Identification of Faults on Transmission Lines using Wavelet Technique

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***Abstract*—**The aim of this paper is to understand wavelet technique and identification of fault using wavelet transform. This paper presents high speed fault identification and protection of power system lines based on wavelet transform technique. It is a unique method which is used to detect the location and identification of fault in power system. Faults in power system are single line to ground, double line to ground and three phase faults. In this paper the conventional time-amplitude response is presented and the result shows that wavelet leads to identify the type of fault and its location. The results indicate that wavelet technique is fast compared to time amplitude technique.

Keywords*—Wavelet, Single Line to Ground fault, Double Line to Ground fault, Three phase fault.*

I. INTRODUCTION

The increased growth of power systems both in size and complexity has brought about the need for fast and reliable relays to protect major equipment and to maintain system stability. The conventional protective relays are either of electromagnetic or static type. Though successfully used, static relays suffer from a number of disadvantages, e.g. inflexibility, incapability to changing system conditions and complexity. In Power Systems, the Protection system consists of a combination of solid state relays and electromagnetic relays. Electromagnetic relays are used in simpler applications such as over correct relaying while solid state relays are used in distance relaying.

The concept of digital protection employing computers which shows much promise in providing improved performance, has evolved during past few decades. In the beginning, the digital protection uses a large computer system for total protection of power system. This protective system proved to be very costly and requires a large space. Digital Computers can easily fulfil the protection requirements of modern power systems without difficulties.

Usually the power stations are situated far away from the load centres resulting in hundreds of kilometre length of overhead lines being exposed to atmospheric conditions. The chances of faults occurring due to storms, falling of external objects on the lines, flashovers resulting from dirt deposits on insulators are greater for overhead lines than for other parts of power system. About 50% of total faults occur on overhead lines.

When a fault occurs on a power system, the fault current is almost always greater than prefault load current in any power system element. A very simple and effective relaying principle is that of using current magnitude as an indicator of a fault. So as a remedy the fault must be identified and faulted phase must be removed by a protective system.

A protective system protects power system from deleterious effects of a sustained fault, which occurs as a random event. If some faulted power system component is not isolated from system quickly, it may lead to power system instability or breakup of the system through the action of other automatic protective devices. A protective system must therefore remove the faulted element from the rest of power system as quickly as possible.

For the remedy of faulted zone, a precise study of waveforms of voltage and current during fault incident is required. Many researchers have suggested techniques for fault type detection. These techniques depend mainly on studying the pattern of voltage and current waveforms associated with the fault. Among these are Fourier analysis and Kalman filtering methods which were main tolls in signal processing for distance relaying.

Wavelets are a recently developed mathematical tool for signal processing. Compared to Fourier analysis, which relies on a single basis function, a number of basis functions of a rather wide functional form are available in wavelet analysis. The basic concept in wavelet transform is to select an appropriate wavelet function "mother function" and then perform analysis using shifted and dilated versions of this wavelet. Wavelet can be chosen with very desirable frequency and time characteristics as compared to Fourier techniques. The basic difference is that, in contrast to short time Fourier transform which uses a single analysis window, Wavelet transform uses short windows at higher frequencies and long windows at low frequencies.

Wavelet Transform has the ability to decompose into different frequency bands using multi resolution analysis. It can be utilized in detecting faults and to estimate phasors of voltage and current signals, which are essential for transmission line distance protection.

A digital distance protection scheme for transmission lines based on analysing the measured voltage and current signals at relay location using Wavelet technique with MRA is presented in this paper. Computer simulation studies have been conducted using MATLAB to generate voltage and current signals from simulated network, which re then fed to Wavelet identification algorithm. The proposed identification algorithm has been tested for line to ground fault, double line to ground fault, line to line fault and three phase fault.

II. FOURIER ANALYSIS

A. *Introduction*

Mathematical transformations are applied to signals to obtain further information from that signal that is not readily available in the raw signal. Most of the signals in practice are time domain signals in their raw format i.e whatever that signal is measuring, is a function of time. In other words, when we plot the signal, one of the axes is time and other is usually amplitude. When we plot time domain signals, we obtain time-amplitude representation of the signal. This representation is not always best representation of the signal for most signal processing related applications. In many cases, the most distinguished information is hidden in the frequency content of the signal. The frequency spectrum of a signal is basically the frequency components of that signal. The frequency spectrum of a signal shows what frequencies exist in that signal. Often times, the information that cannot be readily seen in time domain can be seen in frequency domain.

B. Fourier Transform

The Fourier transform of a signal in time domain is taken, the frequency amplitude representation of that signal is obtained. In other words, we now have a plot with one axis being the frequency and the other being amplitude. This plot tells us how much each frequency exists in our signal. The technique of representing a signal as a sum of exponentials can be extended to non-periodic functions through the use of Fourier Transforms. The transform pair can be obtained by writing a Fourier series and taking limits as period becomes infinite.

Fourier transform of any signal is given by

$$F[x(t)] = X(w) = \int x(t)\, e^{-jwt}\, dt \qquad (1)$$

Inverse Fourier transform of any signal is given by

$$F^{-1}[x(t)] = x(t) = \frac{1}{2\pi}\int X(w)\, e^{-jwt}\, dw \qquad (2)$$

III. WAVELET ANALYSIS

A. Introduction

A wavelet is a waveform of effectively limited duration that has an average value of zero. Wavelet theory is a mathematics associated with building a model for non-stationary signal with a set of components that are called small waves called wavelets. Informally, a wavelet is a short-term duration wave. These functions have been proposed in connection with analysis of signals, primarily transients in a wide range of applications.

The basic concept in wavelet transform is to select an appropriate wavelet function “mother wavelet” and then perform analysis using shifted and dilated versions of this wavelet. Wavelet can be chosen with very desirable frequency and time characteristics.

According to Fourier theory, signal can be expressed as a sum of possibly infinite series of sines and cosines. This sum is referred to Fourier expansion. The big disadvantage of Fourier expansion is it has only frequency resolution and no time resolution. It determines all frequencies present in the signal but does not tell at what time they are present. To overcome this problem, Wavelet transform is proposed. It provides time and frequency information simultaneously.

In wavelet analysis, the use of fully scalable modulated window solves signal cutting problem. The window is shifted along the signal and for every position the spectrum is repeated many times with a slightly shorter window for every new cycle. In the end, the result will be a collection of time representation of the signal, all with different resolutions.

The basis functions used in Fourier analysis, sine waves and cosine waves, are precisely located in frequency information of a signal calculated by classical Fourier transform which is an average over the entire time duration of the signal. Thus, if there is a local transient over small interval of time in the total duration of the signal, the transient will contribute to Fourier Transform but its location on time axis will be lost. Although short time Fourier transform overcomes time location problem to a larger extend, it does not provide multiple resolutions in time and frequency, which is an important characteristic for analysing transient signal containing high and low frequency components.

Wavelet analysis overcomes the limitations of Fourier methods. Unlike Fourier analysis which uses one basis function, wavelet analysis uses number of basis functions of a rather wide functional form. The wavelet functions are generated in the form of translation and dilation of fixed function. The basis wavelet is termed as a mother wavelet.

The basic difference is, Short time Fourier transform uses a single analysis window whereas Wavelet transform uses short windows at high frequencies and long windows at loa frequencies.

B. Capabilities of Wavelet Analysis

One major advantage is the ability to perform local analysis, i.e to analysis a localized area of a larger signal. The Fourier coefficients of a signal shows nothing particularly interesting but a flat spectrum with two peaks representing a single frequency. However, a plot of wavelet coefficients clearly shows the exact location in time of discontinuity.

Wavelet analysis is capable of detecting breakdown points, discontinuities in higher derivatives and self-similarities. Wavelet analysis can often compress or de noise a signal without appreciable degradation.

C. Multi Resolution Analysis (MRA)

MRA analyses the signal at different frequencies with different resolutions. It is designed to give good time resolution and poor frequency resolution at high frequencies and poor time resolution and good frequency resolution at low frequencies.

Wavelet calculations are based on two fundamental equations: the scaling function φ(t) and wavelet function ψ(t).

$$\varphi(t) = \sqrt{2}\sum h_{k\varphi}(2t-k) \qquad (3)$$

$$\psi(t) = \sqrt{2}\sum g_{k\psi}(2t-k) \qquad (4)$$

Wavelet transform can be implemented within specially designed pair of FIR filters called quadrature mirror filters. These filters are distinctive because their frequency responses of two FIR filters separate the high and low frequency components of the input signal. The outputs of these filters are decimated by a factor of two. The low frequency filter output is fed into another identical QMF filter. This operation can be repeated recursive as a tree or pyramid algorithm, yielding a group of signals that divides the spectrum of original signal into octave bands with successively coarser measurements in time as width of each spectral band narrows and decreases in frequency. The pyramid algorithm can be applied to Wavelet transform by using wavelet.

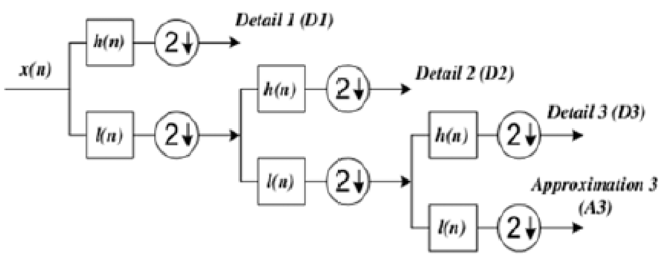

Fig. 1. Wavelet multi resolution analysis

The same wavelet coefficients are used in both low pass and high pass filters. The LP filter coefficients are associated with h_k of scaling function and HP filter is associated with g_k of the wavelet function. The outputs of LP filters are called approximations(A) and the outputs of HP filters are called details. (D)

IV. FAULT DETECTION AND CLASSIFICATION

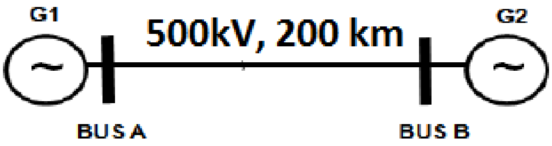

Fig. 2. A 500kV transmission system

A typical 500kV transmission system shown in Fig2. is used in simulation studies for single line to ground fault, line to line fault, double line to ground fault and three phase fault. It consists of a 200km transmission line terminated at two sources of voltage 500kV at bus bars A and B respectively. The nominal frequency is 50 Hz. Fault detection can be obtained from the details of first decomposition level of measured current signals using db1 wavelet. This level contains high frequencies that are associated with faults. The length of sliding data window used for fault detection is equal to one cycle of fundamental frequency. By calculating norm of the detail coefficients(D1) for all currents, the phase(s) on disturbance can be identified. If calculated norm value of any phase current exceeds a certain threshold, that indicates that this phase is exposed to a certain disturbance. This norm can be calculated

$$\text{as} \quad ||D1|| = \left[\sum_{k=1}^{n_d} D1(k) \right]^{1/2}$$

where Nd is the number of detail coefficients at that level.

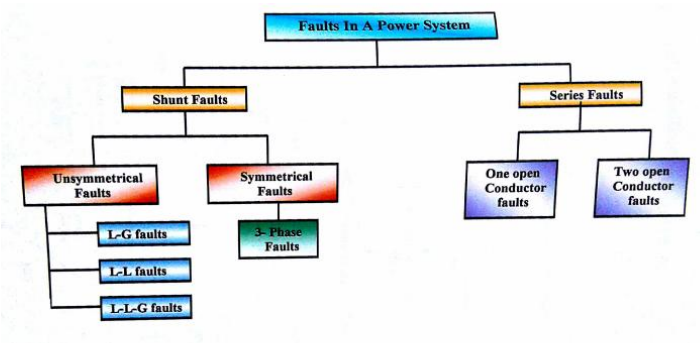

Fig. 3. Classification of Faults

Using db1 and from the decomposition level for the three line currents, a fault can be detected by observing norm of the detail coefficients D1. At this level, the high frequency components can be extracted from signal and any disturbance can be detected. If norm of D1 for all currents is less than a certain threshold (M), it means that lines are healthy. Now the number of faulted lines is identified, if there is fault in only one phase, it is line to ground fault. If all three phases are faulty, it is a three-phase fault. If there are two faulty phases we have to classify as line to line fault or double line to ground fault. So, after number of trails for faults at various distances, it is observed that difference of approximate coefficients is less than some value for line to line fault. Using this we can differentiate line to line faults or double line to ground faults.

The simulation of power system is carried out using MATLAB SIMULINK. The parameters are given below:

Source Voltages: EA=EB=500kV

Source Resistance: 17.177Ω

Source inductance: 145 H

Length of transmission line: 200km

Frequency = 50 Hz

Positive sequence Resistance=0.0249 Ω/km

Zero sequence Resistance=0.634 Ω/km

Positive sequence Inductance=0.00187H/km

Zero sequence Inductance=0.0058H/km

Positive sequence Capacitance=2.34e-8 F/km

Zero sequence Capacitance=1.75e-8 F/km

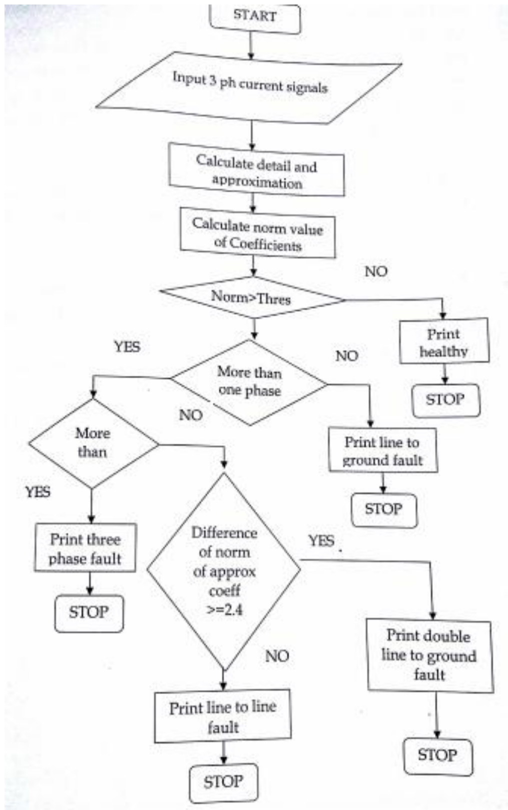

Fig. 4. Fault classification algorithm

V. SIMULATION RESULTS

A. Single Line to Ground Fault:

Fig. 5 shows Simulink of single line to ground fault on phase A.

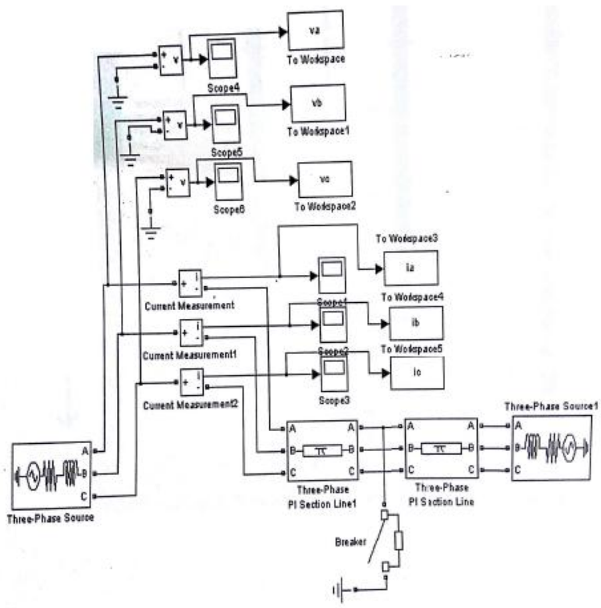

Fig. 5. Simulink diagram of Single Line to Ground fault

The output currents waveforms for three phases are shown in Fig 6.

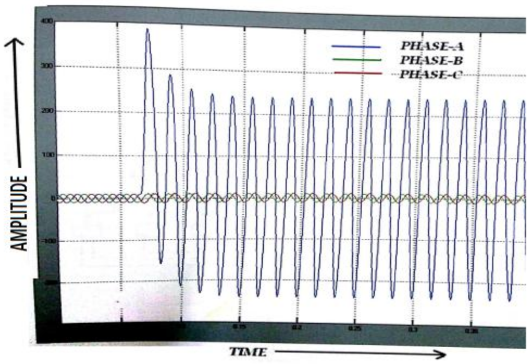

Fig. 6. Output currents waveform for Single Line to Ground Fault

B. *Line to Line Fault:*

Fig.7 shows Simulink of single line to ground fault on phases A and B.

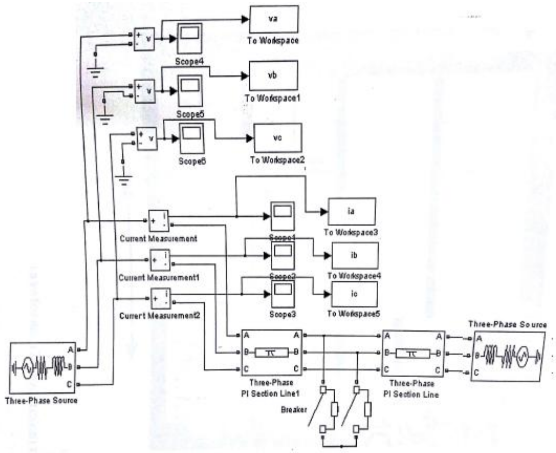

Fig. 7. Simulink diagram of Line to Line fault

The output currents waveforms for three phases are shown in Fig. 8

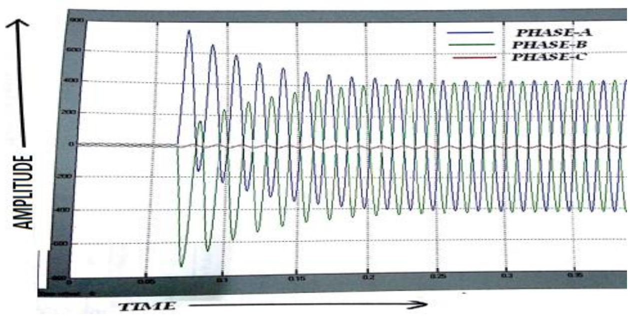

Fig. 8. Output currents waveform for Line to line Fault

C. *Double Line to Ground Fault:*

Fig.9 shows Simulink of Double line to ground fault on phases A and B.

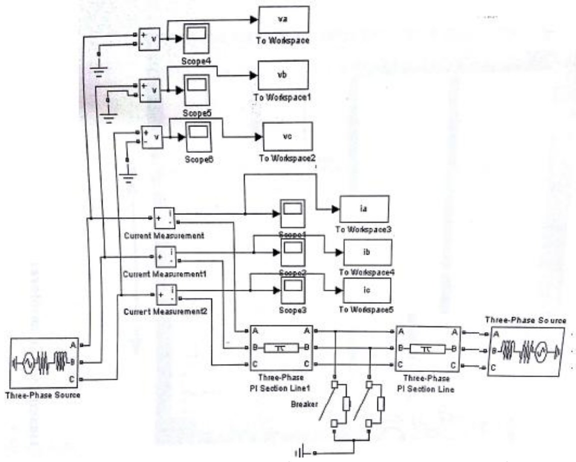

Fig. 9. Simulink diagram of Double Line to Ground fault

The output currents waveforms for three phases are shown in Fig 10.

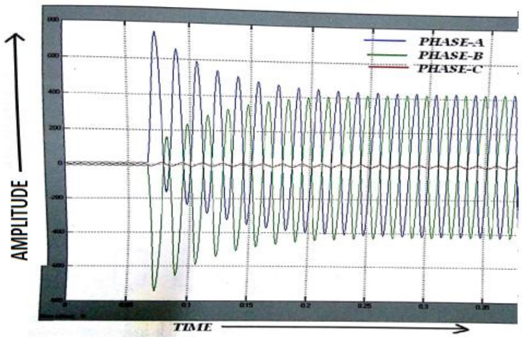

Fig. 10. Output currents waveform for Double Line to ground Fault

D. *Three-phase Fault:*

Fig. 11 shows Simulink of Double line to ground fault on phases A and B.

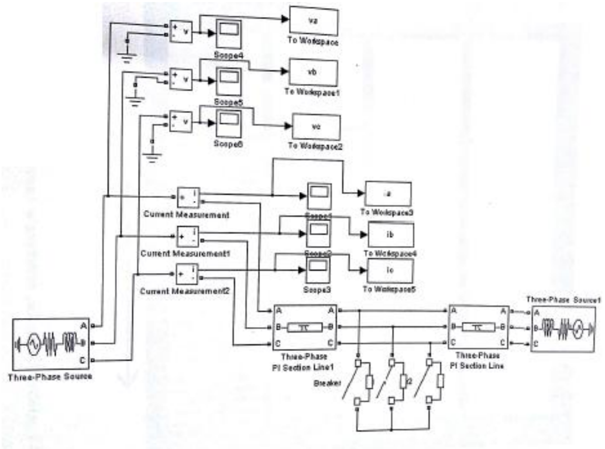

Fig. 11. Simulink diagram of Three phase fault

The output currents waveforms for three phases are shown in Fig 12.

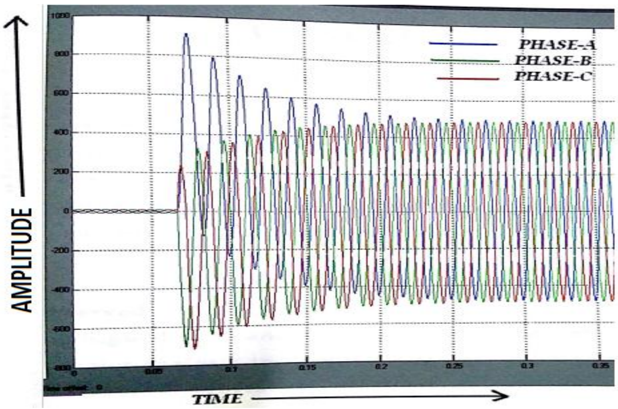

Fig. 12. Output currents waveform for Three phase Fault

CONCLUSION

The simulation results depict the capability of wavelet technique to locate and identify a fault. Wavelet transform technique will be an aid to conventional wave analysers used in power station for de-noising transmitted signals. Wavelet transform method is successful in detection of faults in AC networks.

Comparing the results obtained, it can be observed that wavelet transform method is capable of distinguishing and locating type of fault.

References

[1] Ei Phyo Thwe, Min Min Oo, "Fault Detection and Classification for Transmission Line Protection System Using Artificial Neural Network," Journal of Electrical and Electronics Engineering, Vol 4, Issue 5., pp. 89-96, December 2016. pp.68-73.

[2] S.M. El Safty and M.A. Sharkas, "Identification of Transmission line faults using Wavelet Analysis", IEEE Transactions on Industrial Applications, ID: 0-7803-8294-3/04, 2004.

[3] Fernando H. Magnago and Ali Abur, "Fault Location Using Wavelets", IEEE Transactions on Power Delivery, Vol. 13, No. 4, pp.1475-1480,1998.

[4] "Wavelet Tutorial" by Robi Polikar.

[5] Ramesh Kumar, P.M. Deoghare, "Analysis of Transmission Line fault by using Wavelet," International Journal of Engineering Research and Technology, Vol 3, Issue 5., pp. 36-40, May 2014.

[6] Abhijit Jadav, Kawitha Thakur,"Fault detection and Classification in Transmission Line based on Wavelet Transform" International Journal of Scientific Engineering and Research, Vol. 3 , Issue 5, pp. 14-19, May 2015.