Electric Power Systems Research 161 (2018) 8–16

Contents lists available at ScienceDirect

Electric Power Systems Research

journal homepage: www.elsevier.com/locate/epsr

Wavelet-alienation based protection scheme for multi-terminal transmission line

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ARTICLE INFO

Article history:
Received 23 August 2017
Received in revised form 8 February 2018
Accepted 29 March 2018

Keywords:
Alienation coefficients
Artificial neural network
Line protection
Multi-terminal transmission line
Wavelet transform

ABSTRACT

This paper presents a wavelet-alienation based protection scheme for multi-terminal transmission system. The proposed algorithm makes use of wavelet transform based approximate coefficients of three-phase voltage and current signals, obtained over a quarter cycle to detect, classify and locate various faults. Detection and classification of faults are achieved with the help of approximate coefficients based alienation coefficients of current signals, measured from all the buses of system. The approximate coefficients of voltage and current signals, obtained over a quarter cycle, are fed to artificial neural network to locate the faults precisely, from respective buses. This algorithm has been tested successfully for all the types of faults with variations in location, inception angle and fault impedance. The proposed protection scheme is generalized for N-terminal system followed by successful testing on three-terminal and five-terminal systems.

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1. Introduction

The importance of a power system includes high reliability and efficiency. Multi-terminal lines play an important role in transmitting the power economically, to cope up with the demand in the present scenario of increased industrialization. The quick fault detection and fault location on these lines help in improving the power quality, reliability and economical operation of power system.

Various protection schemes have been introduced in the literature for the detection, classification and location of faults on transmission lines. Wavelet based protection scheme for fault detection, classification and location on transmission lines was proposed by Shaik and Ramana Rao [3,18]. A protection scheme which considers the effect of fault incidence angle had been presented by Costa et al. [8]. A Wavelet-network based algorithm for classification of transients, arising from circuit topology, was proposed by Chatterjee et al. [25,26]. Masoud and Mahfouz introduced a protection scheme for transmission lines based on alienation coefficients of current signals [5]. Shaik et al. developed a transmission line protection scheme using detail coefficients based alienation technique using current signals of local buses [12]. Protection schemes for transmission line faults, making use of wavelet based alienation algorithm, had been proposed by Rathore and Shaik [20,21,24]. ANN based protection schemes for transmission lines had been introduced in Refs. [6,10]. Funabashi et al. proposed a digital fault location scheme for double circuit multi-terminal transmission lines [1]. Protection schemes, making use of supervised learning techniques like Support vector Machine, were proposed in Refs. [27,28]. Tripathy et al. had proposed a differential relaying scheme for tapped transmission lines in presence of both UPFC & wind farm [15]. A protection scheme for multi-terminal transmission lines using distance relay was proposed by Abdelaziz et al. [7]. A universal fault-location method was proposed in [4] for N-terminal ($N \geq 3$) transmission lines. In Ref. [9] a novel wavelet transform-based fault location algorithm was introduced. Fault location schemes for multi-terminal transmission lines using synchronized voltage and current measurement were proposed in Refs. [2,16]. Another fault location schemes for multi-terminal transmission lines using transient current measurement and unsynchronized measurements had been proposed in Refs. [17,22]. Ahmadimanesh and Shahrtash proposed a transient based fault location method for multi terminal transmission lines based on S-transform [11]. An advanced fault location technique, making use of Phase-Measurement Unit was introduced by Jiang et al. [13]. A fault location scheme for three-terminal and multi-terminal transmission lines, making use of synchrophasor measurement, had been proposed in Refs. [14,23]. Uday Bhaskar et al. proposed a wavelet-fuzzy based fault location technique for three-terminal transmission system [19].

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https://doi.org/10.1016/j.epsr.2018.03.025
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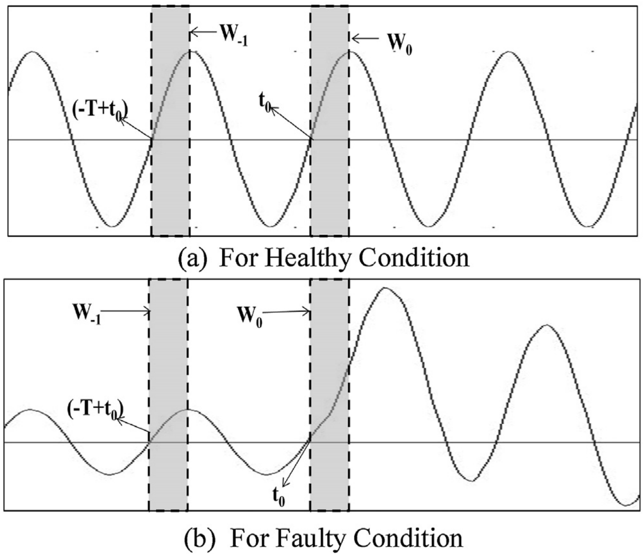

Fig. 1. Comparison of windows for computing alienation coefficients.

However, there is a need to explore a high speed and efficient protection scheme, which can make use of GPS and communication technology. In this work, an algorithm has been proposed, which can detect, classify and locate the faults, within a quarter cycle.

Section 2 describes the wavelet-alienation based algorithm. The proposed algorithm has been explained in Section 3 and simulation results are presented in Section 4. In Section 5, case studies are done for proposed algorithm with different fault locations, incipient angles and fault impedances. Estimation of fault location is discussed in Section 6. In Section 7, generalization to N-terminal system is discussed and Section 8 concludes the paper.

2. Wavelet-alienation based algorithm

2.1. Wavelet transform

Wavelet transform is a multi-resolution analysis based technique which provides information in both time and frequency domains. It decomposes the signal into high frequency (detail coefficients) and low frequency (approximate coefficients) components, when passed through filters. The high pass filter is defined as h (n) and low pass filter as g (n). These filters are related as $g(n) = (-1)^n h(1-n)$. Wavelet transform includes scaling function and wavelet function, which can be represented as follows:

$$\Phi(t) = \sqrt{2}\sum h(n)\varphi(2t-n) \quad (1)$$

$$\Psi(t) = \sqrt{2}\sum g(n)\psi(2t-n) \quad (2)$$

There are different mother wavelets available like Haar, Daubachies, Symlet, etc. and they are selected depending on application.

2.2. Alienation coefficients

In the proposed algorithm current signals are sampled over a quarter cycle. These samples are decomposed to obtain approximate coefficients. The alienation coefficients based on approximate decomposition is calculated as:

$$A_a = 1 - r_a^2 \quad (3)$$

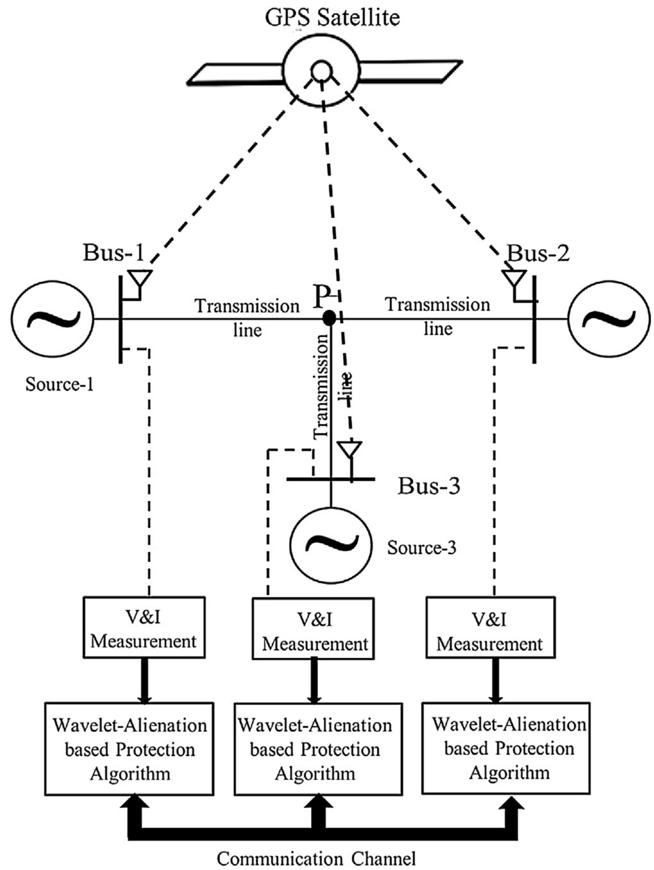

Fig. 2. Proposed system.

where r_a is correlation coefficient which is calculated, using approximate coefficients as:

$$r_a = \frac{N_s(\sum x_a y_a) - (\sum x_a)(\sum y_a)}{\sqrt{[N_s\sum x_a{}^2 - (\sum x_a)^2][N_s\sum y_a{}^2 - (\sum y_a)^2]}} \quad (4)$$

where

N_s = no. of samples in a quarter cycle.

x_a = approximate coefficients obtained at t_0, from window-W_0.

y_a = approximate coefficients obtained at $(-T+t_0)$, from window-W_{-1}, T (time period) = 20 ms.

3. Proposed algorithm

The single line diagram of the system considered, along with various blocks of the proposed scheme, is shown in Fig. 2. The transmission system under consideration has a voltage rating of 345 kV and operates at a frequency of 50 Hz, connecting three AC systems. The parameters of the system under study are presented in Table 1 [11].

The sampling of three-phase voltage and current signals, at all terminals, is carried out at a frequency of 1.6 KHz. The sampling process is synchronized with the help of GPS clock. The three-phase differential current is obtained by adding the respective phase currents from all the terminals. The samples of this differential current of each phase, obtained over a moving window of quarter cycle length, are decomposed with db2 mother wavelet to compute approximate coefficients. Alienation coefficients are computed by comparing approximate coefficients of current window (W_0) with those of previous window (W_{-1}) as shown in Fig. 1, which is termed as fault index.

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