International Academic Institute for Science and Technology

International Academic Journal of Science and Engineering
Vol. 3, No. 1, 2016, pp. 23-32.

ISSN 2454-3896

International Academic Journal of Science and Engineering

www.iaiest.com

Detection of fault location on transmission systems using Wavelet transform

Saeed Shahmordi[a]

[a]*Khozestan Regional Electric Company (KZREC), Ahvaz, Iran.*

Abstract

This paper presents a new method to detect fault location accurately on a transmission line. In the proposed algorithm of travelling wave theory to calculate time between fault point and relay location is used in high frequency which this transients analysis by efficient wavelet transform are variable unlike Fourier transform in the multiple accuracy of time–frequency transform. Considering the relation between forward and backward traveling waves and polarity variations of them can be located the fault. In this paper, first, the concept of Wavelet transform and traveling waves theorem are introduced and in the following, characteristics of multilevel analysing in the time and frequency domain are described. Then, an algorithm based on Wavelet transform is presented for fault detection in the high voltage transmission lines. In the following, this algorithm is executed on a transmission line that simulation results is presented for single line to ground and phase to phase faults in different places.

Keywords: Detection of fault location, Transmission lines, travelling wave theory, Wavelet transform

Introduction:

Detection of location fault is one of the most important topics in power system protection Which many researchers have considered in recent years and many methods have proposed for it. These methods can be divided into two categories:

- Impedance methods (T. Takagi et al 1982) and (M. S. Sachdev, and R. Agarwal 1988): The methods based on voltage samples and main frequency flow and measurements can be performed from one terminal or two terminals. The method for extracting main components of current and voltage phasors can be used from conventional Fourier or Wavelet transform.
- The methods based on travelling wave theory (Z. Q. Bo, G. Weller, and M. A. Redfern 1999): These methods are based on high-frequency transient of power system that to detect transient is used short-time Fourier transform.

In this paper analysis power system transients for wavelet transform instead of short-time Fourier transform That it is a transform multi accuracy time and frequency Which enables transient signals with different frequencies revealed at different times (D. C. Robertson et al 1999).
In order to supply uninterrupted and high quality energy, it should be considered suitable protections in the network. Early detection of fault in high voltage transmission lines has a specific importance due to remove the fault and lower blackouts. To this purpose, various methods have been presented including use of the traveling waves due to the fault for ultrafast protection of high voltage lines. (OMAR A.S.YOUSSEF 2003) The traveling waves due to the fault have a bandwidth about several hundred kHz. By comparing the polarity of voltage and current traveling waves in two line ends can be detected the fault in the line. (M Chamia, and S Liberman 1978) In order to extract these waves from the voltage and current waveforms under the fault, there are several methods such as Principal Component Analysis (PCA) (Ernesto Vázquez et al 2007), neural network (Ángel L et al 2002), mathematical morphology (Q. H. Wu et al 2003), DSP (Marcello Artioli et al 2004), and also use of the Wavelet theorem (Wei Chen et al 2003).

It has been shown that applying the Wavelet transform to the Clarke transform components for obtaining the traveling waves due to the fault is one of the best methods to detect the fault in the line (F. H. Magnago and A. Abur 1998). The Wavelet transform can analyse the instable signals (such as voltage and current signals in a power system) in time domain as well. Most of the fault detection methods based on the traveling waves use one of the voltage or current signals or both of them (S. Rajendra and P.C. McLaren 1985). One of the main limitations of the ultrafast protection methods is for the faults that occur near the bus. In this case, because of high velocity of the waves and propagating and reflecting the waves between the fault point and bus, it is very difficult to detect the first set of traveling waves that propagate from the fault point to the bus. Use of the Wavelet transform in order to filter the traveling waves considering the voltage and current waveforms solves this issue completely.

Wavelet transform(C. Hwan and R. Aggarwal, 2001)

Basically, continuous Wavelet Transform (WT) and continuous time signal x(t) is defined as follows:

$$WT(a\ b) \quad \frac{}{\sqrt{a}}\int \quad x(t).\,g\left(\frac{t-b}{}\right). \tag{1}$$

Where g(t) is mother wavelet function and { g(t-b)/a } daughter wavelet functions that it is scaled and transferred version g(t) and depending on the shape signal x(t) , mother wavelet function can be functions like Haar, coiflets, Daoubechies, Morlet and so on… . Discrete Wavelet Transform (DWT) and discrete time signal x[n] Defined as follows:

$$WT[m\ k] \quad \frac{}{\sqrt{a}}\sum \quad x[n]\,.\,g[\frac{}{}] \tag{2}$$

Where x[n] is sampled values of the time functions x(t).
One of the main tasks of the wavelet transform analysis of power system transients that can be analyzed by a conventional Fourier but the efficient of wavelet transform more than Fourier transform Because:

A. Wavelet transform unlike Discrete Fourier Transform (DFT) has a two dimensional representation of time and frequency which will have the ability to detection time of the transient signals.
B. Wavelet transform unlike Window Discrete Fourier Transform (WDFT) has a variable time window that uses high frequency during the period of small and low frequencies during the period of great that it creates multi accuracy analysis.

In this paper, the accurate coefficients of wavelet transform on scale1 and 2 is used to extract the appearance characteristic of transients which it has come in the next sections.

The structure of the proposed algorithm

A three-phase transmission line without losses to length l consider Figure 1 that located between lines A and B and has a impedance characteristic Z_c and high wave speed (u). If an fault occurs on a distance x from bus A, it causes high frequency transient signals along the line which can be received by fault digital registers in two buses A and B.

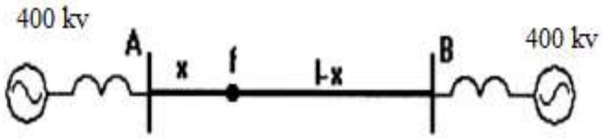

Figure 1. The view of circuit in a sample transmission line

In order to implement travelling waves in three-phase systems sampled signals by Clark modal transformation matrix becomes to modal components. If S_{phase} is the phase signals vectors and S_{mode} signals modal vectors then we will have

(3)

Where Clark modal transformation matrix T achieved from equation (4) :

$$-\begin{bmatrix} 2 & & \\ & \sqrt{3} & -\sqrt{3} \end{bmatrix} \qquad (4)$$

The first mode of S_{mode} is called ground mode and when the ground fault occurred, its amplitude will be felt and for aerial faults by choosing a suitable threshold can be considered its amplitude as zero.
The second mode of S_{mode} is called aerial mode and for all types of faults used for both aerial and ground faults. Fault detection in the given transmission line, depending upon telecommunication relationship between two terminals A and B can be studied in the following two sections:

Synchronous recording data from two terminals

In this case, the fault signals synchronously are recorded at both ends of the transmission line through two separate channels that synchronized via GPS. The sampled signals after conversion to modal components using wavelet transform are analyzed at different scales.
If t_A and t_B are time of the first peak at scale1 modal signals and t_d time difference, then fault distance X from bus A obtained from the following equation (Mousavi, De Roo, Sarabandi, England, and Nejati, 2016) and (Mousavi, De Roo, Sarabandi, England, and Nejati, 2016):

$$\frac{\quad}{\quad} \qquad (5)$$

In the above equation, travelling wave speed is about mode M.

To record data from a terminal

In this case the fault signals only sampled from one terminal and actually there is no need to synchronize with GPS. During fault, available fault digital register in the close bus (A) receives the same reflections of fault location and also the away bus (B), which should be considered good patterns for detecting these reflections. These patterns are different for aerial and ground faults which in the follow has been paid it.

Aerial faults

Basically, aerial faults include phase to phase and symmetrical faults that doesn't have receive critical reflections away from bus during fault. Therefore, by measuring the time difference between two first peaks scale1 the aerial mode t_d can be calculated fault distance from equation 6.

$$\frac{\quad}{\quad} \qquad (6)$$

Ground faults

In ground faults, fault digital register receives an important reflection of fault point and as well as away bus, that depending upon where is the fault location, the first reflection from away bus may before or after first reflection from the fault point arrives to relay location.

Using Lattice diagram in figure 2 & 3 can be proved if a fault in the first half of transmission line close to relay location occurred, the first reflection from away bus after first reflection from fault point arrives to close bus and conversely.

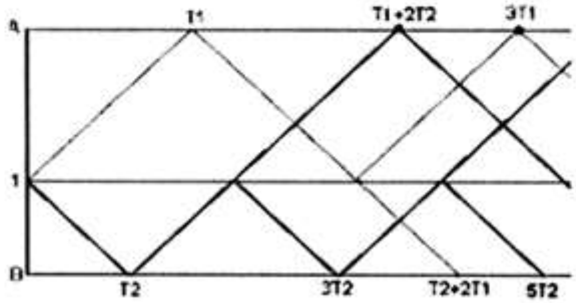

Figure2. Lattice diagram related to faults occurrence in the first half of the transmission line

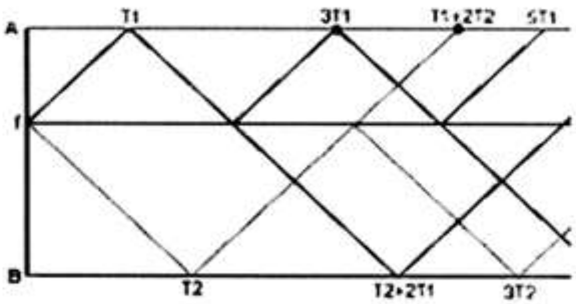

Figure3. Lattice diagram related to faults occurrence in the second half of the transmission line

It can be seen easily that the scale 2 of ground mode have important peaks for ground faults, while for aerial faults can assume a threshold it had zero, therefore scale 2 of ground mode is a good measuring to detect faults in ground and aerial.

If fault is in the first half of transmission line and t_d time difference of first two peaks scale1 at aerial mode, the fault distance X is obtained from equation 6. If the fault is in the second half of transmission line and t_x time difference of first two peak scale 1 at aerial mode, the fault distance X is obtained from equation 6 Where t_d can be calculated from equation 7 as follows (Mousavi et al., 2016):

(7)

In equation above mentioned, τ is the time of travelling length of transmission line by travelling wave. The view of proposed algorithm for fault detection based on wavelet coefficients is shown in Figure 4.

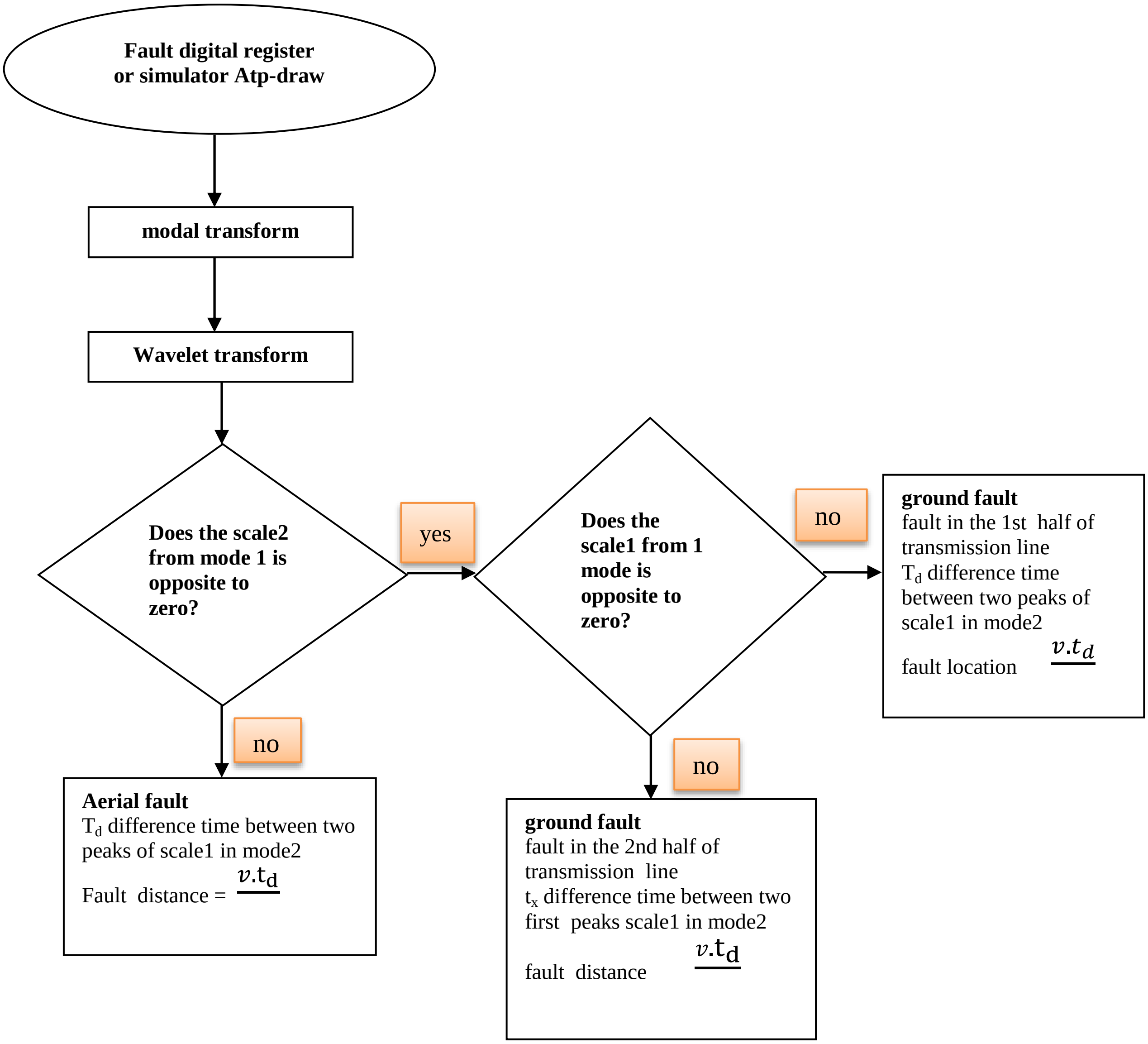

Figure4. process of overview the proposed algorithm

Simulation results

To check accuracy of proposed algorithm by Figure 4, This algorithm was implemented on a transmission line. Information about transmission line come in the table 1. The substations two ends of line are respectively short circuit level of 3507 and 4125 MVA at a voltage of 400 KV.

Table1. Information about transmission line

Susceptances (Siemens)	Zero sequence impedance (ohms)	Positive sequence impedance (ohms)	Line length (km)	Voltage (kv)
0.000136	**45/26 + j139/769**	**2/6 + j42/77**	**142/7**	**400**

Simulations done by ATP/EMTP and voltage and current signals sampled with time of 10µs sampled and in MATLAB software are analyzed after transform to modal components with daubechise mother wavelet at 4 points.

Aerial faults

In this case, a phase to phase fault simulated in the distance 50 km from first of line that after sampling and applying Clark modal matrix and wavelet transform, results in scales 1 and 2 aerial and ground modes is shown in Figure 5.

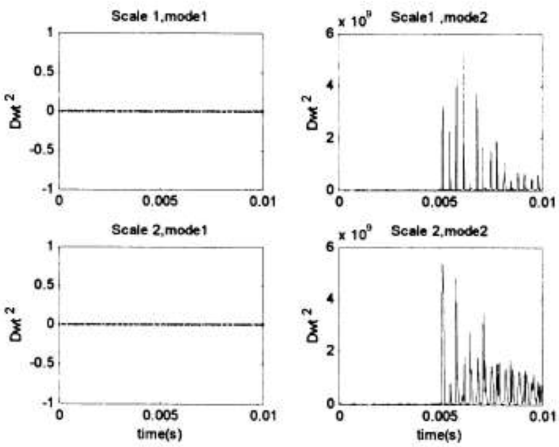

Figure 5. phase to phase fault in the 50km bus A

Given that the fault is aerial, causes peaks amplitude of scale 2 to ground mode is zero as shown in Figure 5. To calculate the fault distance X, time difference between the first two consecutive peak in scale 1 aerial modes that in Figure 5 is as follows:

Ground faults

In this case we simulate a single line to ground fault at intervals of 50 and 100 km from first of line that results of the outputs of scales 1 and 2 on ground and aerial, in fig (6) and (7) is shown.

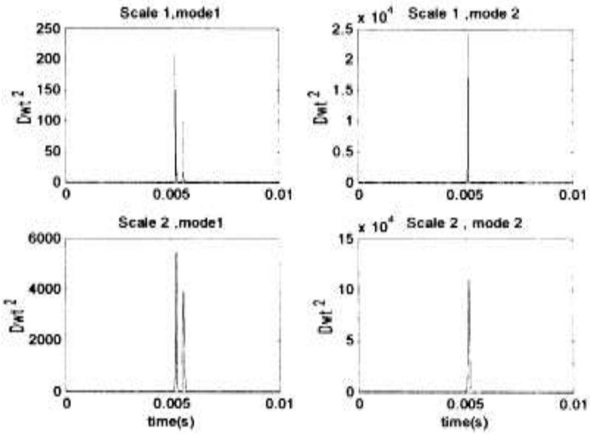

Figure 6. single line to ground fault at 50 km bus A

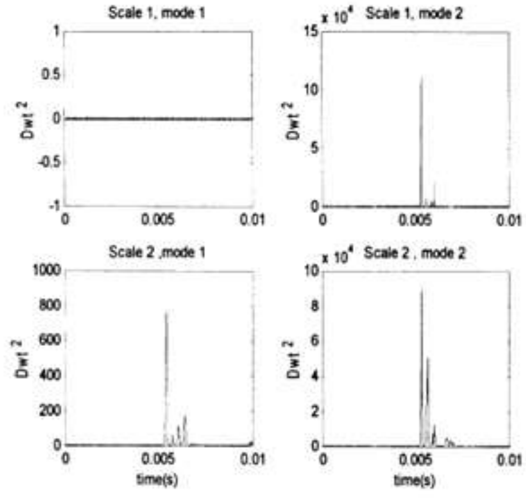

Figure7. single line to ground fault at 100 km bus A

Since the fault has ground connection, peaks amplitude scale 2 ground mode will be opposite to zero. Also observed that peak amplitude scale 1 ground mode in figure7 is negligible because the fault occurred on the second half of transmission line.

Fault distance X for the 50 km will be as follows:

And fault distance X for the 100 km will be:

Due to the calculated faults intervals can be seen that the proposed algorithm has good accuracy and faults of simulation different modes are less than 5 percent.

Conclusion

This paper presents a new method for fault location based on wavelet transform using travelling wave theory in transmission lines. High frequency transient signals of fault at first breakdown into modal components and then using wavelet transform converted from the time domain to the frequency-time domain and using the wavelet coefficients at two scales1 and 2 were estimated fault location for different types of aerial and ground faults.
This algorithm on a transmission line simulated for various faults and it was observed the algorithm has high accuracy. The new method of fault detection with wavelet transform, isn't related to fault impedance and it is only dependent on sampling time voltage and current signals.

References

Ángel L. Orille Fernandez, Member, IEEE, and Nabil Khalil I. Ghonaim *"A Novel approach Using a FIRANN for Fault Detection and Direction Estimation for High-Voltage Transmission Lines* " IEEE TRANSACTIONS ON POWER DELIVERY, Vol. 17, No. 4, OCTOBER 2002.
C. Hwan and R. Aggarwal, "*Wavelet Transform in Power System, Part 1: General introduction to the Wavelet Transforms*", IEE Power Engineering Journal, August 2001, pp. 81-87.
C. Hwan and R. Aggarwal, *"Wavelet Transform in Power System, Part 2: Examples of application to actual Power System Transients*", IEE Power Engineering Journal, August 2001, pp. 193-202.
D. C. Robertson, O. I. Camps, J. S. Meyer and W. B. Gish, "*Wavelets and Electromagnetic Power System Transients*", IEEE Trans. On Power Delivery, Vol. 11, No. 2, Appril 1999, pp. 1050-1058.
Ernesto Vázquez, Member, IEEE, Jorge Castruita, Oscar L. Chacón, Member, IEEE, and Arturo Conde, Member, IEEE "*A New Approach Traveling-Wave Distance Protection—Part I:Algorithm* " IEEE TRANSACTIONS ON POWER DELIVERY, Vol. 22, No. 2, APRIL 2007.
F. H. Magnago and A. Abur, "*Fault location using wavelets,*" IEEE Trans. Power Delivery, Vol. 13, pp. 1475–1480, Oct. 1998.
M Chamia, and S Liberman, "*Ultra High Speed Relay for EHV/UHV Transmission Lines -development, Design and Application*", IEEE Trans. PAS-97, pp.2104-2112, 1978.

M. S. Sachdev, and R. Agarwal, "*A Technique for Estimating Transmission Line Fault Locations from Digital Impedance Relay Measurements*", IEEE Trans. On Power Delivery, Vol. 3, No. 1, 1988, pp. 121-129.

Marcello Artioli, Gaetano Pasini, Lorenzo Peretto, Senior Member, IEEE, Renato Sasdelli, Senior Member, IEEE, and Fiorenzo Filippetti, Member, IEEE "*Low-Cost DSP-Based Equipment for the Real-Time Detection of Transients in Power Systems* " IEEE TRANSACTIONS ON INSTRUMENTATION AND MEASUREMENT, Vol. 53, NO. 4, AUGUST 2004

OMAR A.S.YOUSSEF, "*Online Applications of Wavelet Transforms to Power System Relaying*", IEEE TRANSACTIONS ON POWER DELIVERY, VOL.18, NO. 4, pp.1158-1165, OCTOBER 2003.

Q. H. Wu, Senior Member, IEEE, J. F. Zhang, and J. Zhang, Student Member, IEEE "*Ultra-High-Speed Directional Protection of Transmission Lines Using Mathematical Morphology* " IEEE TRANSACTIONS ON POWER DELIVERY, Vol. 18, No. 4, OCTOBER 2003.

S. Rajendra and P.C. McLaren, "*Traveling Wave Techniques Applied To The Protection of Teed Circuits: multi-phase/multi-circuit system*'', IEEE transactions on power apparatus and systems , vol. PAS-104, NO 12, pp. 3551-3557, Dec 1985.

T. Takagi, Y. Yamakoshi, M. Yamaura, R. Kondow, and T. Matsushima, "*Development of a New Type Fault Locator Using the One-terminal Voltage and Current Data*", IEEE Trans. On Power Apparatus and System, Vol. PAS-101, No. 8, August 1982, pp. 2892-2898.

Wei Chen, O. P. Malik, Xianggen Yin, Deshu Chen, Senior Member, IEEE, and Zhe Zhang "*Study of Wavelet-Based Ultra High Speed Directional Transmission Line Protection*" IEEE transactions on power delivery, VOLol. 18 , No. 4, OCTOBER 2003.

Z. Q. Bo, G. Weller, and M. A. Redfern, "*Accurate Fault Location Technique for Distribution System Using Fault-generated High-frequency Transient Voltage Signals*", IEE Proceeding., Generation, Transmission and Distribution, Vol. 146, Issue. 1, January 1999, pp. 73-79.

S. Mousavi, R. De Roo, K. Sarabandi, A. England and H. Nejati, "Dry snowpack and freshwater icepack remote sensing using wideband Autocorrelation radiometry," *2016 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)*, Beijing, 2016, pp. 5288-5291.

S. Mousavi, R. De Roo, K. Sarabandi, A. England and H. Nejati, "Remote sensing using coherent multipath interference of wideband planck radiation," *2016 IEEE International Symposium on Antennas and Propagation (APSURSI)*, Fajardo, 2016, pp. 2051-2052.