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Improved fault location algorithm for radial distribution systems with discrete and continuous wavelet analysis

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ABSTRACT

This paper presents a novel wavelet based approach for fault location using voltage transient waveforms in power distribution systems. The proposed method includes two main stages. Firstly, the approximate location of the fault or fault section is determined using a new algorithm with discrete wavelet transform. The difference between arriving times of transient components in different measurement units is used for this purpose. The accurate location of the fault is determined in the second stage. Depending on the determined fault section, the difference between arriving times of transient components in different measurement units or the frequency content of the voltage transients are used. The time difference and frequency content are calculated using discrete and continuous wavelet transform (DWT and CWT) respectively. The proposed technique is implemented on an unbalanced 34 bus distribution system with two distributed generation units which is simulated in ATP–EMTP. The comparison of the results of the proposed method with previous works verifies its better accuracy and more robustness to fault conditions including fault inception angle and fault resistance.

Introduction

Fast and accurate location of the faults in a distribution network is essential for reducing the number and duration of power interruptions and increasing the reliability of the distribution systems. This will lead to consumers satisfaction and will reduce damages due to the interruption. Proposing effective and fast methods for fault location is a main stage of distribution network automation. Fault detection, isolation and automatic location are necessities of smart grids. Several approaches have been proposed for fault location in the literature. They can be classified into three main categories including impedance based methods, traveling wave methods, and artificial intelligence. The first category is based on the impedance measurements [1–7]. Different answers for fault location, dependence to the load changes, and fault resistance with inaccurate performance in the case of short-time faults makes these methods unreliable for fault location purpose [8]. In addition, the impedance methods are inappropriate in the presence of distributed generation (DG) resources.

The second category includes the methods that use fault-originated traveling waves. Some of these methods use the traveling time of the forward and backward traveling waves and the successive reflections observed in the measuring points [9–11]. Many measurement units are required for these methods which makes them uneconomical. Therefore, in some papers, the number of the required measurement units is minimized [12]. However, the proposed method in [12] is suitable for transmission networks which have generally a loop structure and such methods are not useful in distribution networks and the required number of measurement units is high. Current transient signals are used in [13] with the energy content of the discrete wavelet transform levels which also suffers the problem of high number of measurement units. Another transient-based method is proposed in [14] which only uses the measurements in the substation. Continuous wavelet transform (CWT) is used to calculate the energy spectrum of the voltage signal and determination of characteristic frequencies. This method is improved in [15] using the time domain analysis. Wavelet packets and Fast Fourier Transform (FFT) is used in [16] to determine the characteristic frequencies. Although these methods use only the measurement on the substation, but they may find multiple answers in the case of the distribution networks with many ramifications. Recently, using the difference between the first and the second peak in the frequency spectrum of the transient components is proposed in [17] for determination of the

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faulted section to overcome this problem. However, this reference has used a small balanced network for testing performance of the proposed approach.

The third category of fault location methods includes artificial intelligence based methods [18–21]. Artificial Neural Networks (ANN), support vector machines (SVM), and fuzzy logic are used for this purpose in recent years. Generally, these methods require considerable training data which is difficult to provide in many cases. For instance, 3500 simulations are performed to obtain training data for a relatively small 6 bus test network in [20] while only phase to ground faults are considered. Consequently, large number of simulations is required to consider other possible fault types.

A novel and more accurate method is proposed in this paper which is based on continuous and discrete wavelet transform. At the first step, the fault section is located using the time difference between arrivals of the voltage transients in different measurement points. Then the accurate location of the fault is determined by the mentioned time difference or analysis of the frequency contents of the measured voltage transients in the substation. The proposed approach is implemented on an unbalanced 34 bus distribution network with two distributed generation (DG) units. The required voltage waveforms are obtained with simulation of this network in ATP–EMTP.

The paper is organized as follows. Section ‘Wavelet transform’ is dedicated to introduction of wavelet transform. Different stages of proposed method including the determination of fault section and fault type and calculation of accurate fault location are presented in Section ‘Methodology’. Results of the implementation of the proposed algorithm in 34 bus case study system is presented and compared with other methods in Section ‘Results’. Finally, Section ‘Discussion’ concludes the paper.

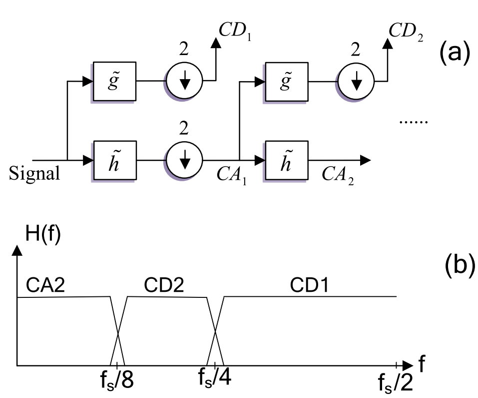

Fig. 1. Discrete wavelet analysis. (a) Multi resolution decomposition of a signal with down-sampling, and (b) frequency bands in a two level decomposition.

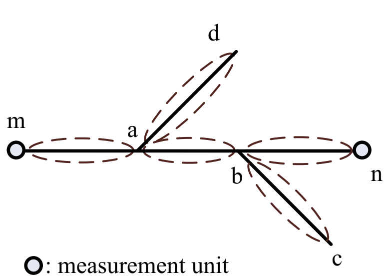

Fig. 2. A simple network with its fault sections and measurement units.

Table 1
Determination of the fault section in the network shown in Fig. 2.

Section	Time difference
m–a	$\Delta t < \Delta t_a$
a–d	$\Delta t = \Delta t_a$
a–b	$\Delta t_a < \Delta t < \Delta t_b$
b–c	$\Delta t = \Delta t_b$
b–n	$\Delta t > \Delta t_b$

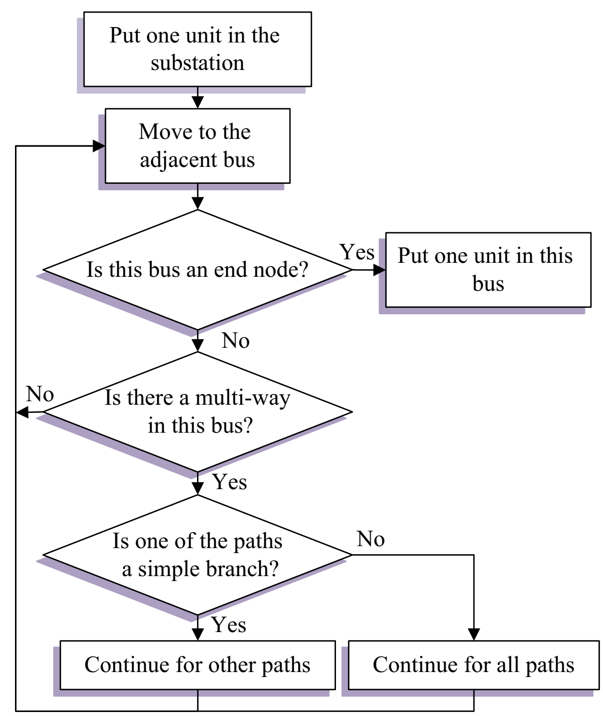

Fig. 3. The flowchart for determining location of the measurement units.

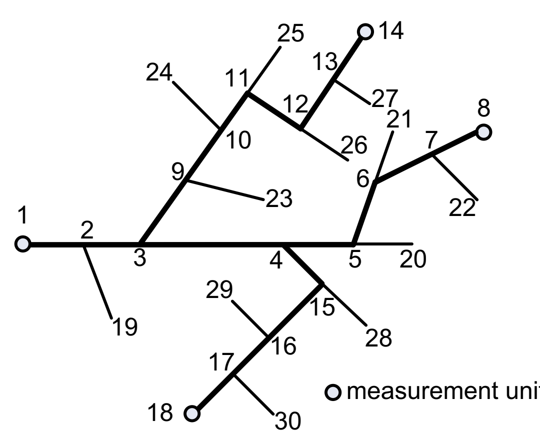

Fig. 4. A network with measurement locations determined by the proposed method.

Wavelet transform

A wavelet is a small wave which its energy is concentrated in time. Therefore, it is a powerful tool for analysis of the transients and non-stationary and time varying events. Wavelet transform can be defined in two forms as continuous and discrete wavelet