

# The Wavelet Technique Application for Distance Protection

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**Abstract:** : accuracy and speed are among the main features which relays were classified . This paper present a digital distance relay designed by using wavelet transform (WT). The designed relay have the ability to detect the faults , recognize it from other disturbance cases , classify its types as well as indicate the protection zone. The relay has been tested for both simulation case , practically case by using transmission line board in the lab.

## 1. Introduction

There are several types of electric devices affected by faults and disturbances, distance relay is one of these devices. This relay is an important device to keep protection and ensuring accuracy for power system .Its good feature gives a primary and back up protection for transmission line . The main target of this relay is to calculate impedance at the fundamental frequency from the relay point to the fault point. According to this impedance, the distance relay will determine if the fault was inside or outside the protection zones. This impedance is calculated from the measured values of voltage and current signals at the relay point[1].

In this work wavelet transform (WT) used to design a digital distance relay, Wavelets are a mathematical tool for signal processing. Compared to Fourier analysis, which relies on a single basis function, a number of basic functions of a rather wide functional form are available in wavelet analysis. The basic idea in wavelet transform (WT) is to choose a suitable 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 as compared to Fourier techniques. The basic difference is that, as it compare to the short time Fourier transform which uses a single analysis window, the WT uses short windows at high frequencies and long windows at low frequencies. The basic functions in WT employ time compression or dilation rather than a variation in time frequency of the modulated signal [1].

## 2. Wavelet And Filter Bank

The wavelet transform is a useful time-frequency method to analyze a signal within different frequency

ranges, by means of dilating and translating a single function named mother wavelet [2].By wavelet we use the high-pass  $G(n)$  and the low-pass  $H(n)$  filters to divide the frequency-band of the input signal into high and low-frequency components. This operation may be repeated recursively, feeding the down sampled low-pass filter output into another identical filter pair, decomposing the signal into approximation  $a(n)$  and detail  $d(n)$  coefficients for various scales of resolution. In this way, the DWT may be computed through a filter bank framework: in each scale,  $G(n)$  and  $H(n)$  filter signals, yielding to a new approximation and detail coefficients, respectively. So, this process divides the frequency spectrum of the original signal into multi bands. This filter bank framework is shown in figure 1.1 The down-pointing arrows denote a decimation by two and the boxes denote a convolution by  $G(n)$  or  $H(n)$  [3].

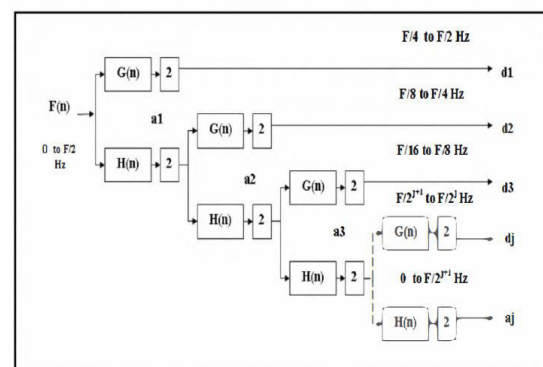


Figure 1.1: DWT filter bank framework

## 3. Phasor Estimation

Theoretically, the phasors should be estimated from the sixth decomposition level (0-78.125 Hz). Since the compact support wavelets do not have ideal cutoff frequency characteristics, since the phasor scan not be estimated from this level. From the fifth level of decomposition the phasor (magnitude and angle) of each signal can be estimated by using the approximation coefficients vector of  $A_5$  as discussed below. The phasors of the measured voltage and current signals at the fundamental frequency can be estimated by using a unity amplitude 50- Hz

sinusoidal reference signal (X1), sampled at the same sampling rate as the measured signals (10 kHz) for simulation work and (12.8KHz) for practical work. For each data window, the sinusoidal reference signals and the measured signals are decomposed into fifth level of decomposition using "db4" mother wavelet. As aforementioned, the phasors are estimated from the approximate coefficients A5 vector of the fifth decomposition level. The magnitude and angle with respect to the reference sinusoidal signal for each measured signal can be estimated using the basic vector mathematics. For example, if the approximate coefficient vector of the fifth decomposition level of the sinusoidal reference is A5X1 and for one of the measured Signals is A5S, then the angle (theta) between the two vectors is defined as:

$$\theta = \cos^{-1} \left( \frac{A5X1 \cdot A5S}{|A5X1| |A5S|} \right)$$

Where (A5X1 • A5S) is the dot product of the two vectors and (|A5X1| |A5S|), are the norms of the two vectors.

A new unity amplitude sinusoidal signal (X2) with a phase shift equal to the calculated angle (theta) is constructed and sampled at the same previous sampling frequency. The new signal is then decomposed into fifth decomposition levels using the same mother wavelet as used before. Using the fifth approximate coefficient vector A5X2 of this constructed sinusoidal signal, and the fifth approximate coefficient vector A5S of the measured signal, the magnitude Y of the measured signal can be defined as:

$$Y = \frac{|1| |A5S|}{|A5X2|}$$

The same procedure can be used for all the other measured signals to estimate their phasors[4].

#### 4. Computer Simulation Tests

In order to investigate the applicability of the proposed wavelet transform distance relay, a simulation of transmission line model for different disturbances and different faults is formulated by using MATLAB simulink. The system of simulation shown in fig 4.1. by taking several cases of fault on the transmission line with different fault locations and many disturbance cases the thresholds is chosen depending on the maximum peak of currents for each phase. A value

of the threshold (Th1) is taken (4 Amp). The fault is detected and recognized from other disturbances and its type classified by comparing the peak value of the

currents as well as indicating the fault zone by using wavelet transform as in section 3.

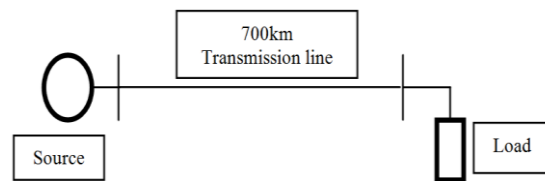


Figure 4.1: The system of simulation

#### 5. Simulation Results

some typical results which illustrate the performance of the protection technique is given. Many faults at more than one location on the transmission line shown in fig 4.1 are implemented for A to ground, A-B to ground fault and A-B-C to ground fault.

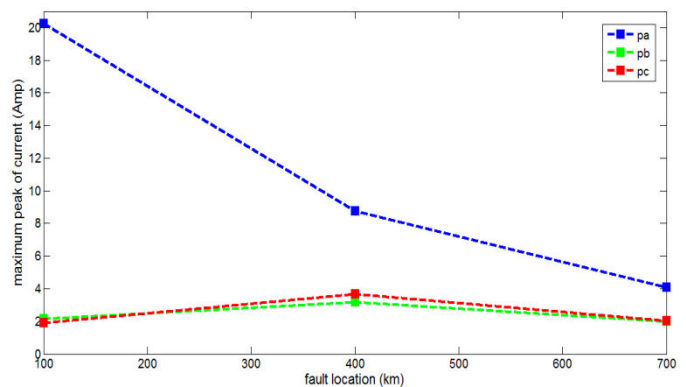


Figure 5.1: A-G solid fault

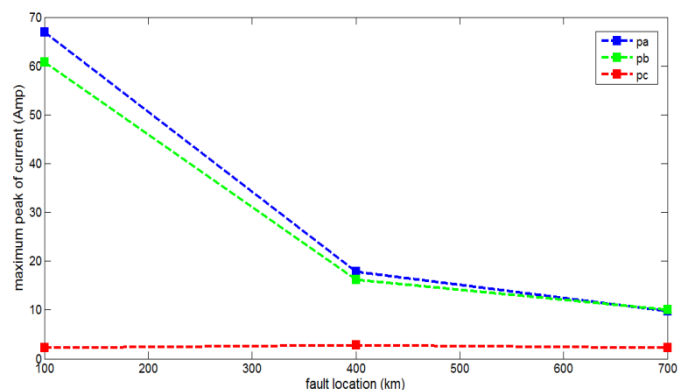


Figure 5.2: A-B-G solid fault

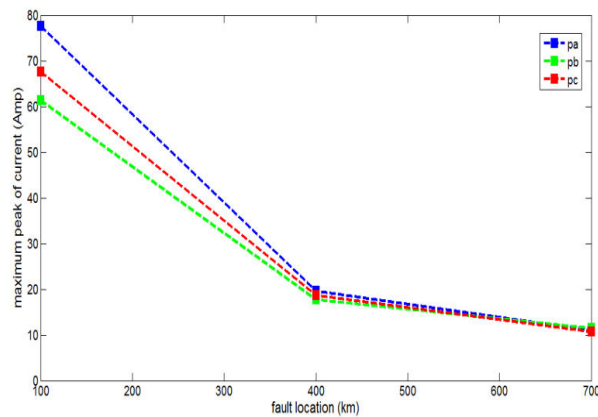


Figure 5.3: A-B-C-G solid fault

Figures 5.1, 5.2, 5.3 shows the relation between the fault location on the x-axis with maximum peak for three phase currents on the Y-axis where (pa) is the maximum peak of current for phase (A) and (pb) is the maximum peak of current for phase (B) and (pc) is the maximum peak of current for phase (C). In all figures we note that the maximum peak of currents for the faulted phases are greater than (Th1=4 Amp) while the maximum peak of currents for unfaulted phases are less than (Th1=4 Amp), so the relay will respond to the faulted phase or phases.

Table.1 Simulation results of the disturbances on the line system of fig (4)

| Type of the disturbance                                     | Pa [A] | Pb [A] | Pc [A] | Trip |
|---|--------|--------|--------|------|
| Add load of 96MW to the initial load at the end of the line | 2.2852 | 2.3507 | 2.9584 | 0    |
| Add load of 96MW to the initial load at the mid of the line | 2.2317 | 2.5038 | 2.4333 | 0    |

From the results shown in table 1 it can be seen that all peak of currents are less than the threshold value (Th1=4 Amp), so the relay will not respond to these disturbance cases.

## 6. Practical Results

The theoretical results were obtained on a practical simulation transmission line in the lab figure 6.1. The values of thresholds are chosen in the same way in section 3. The value of the threshold was (Th1=4 Amp). Several cases for non fault transient events were tested as well as the fault events. The "power pad" device was used to take the results practically by 12.8 KHz sample frequency

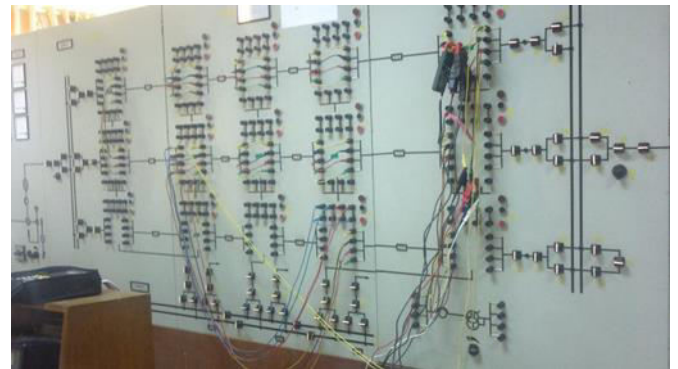


Figure 6.1: practical simulation transmission system

Many faults at many locations on the transmission line in fig.6.1 are implemented and the following curves show the results.

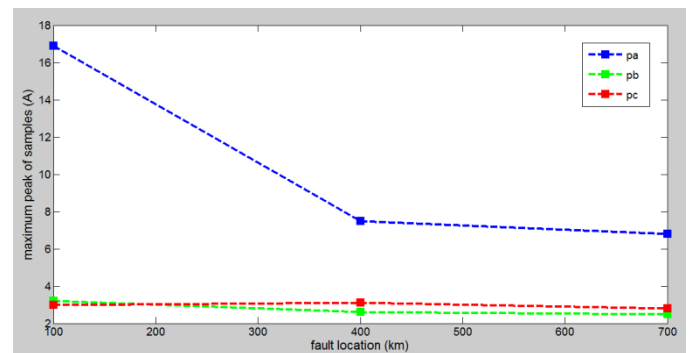


Figure 6.2: A-G solid fault

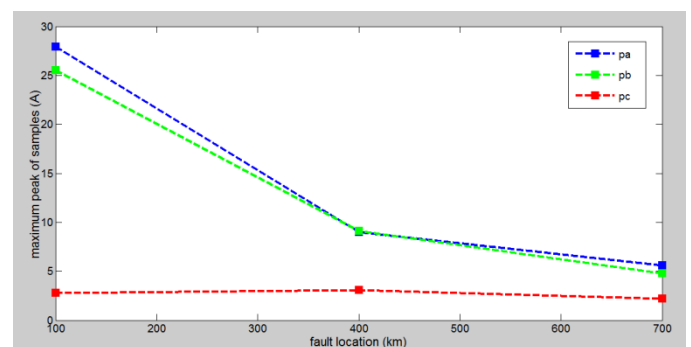
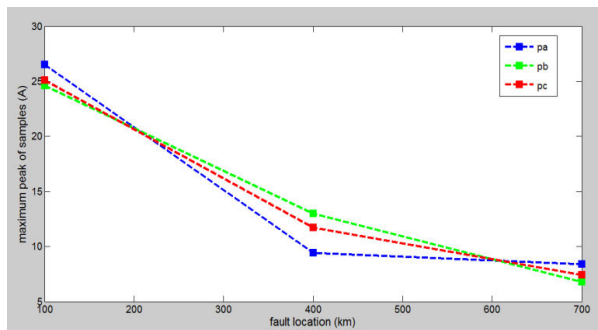


Figure 6.3: A-B-G solid fault



**Figure 6.4: A-B-C-G solid fault**

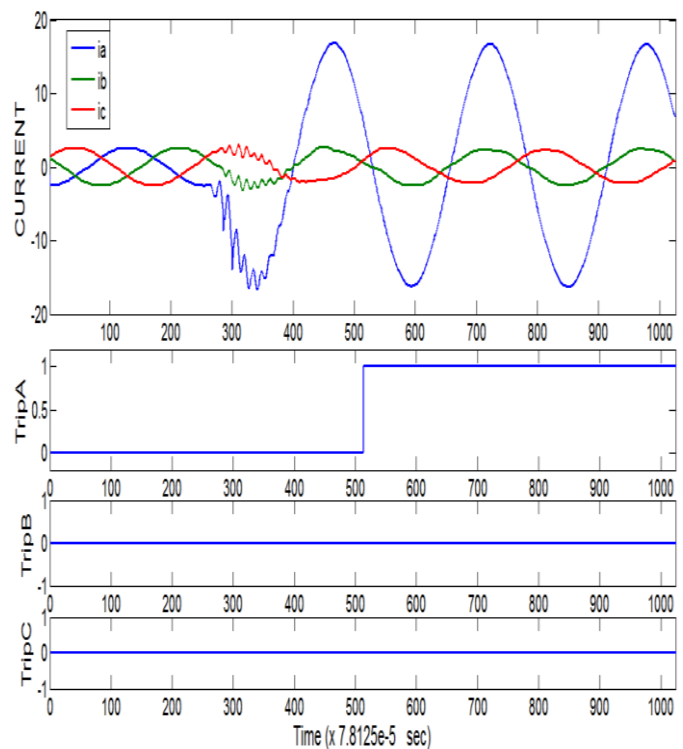
Figures 6.2, 6.3, 6.4 .shows the relation between the fault location in (km) on the x-axis with maximum peak of currents for three phase currents on the Y-axis. In all figures we can see that the maximum peak of currents for the faulted phases are greater than (Th1=4 Amp) while the maximum peak of currents for unfaulted phases are less than the threshold value (Th1), so the relay will respond to these faults in the faulted phase or phases.

**Table.2 Results of the disturbances on the lab transmission line**

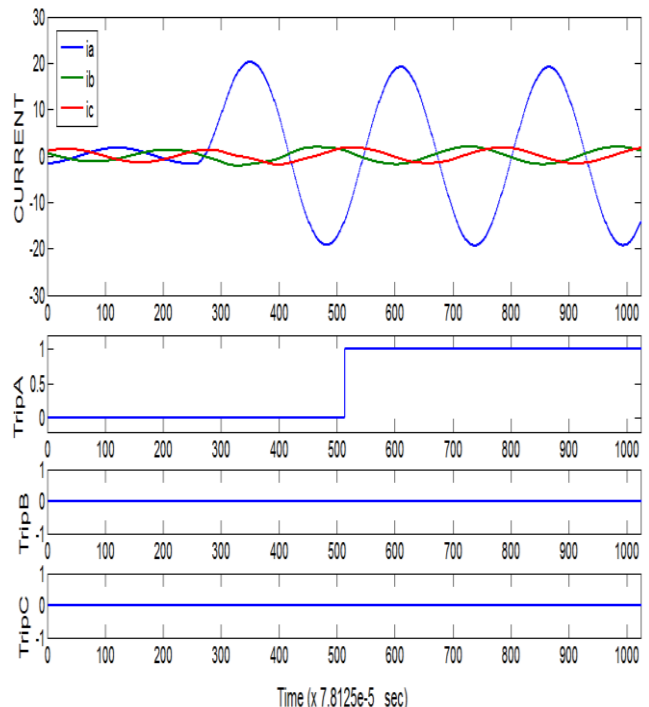
| Type of the disturbance                                     | Pa [A] | Pb [A] | Pc [A] | Trip |
|---|--------|--------|--------|------|
| Add load of 96MW to the initial load at the end of the line | 3.1    | 3.1    | 3.1    | 0    |
| Add load of 96MW to the initial load at the mid of the line | 3.5    | 3.4    | 3.4    | 0    |

From the results shown in table 2 it can be seen that all peak values of the samples are less than the threshold value (Th1=4 Amp) .

From the results shown in the six previous figures we can see that the designed relay worked by same principle and same performance for both simulation and practical transmission lines.



**Figure 6.5: three phase currents and trip signals for A-G fault at 100km for lab. line**



**Figure 6.6: three phase currents and trip signals for A-G fault at 100km for simulated line**

Fig.6.5 and 6.6 show the three phase currents and trip signals for both practical and simulation cases. from fig.6.5 we can see the distortion existence in the

practical current signal, while the simulation waves fig.6.6. without distortion ,and in spite of this distortion the designed relay respond in correct form and gave a true decision in both simulation and practical cases..

## **7. Conclusion**

The designed distance relay tested with both computer simulation program and practically transmission line board in the lab. This distance relay proved its capability to work with high speed and high accuracy for detecting the faults within the first quarter of the wave. Its classify the fault type and recognize it from the disturbance cases. The relay has the ability to indicate the fault position whether it is inside zone one and take the decision to disconnect the system ,or in zone two, so it take the action after a delayed time. .

## **8. References**

- [1] A. H. Osman and O. P. Malik, "Transmission Line Distance Protection Based On Wavelet Transform". IEEE Trancaction On Power Delivery, VOL. 19, NO. 2, APRIL 2004
- [2] Feng Liang and B.Jeyasurya " Transmission Line Distance Protection Using WaveletTransform Algorithem "IEEE Trans.Power Delivery,Vo1.19,No.2,april. 2004
- [3] Francisco martin , Jose A. Aguado, "Wavelet-Based ANN Approach for Transmission Line Protection " IEEE Transactions on Power Delivery 4, October 2003. Vol. 18, No.
- [4] Dr. Maamoon F.AL\_KABABJIE , Nagham .H . AL\_NAMEE,"DISTURBANCE PERFORMANCE IMPROVMENT OF DISTANCE RELAY WITH AID OF WAVELET",2010 7th International Multi-Conference on Systems, Signals and Devices,2010.

## **9. Appendix**

Transmission line parameters:

$$R1= 0.034672 \ \Omega/\text{km}$$

$$L1=1\text{e-}3 \ \text{H}/\text{km}$$

$$C1= 23.23\text{nf}/\text{km}$$

Generator parameters:

$$V=220\text{kV}$$

$$N=1500\text{rpm}$$

$$F=50\text{Hz}$$

$$I=422\text{A}$$

Load parameters:

$$P=52.8\text{MW}$$

$$Q=39.6\text{MVAR}$$