bg, Cg), phase to phase to ground faults (ABg, BCg, CAg), phase to phase faults (AB, BC, CA), and three phases fault (ABC). To study the effectiveness of the proposed method, a distributed-parameter model for the physical components of the system has been constructed. And then the wide variations in fault type, fault resistance, fault location and fault inception angle have been taken into account.

Proposed approach

The proposed approach for transmission line fault classification involves two modules named features extraction module and classification module, which is shown in Fig. 1.

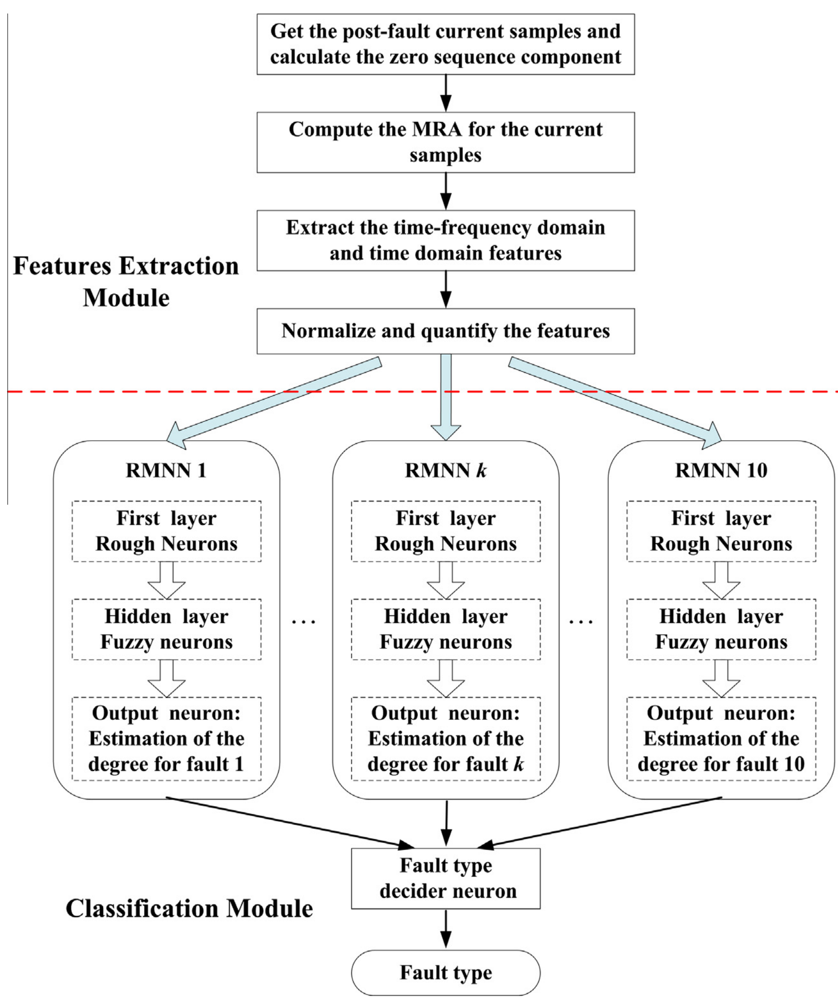

Fig. 1. Flowchart of the proposed fault classification approach.