FAULT DETECTION, CLASSIFICATION AND LOCATION ON AN UNDERGROUND CABLE NETWORK USING WAVELET TRANSFORM

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ABSTRACT

This paper describes a technique to detect, classify and locate faults on an underground cable system based on the principles of travelling waves. The occurrence of faults on power systems will result in the high frequency voltage and current signals to propagate along the power systems. These signals contain a lot of information and can be used for fault detection, classification and location. Using the wavelet technique, the high frequency components are extracted and analysis of the extracted signals is done. The power system simulator, PSCAD/EMTDC is used to model the network and faults at various locations are simulated. The resulting wavforms are subjected through a wavelet transform to extract the required signals for analysis. The results show that the wavelet transform is very effective to extract the transient components from the fault signals and detection, classification and location of faults can be done accurately.

Keywords: *Wavelet Transform, fault location, transient*

INTRODUCTION

Underground cable is used largely in urban areas and compared to overhead line, fewer faults occur in underground cables. However if faults occur, it's difficult to repair and locate the fault. Faults that could occur on underground cables networks are single phase-to-earth (SLG) fault, double phase-to-earth., phase-to-phase fault, three phase fault and three phase-to-earth fault [1]. The single line to earth fault is the most common fault type and occurs most frequently.

Fault detection and location based on the fault induced current or voltage travelling waves has been studied for years [2-10]. In all these techniques, the location of the fault is determined using the high frequency transients. The main idea behind these techniques is based on the reverberation of the fault generated travelling waves in the faulty system.

Fault location based on the travelling waves can generally be categorised into two: single-ended and doubleended.

For single-ended, the current or voltage signals are measured at one end of the line and fault location relies on the analysis of these signals to detect the reflections that occur between the measuring point and the fault. For the double-ended method, the time of arrival of the first fault generated signals are measured at both ends of the lines using synchronised timers. The double-ended method does not require multiple reflections of the signals. However, single-ended location is preferred as it only requires one unit per line and a communication link is not necessary.

This paper presents a wavelet technique that can extract the high frequecy fault signals for cable fault detection, classification and location. The technique determines the fault position by measuring the travelling time of the high frequency current signals. An 11kV distribution cable is modelled using PSCAD/EMTDC software, the faulted response of which is examined with respect to different system configurations and fault conditions. The Wavelet Transform band pass filter is used to analyse the high frequency fault signals and to derive the fault location accurately.

WAVELET TRANSFORM

Wavelet transform is much like the Fourier transforms, however with one important difference: it allows time localization of different frequency components of a given signal. Windowed Fourier transform also partially achieves this same goal, but with a limitation of using a fixed width windowing function. In the case of wavelet transform, the analyzing functions, which are called wavelets, will adjust their time-widths to their frequency in such a way that, higher frequency wavelet will be narrow and lower frequency ones will be broader. So this property of multi resolution is particularly useful for analyzing fault transients which contain localized high frequency components superposed on power frequency signals. Thus, wavelet transform is better suited for analysis of signals containing short lived high frequency disturbances superposed on lower frequency continuous waveform by virtual of this zoom-in capability [2].

Given a function f (t), its continuous wavelet transform (WT) will be calculated as follows:

$$WT\ (f, a, b) = \frac{1}{\sqrt{a}} \int f\ (t)\ \psi^{*}\ \frac{(t-b)}{a}\ dt \quad (1)$$

Where, a and b are the scaling (dilation) and translation (time shift) constants respectively, and ψ is the wavelet function (mother wavelet).

PRINCIPLE OF FAULT DETECTION, CLASSIFICATION AND LOCATION

The fault generated transient signal is nonstationary, covers a wide band of frequencies (tens to hundreds kHz). When a fault occurs in a network, the fault generated transients signals will travel in the network. On the arrival at a discontinuity position, the transient wave will be partly reflected and the remainder is incident to the line impedance. The transient reflected from the end of the line travels back to the fault point where another reflection and incident occur due to the discontinuity of impedance. In order to capture these transients signals, wavelet analysis will be used.

The arrival of the first transient signal at the measurement point will indicate that a disturbance had occurred in the network and this can be used as the detection method. The classification of the fault can be made by comparing the transient signals at all phases. If the transient signal appears at only one phase, then the fault is a one phase to earth fault.

The fault location can be carried out by comparing the aerial mode wavelet coefficient to determine the time instant when the energy of the signal reaches its peak value. The distance between the fault point and the bus of the faulted branch will be given by [11]:

$$d = \frac{v\ x\ t_d}{2} \quad (2)$$

where d is the distance to the fault, t_d is the time difference between two consecutive peaks of the wavelet transform coefficients of the recorded current and v is the wave propagation velocity of the aerial mode.

MATERIALS AND METHODS

A. System Modelling and Simulation

The response of the complete system is evaluated by modeling the underground cable system. The simulation of the faulted power system was carried out using PSCAD/EMTDC. Wavelet transform effectively acts as a band pass filter which extracts a band of high frequency transient current signals from the faulted cable.

B. Simulation studies

Results from simulations are obtained with 1600 Hz sampling rate and with Wavelet transform of Daubechies Db-4. The travelling wave velocity of the signals in the 11kV underground cable system is 1.9557×10^5 km/s. A sampling time of 10μs is used.

Figure 1 shows a typical 11kV underground cable system. The three stranded phase conductors in the cable have their own insulation and are belted within and aluminium armour and outer insulation. The total length of cable is 100km.

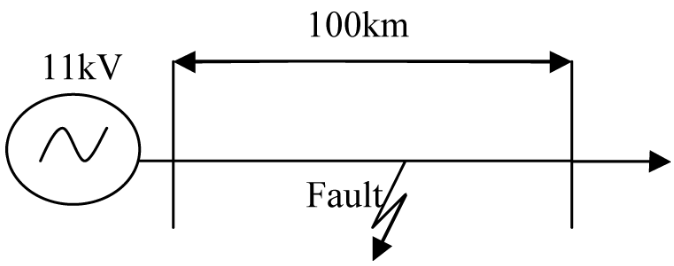


Figure 1: An 11kV underground cable system

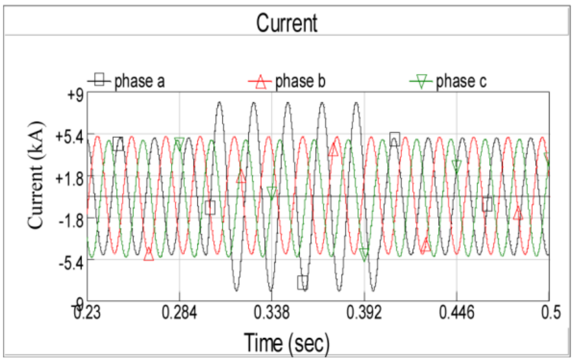
RESULTS AND DISCUSSIONS

A. Fault Detection

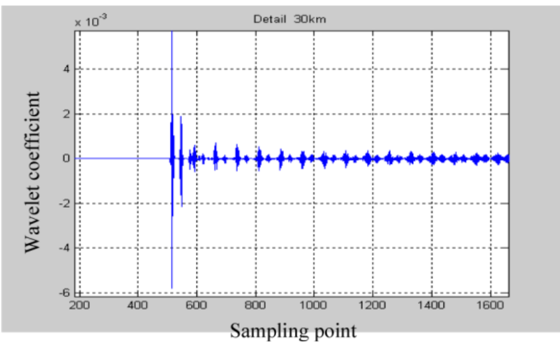
Fault detection and classification are important because they are the basic of protective relaying. Without accurate fault detection and classification, the protective relaying cannot start and trip correctly.

Figure 5 shows a single line to earth fault at 1 km with 1Ω fault resistance for the two terminal systems. Figure 5a is the phase current fault and Figure 5b is the transient current extracted using the wavelet transform.

Figure 6 shows a single line to earth fault at 1 km with 50Ω fault resistance. The higher fault resistance caused the current magnitude to be only slightly higher than normal and may not be that obvious for the naked eyes. However with wavelet transform as shown in Figure 6b, the fault can still be detected as the transient signals are present to indicate a disturbance in the system.

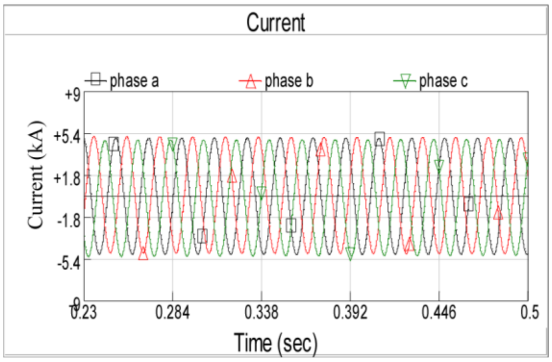


(a)

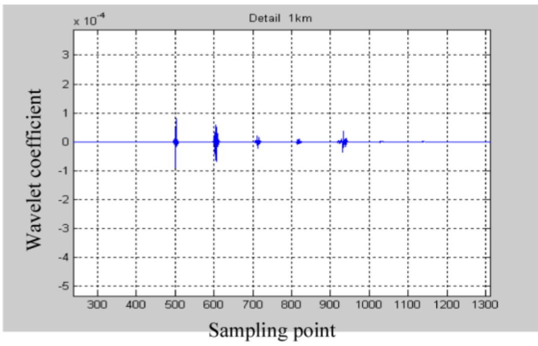


(b)

Fig 5: Technique used in fault detection at 1km with 1Ω fault resistance



(a)



(b)

Fig 6: Technique used in fault detection at 1km with 50Ω fault resistance

B. Fault Classification

The identification of the faulted phases is based on comparisons of fault transient on all phases using wavelet transform. Classifications of faults are important so that the protective equipments are able to trip correctly.

Figure 7 shows the phase currents for a single line to earth fault at phase A. Using wavelet transform, the transient signal for each phase are taken and shown in Figure 7a (phase A), 7b (phase B) and 7c (phase C). Only Fig 7a shows there is a transient signal which means that the fault is a Phase A to earth fault. Figure 8 shows the current waveforms for a double line to earth fault. With wavelet transform applied to extract the transient signals from all phases as shown in Fig 8a, b, and c, it indicates that the fault is actually a Phase A to B to earth fault as the transients appear in Phase A and B but not in Phase C.

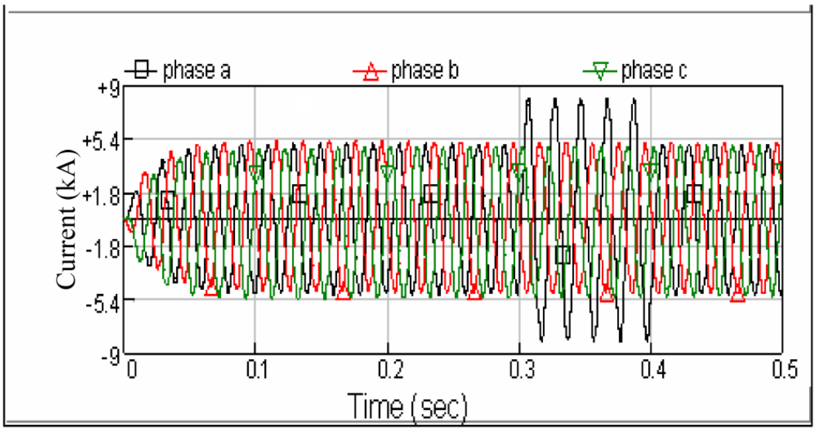
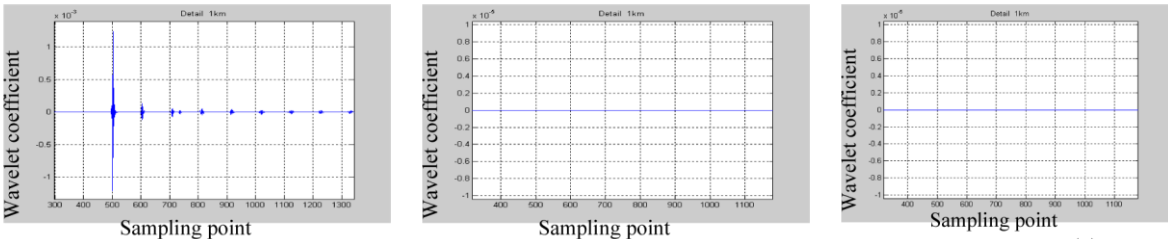


Figure 7: Current for a single line to earth fault



(a) (b) (c)

Figure 7a, b, c: Current transient for a Phase A, B and C

C. Fault Location

Figure 10a and 10b present the signal components resulting from wavelet transform on the fault generated transient signal measured at the source terminal for fault locations of 30km and 50km with a fault resistance of 1Ω. The transient signal at t1 indicates the arrival of the first fault signal whereas t2 indicates the arrival of the reflected fault signal from the fault point. The distance of the fault from busbar for fault location can be calculated using equation 2. Since a 10µs sampling time is used, the difference between t2 and t2 in sampling numbers will be multipled by 10µs. Using the velocity of travelling time in the cable as $1.9557x10^5$ km/s, the distances to the fault from the measurement point are 30.85km and 49.13km respectively. These distances are within 1000m from the actual fault distances of 30km and 50km respectively.

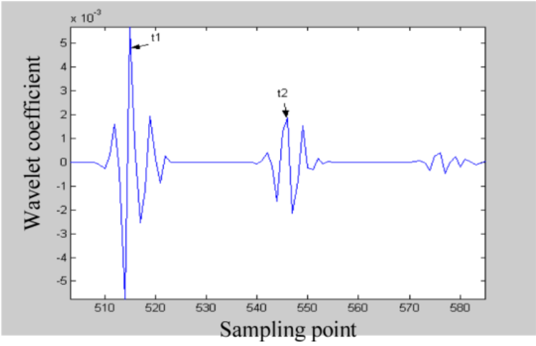


Figure 10a: Transient signal for fault distance of 30km

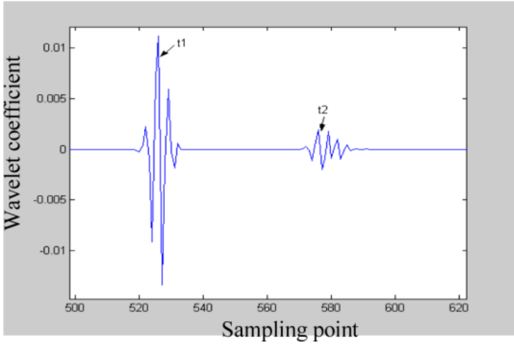


Figure 10b: Transient signal for fault distance of 50km

CONCLUSIONS

This paper introduces a wavelet technique for fault detection, classification and fault location for underground cable network. The wavelet transform is used to extract the fault generated high frequency current transient signals. The resulting signals are used to detect, classify and locate the faults in the network.

Studies show that the scheme is insensitive to fault type, fault resistance and fault position on the cable. Studies also show that the wavelet technique is able to offer a very high accuracy in fault detection and fault location on underground cable.

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