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Electric Power Systems Research 73 (2005) 107–112
ELECTRIC POWER SYSTEMS RESEARCH
www.elsevier.com/locate/epsr

A new digital relaying scheme for EHV three terminal transmission lines

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Received 16 February 2004; received in revised form 12 April 2004; accepted 19 June 2004
Available online 21 September 2004

Abstract

The paper describes a new technique for protecting asymmetrical and symmetrical EHV three terminal lines. One relay is installed to recognize a blocking or a tripping terminal at the terminal that uses two circuits. The polarity of fault current is detected at each end using the Haar wavelet function. A communication channel is used to receive the status of the polarity at each end. A gate logic circuit at each end is used to issue final decision based on the collected polarities. The problem areas of the current protective techniques are solved. No voltage signal is used. An EMTP/ATP simulator is used to demonstrate the performance of the proposed technique.

Keywords: EHV three terminal lines; Asymmetrical circuits; Current signal; Haar wavelet function

1. Introduction

Pilot relaying is the best type for line protection. It is used whenever high-speed protection is required for all types of short circuits and for any fault location. At a given terminal the direction of a fault is determined. By transmitting this information to the remote end and applying the appropriate logic, both ends can determine whether a fault is within the protected line or external to it [1].

Different schemes [2–4] for detecting faults on teed circuits using the fault generated HF voltage signals measured at every end are proposed. The HF signals are captured using a specially designed stack tuner connected to a standard capacitor voltage transformer. A directional comparison technique for line protection by comparing the polarity of fault generated transient current signals in the system is proposed in [5].

Directional comparison relaying is applicable to any multi-terminal line. Under some circumstances proper operation will not be obtained without a very careful choice of the type of equipment and of the blocking and tripping relay adjustments [6]. From the protection point of view, the asymmetrical teed circuits have presented difficult problems [6] which are not readily solved using conventional unit or non-unit techniques.

This paper describes a new technique for discriminatively detecting faults on asymmetrical and symmetrical teed circuits. One relay instead of two is located at each terminal that has two circuits. The relay successfully recognizes a blocking or tripping terminal before computing the polarities. Then, a very powerful tool such as the CWT based Haar basis function is applied to identify the polarity of the fault at each terminal. A communication channel is used to send the status of polarity at each end. A final decision is issued based on a comparison between the polarities at each terminal using the “logic decision”. The problem areas of the current protective techniques are solved. The suggested technique relies on current signal only and excludes the voltage signal. Fig. 1 shows the studied configuration system.

2. Continuous wavelet transform

The continuous wavelet transform (CWT) is used to decompose a signal into wavelets, small oscillations that are

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doi:10.1016/j.epsr.2004.06.009

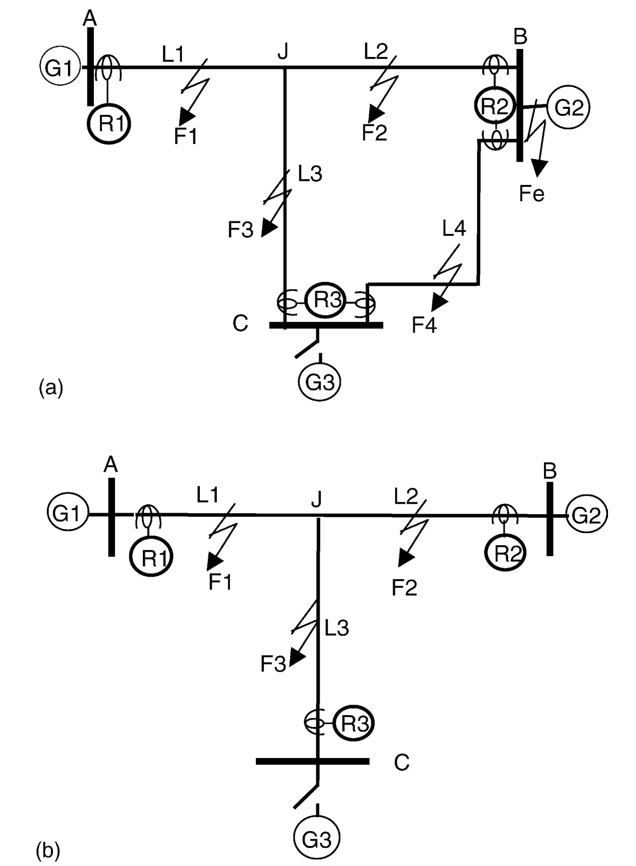

Fig. 1. The studied configuration system: (a) asymmetrical teed circuit; (b) symmetrical teed circuit.

highly localized in time. Whereas the Fourier transform decomposes a signal into infinite length sines and cosines, effectively losing all time-localization information, the CWT's basis functions are scaled and shifted versions of the time-localized mother wavelet. The CWT is used to construct a time–frequency representation of a signal that offers very good time and frequency localization [7].

The CWT is an excellent tool for mapping the changing properties of non-stationary signals. The CWT is also an ideal tool for determining whether or not a signal is stationary in a global sense. When a signal is judged non-stationary, the CWT can be used to identify stationary sections of the data stream.

Wavelets are a class of functions used to localize a given function in both space and scaling. A family of wavelets can be constructed from a function $\psi(x)$, sometimes known as a "mother wavelet", which is confined in a finite interval. "Daughter wavelets" $\psi^{a,b}(x)$ are then formed by translation (b) and contraction (a). Wavelets are especially useful for compressing image data, since a wavelet transform has properties which are in some ways superior to a conventional Fourier transform [8].

An individual wavelet can be defined by [9]

$$\psi^{a,b}(x) = |a|^{-1/2}\psi\left(\frac{x-b}{a}\right) \qquad (1)$$

Then

$$W_\psi(f)(a,b) = \frac{1}{\sqrt{a}}\int_{-\infty}^{\infty} f(t)\psi\left(\frac{t-b}{a}\right)\mathrm{d}t \qquad (2)$$

$$f(x) = C_\psi \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} \langle f, \psi^{a,b}\rangle \psi^{a,b}(x) a^{-2}\,\mathrm{d}a\,\mathrm{d}b \qquad (3)$$

2.1. Wavelet basis functions (mother wavelets)

Unlike a Fourier decomposition which always uses complex exponential (sine and cosine) basis functions, a wavelet decomposition uses a time-localized oscillatory function as the analyzing or mother wavelet. The mother wavelet is a function that is continuous in both time and frequency and serves as the source function from which scaled and translated basis functions are constructed. The mother wavelet can be complex or real, and it generally includes an adjustable parameter which controls the properties of the localized oscillation. Wavelet analysis is more complicated than Fourier analysis since one must fully specify the mother wavelet from which the basis functions will be constructed.

The paper introduces a method of applying the Haar wavelet transform to detect the polarity of the current signal at each terminal. Its basis elements are translated and scaled versions of the following functions:

$$\begin{aligned} \psi(t) &= 1 && \text{for } t \in (0, 0.5) \\ \psi(t) &= -1 && \text{for } t \in (0.5, 1) \\ \psi(t) &= 0 && \text{elsewhere} \end{aligned} \qquad (4)$$

The Haar function is a compactly supported step function. This symmetric mother function is also known as a square wave. Note that this function is already normalized with respect to inner product on $L^2(R)$. The wavelet framing function may immediately be applied to generate the family of basis factions. This function is very useful in exposing the properties of the wavelet transform and very popular in signal processing application.

3. Principle of operation

The suggested technique is explained in the following sections.

3.1. Fault detection

The fault is detected by comparing the most recent samples with the samples memorized one cycle earlier. The difference between the pre- and the post-fault values of the currents are checked to determine if it exceeds a pre-defined threshold.