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Time domain complete protection scheme for parallel transmission lines

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Abstract In this paper, time domain relaying schemes for complete protection of parallel transmission lines using wavelet and artificial neural network (ANN) are presented. Four different ANN networks are designed for detection of the fault, fault section identification, classification of fault and location of fault in time domain. The 3rd level approximate discrete wavelet transform (DWT) coefficients of signals of one end are used as input to ANN network. Proposed method is tested with varying fault location, inception angle, fault type and fault resistance. The test results show that the fault is detected and located within 5 ms time accurately. This scheme offers primary protection as well as backup protection to the lines.

1. Introduction

Modern extra high voltage networks require faults to be detected and cleared rapidly and selectively to improve the transient stability and maintain reliable power supply. Also in re-structured power systems where the lines are utilised at their boundary limits of stability, high speed fault detection is required. The fundamental objectives of protective relaying are fault detection, fault direction estimation, fault section identification, fault classification and fault location. Distance relays are based on impedance calculation with operating time of one cycle. Besides the first zone reach setting is 80–85% only, if fault occurs in far end, the fault would last for long duration before it is identified in second zone of protection. Travelling wave based directional relaying scheme [1,2] is one of the high speed fault detection techniques but has the inherent disadvantage of unable to solve the zero inception angle faults near to zero crossing of the voltage waveform. Synchronised phasor measurement techniques using global positioning system (GPS) are proposed [3,4] which operates faster, but it depends upon availability communication link. The soft computing technique such as artificial neural network has been also applied in directional fault detection in [5,6], but they do not identify fault type and do not locate the fault. ANN has been applied for protection of transmission line [7], but it does not estimate the exact location of fault. In [8,9] ANN based schemes have been developed, but these ANN based relays are not directional and also they do not estimate the fault location.

Wavelet transform based schemes have been proposed in [10–12] for fault classification. Various other soft computing

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techniques combining the wavelet transform with fuzzy logic [13] and ANN [14–16] have also been proposed. But the researchers in [13–16] deal with single line section and do not estimate fault direction and location. Directional protection schemes based on wavelet transform have also been developed in [17–19]. However the fault classification/phase identification and distance location functions have not been considered in these papers [17–19]. Another scheme for direction estimation, fault phase identification and location [20] has been proposed which requires the remote end data also. Thus its reliability depends upon the availability of the communication link.

In the last two years, various researchers has developed the transmission line protective relaying schemes using support vector machines (SVM) [21], adaptive distance relaying [22] and s-transform based distance relaying [23]. But they [21–23] do not deal with fault direction estimation. Further some algorithms [24–26] based on phase angle difference of sequence component and wavelet analysis of current signals [27] are reported, but they do not identify the faulty phase nor do they estimate the fault location. Moreover the reach setting of one terminal data based schemes is 80–85% only. Recently authors have proposed ANN based directional relay [28] using fundamental components of signals with fault detection time of 10 ms. But this technique does not estimate the fault location which is required to reduce the down time, to speed up the power restoration and to enhance the power system reliability and availability. Further another paper has been reported based on ANN for six phase transmission protection line [29] using fundamental components. But this ANN based relay is non-directional.

In this paper, a complete protection scheme is presented which provides all the protective relaying functions i.e. fault detection, section identification (direction), phase identification and location estimation. Combined wavelet transform and ANN based protection scheme is proposed for parallel transmission lines which provides both primary and backup protection. Proposed method is not affected by variation in fault type, fault distance, fault inception angle, and fault resistance.

2. Description of power system under study

Power system under study is represented in Fig. 1. It consists of 400 kV, 50 Hz transmission line trifurcated into sections 1, 2 and 3 each of 100 km length extending between two sources. The power system network parameters have been taken from [28]. The proposed relay is designed to indicate the direction of fault, thus indicating the absence or presence of a fault in forward or reverse line section from bus-2. The proposed protection scheme consists of four ANN modules for detection, section identification, phase identification and location estimation in time domain. The output of first three ANN modules in time domain is zero (low) during no-fault situation. However the moment the fault occurs, and the output(s) of ANN modules starts changing and reaches to ≈1 (high) value within quarter to half cycle time. On the other hand during the no-fault situation, the output of fault location module in time domain shows the fault location value as 210 km i.e. outside the zone of primary and backup protection range (200 km from the relaying point) and after the instant of fault inception, it starts decreasing and settles down to the actual fault location value with reasonable accuracy.

3. Wavelet and ANN based complete protection scheme

Protection scheme designed has four artificial neural network modules to detect and identify the section, classify and locate the faults in time domain. Different steps involved in the method are described below.

3.1. Pre-processing of signals using discrete wavelet transforms

The wavelet transform has emerged as a very effective tool to analyse the non-stationary signals such as faulty phase current and voltage signals. In this study, the signals of both the circuits are analysed using Daubechies wavelet and decomposed up to 3 levels of detailed and approximate coefficients using wavelet analysis toolbox of MATLAB software. DB wavelets are orthogonal wavelets used for signal discontinuities, and after many investigations it was found that DB-4 depicts the pattern of the fault more accurately [30]. Number 4 represents the number of wavelet coefficient. Decomposition of current and voltage signals up to level 3 using DB-4 is shown in Fig. 2(a). After decomposing the signal up to level 3, approximate coefficient of the signal is taken for further analysis. In this study wavelet coefficient reconstruction technique is used to get the approximate coefficient signal of the same length as original signal. In wavelet reconstruction process, zero padding is used to obtain the original signal as shown in Fig. 2(b). Feature signals that are obtained after wavelet reconstruction process are shown in Fig. 3 for both current and voltage signals during A1G fault at 25 km in section 2 at 60 ms time.

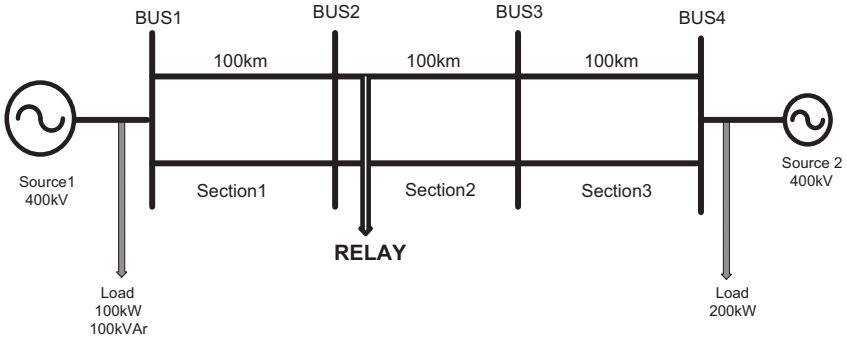

Figure 1 400 kV Three phase power system network under study.