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Power System'stransmission Line Relaying Improvement Using Discrete Wavelet Transform

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ABSTRACT
Transmission line is a path between the generating station and load(Industries & Domestic). These lines are several kilometres and always attracted towards faults. These Faults are Phase to Ground (P-G), Phase to Phase (P-P), Phase to Phase to Ground (P-P-G) and Symmetrical Fault (P-P-P\P-P-P-G).In order to protect the power system, faults should be cleared within stipulated time. Relay plays a key role in power system protection, before employing them in system, their parameters should be pre-determined.The proposed system uses Discrete Wavelet Transform to determine the fault levels in power system. It is used to extract the hidden factors *i.e.* Transients, from the faulty current signals by performing decomposition at different levels. Test system is modelled and fault signals are imported to workspace and test the reliability of the algorithm. The proposed system modelled in MATLAB\SIMULINK to detect, classify and locate all the possible faults in the transmission line in the power system which are nothing but parameters of relays.
Keywords – Discrete Wavelet Transform, Faults, Relay Parameters, Transients, Transmission Line.

I. INTRODUCTION

Electricity is very important component to universe. Power System is a system which generate electricity and dispatch to the loads these are generally industries and households. Power System consists Generating stations, Transmission lines and Load Centres.

Transmission line interconnects the generating station to different load centres, they run over several kilometres and fascinated to faults, and to maintain continuity of operation we should clear the faults within short period. Relay plays main role in protection of transmission line, and assimilated to detect the abnormal condition in the system which notice faults and isolate the faulty part from the power system with negligible disturbance in the system. There are several relaying schemes are available they are

- Overcurrent relaying scheme.
- Differential relaying scheme.
- Distance relaying scheme.

Out of these schemes distance relaying is used for transmission line protection, due to their high speed fault clearance compared to other schemes. A distance relay estimates the electrical distance from fault point to relay position and then compared to threshold value which is pre-determined parameters of relay. To determine parameters of relay we need the measuring techniques, which have to ability to detect changes in system configuration, source impedance and fault resistance. So many techniques proposed previously, they are listed below

- Artificial Neural Network (ANN).
- Fuzzy Logic & Fuzzy Neuro.
- Wavelet based systems.

The aim of this paper is to determine the parameters of relay circuit before employing them in protection system by calculating the threshold values from fault detection, fault classification and fault location with respect to relay point. In this paper we used 'Discrete Wavelet Transform' which is wavelet based measuring system.

II. FAULTS IN TRANSMISSION LINE

Transmission line faults can be categorise into two types, they are
- Shunt faults.
- Series faults.

2.1 Shunt Faults

Shunt faults are further classified as symmetrical and unsymmetrical faults, symmetrical faults having equal phase voltages *i.e.* balanced on the other hand unsymmetrical faults has different phase voltages. The unsymmetrical faults are

- Phase to Ground Fault
- Phase to Phase Fault.
- Phase to Phase to Ground Fault.

2.1.1 Phase to Ground Fault

The block diagram of single phase to ground fault is shown figure 2.1.1, here 'p' denotes fault point, 'Z^F' represents fault impedance and 'I_A','I_B','I_C' are respective phase currents.
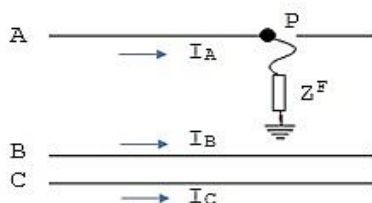
Fig.2.1.1 : Single Phase to Ground Fault

The fault current can be given as

$$I_F = I_A = \frac{3E}{Z_1 + Z_2 + Z_3 + 3Z^F}$$

Where

Z_1=Positive sequence impedance
Z_2=Negative sequence impedance
Z_0=Zero sequence impedance
E=Voltage at fault point.

2.1.1 Phase to Phase Fault

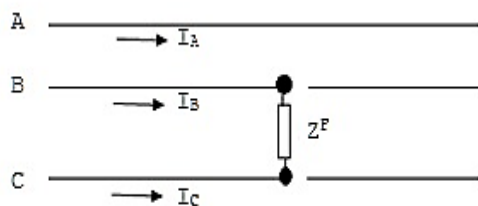The block diagram of phase to phase fault is shown in figure 2.1.2

Fig.2.1.2 : PHASE TO PHASE FAULT

The fault current can calculated using below formula

$$I_F = I_B - I_C = \frac{\sqrt{3}E}{Z_1 + Z_2 + Z^F}$$

2.1.2 Phase to Phase to Ground Fault

The block diagram of phase to phase to ground fault is shown in figure 2.1.3. Fault impedance may not be involve.
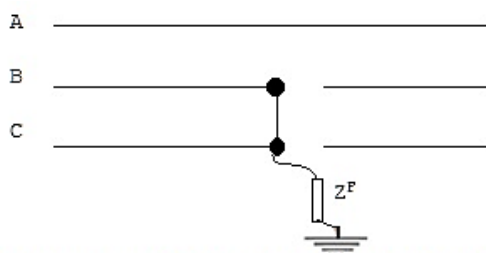

Fig.2.1.3 : DOUBLE PHASE TO GROUND FAULT

The fault current in double line to ground fault is combination all sequence components currents, we can calculate all sequence currents of phase 'A'. The fault current given as follows

$$I_F = I_B + I_C = 3I_{A0}$$

Zero sequence current of phase 'A' given as

$$I_{A0} = \frac{Z_1 * I_{A2} - E}{Z_0 + 3Z^F}$$

Negative sequence current of Phase 'A' given as

$$I_{A2} = \frac{Z_1 * I_{A1} - E}{Z_2}$$

Positive sequence current of phase 'A' given as

$$I_{A1} = \frac{E}{Z_1 + \frac{Z_2(Z_0 + 3Z^F)}{Z_2 + Z_0 + 3Z^F}}$$

2.1.3 Symmetrical Fault

Symmetrical fault can also be known as three phase fault with or without ground. The block diagram of three phase fault is shown in figure 2.1.4.
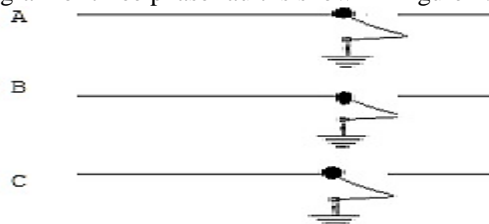

Fig.2.1.4 : THREE PHASE FAULT

In symmetrical fault negative sequence and zero sequence components become zero, the fault current is given as follows

$$I_F = \frac{E}{Z}$$

2.2 Series Faults

In broken conductor faults the load currents can't be neglected, as these are the only currents that are flowing in the network. The pre fault load currents are assumed to be balanced, these faults are classified as follows

- Two conductors open.
- One conductor open.

The one conductor open fault is mathematically identical to double phase to ground fault except that the voltages measured. The two conductor open fault mathematically identical to phase to ground fault.

III. DISCRETE WAVELET TRANSFORM

The discrete wavelet transform is a multi-resolution analysis and is used extensively in power system applications to analysing transient phenomenon associated to abnormal conditions *i.e.* Faults.

The discrete wavelet transform (DWT) consists only two filters one is low pass filter and other is high pass filter. The output of low pass filter is known as 'approximations' and denote as A(k) on the other hand output of high pass filter is known as 'details' and denote as D(k).

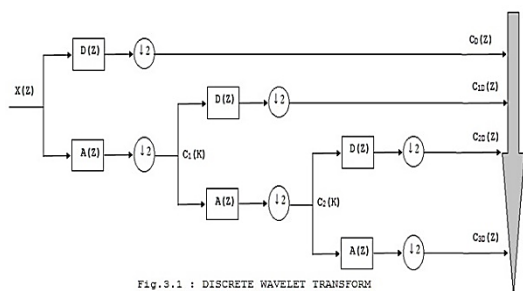The block diagram of third order discrete wavelet transform is shown in figure 3.1.

Fig.3.1 : DISCRETE WAVELET TRANSFORM

We consider only detail coefficients only because low pass filter give output almost same as input *i.e.* smooth version of input. For DWT some special families of wavelet functions are developed these are commonly known as mother wavelets, these are Daubechies, Haar, Coiflets and Symlets.

IV. PROPOSED METHODOLOGY

The proposed methodology uses the Discrete Wavelet Transform for extracting the transient information in the current waveform, which is used to calculate the parameters of Relay Circuit.

3.1 Waveform Decomposition

The three phase signals are fed individually through a Discrete Wavelet Transform filter to decompose current waveforms into a series of wavelet components, these wavelet components are very useful for sensing, focussing and classifying the abnormal conditions in transmission line.

In this paper we use Daubechies (dB) as mother wavelet, which most commonly used in protection applications and 'dB5' wavelet is used to decompose the current signal effectively.

3.2 Fault Detection

A fault detector must has ability to detect the abnormal condition to dispute an output signal indicating the phase condition. During normal condition both current, voltage waveforms are sinusoidal. Fault signals can be adulterated with different transient components such as exponentially decaying DC offset and high frequency damped oscillations.

The coefficients of 'Details' are used whether the fault is exist or not. If the absolute sum of all detail coefficients greater than the threshold value, fault is exist otherwise no fault in the system.
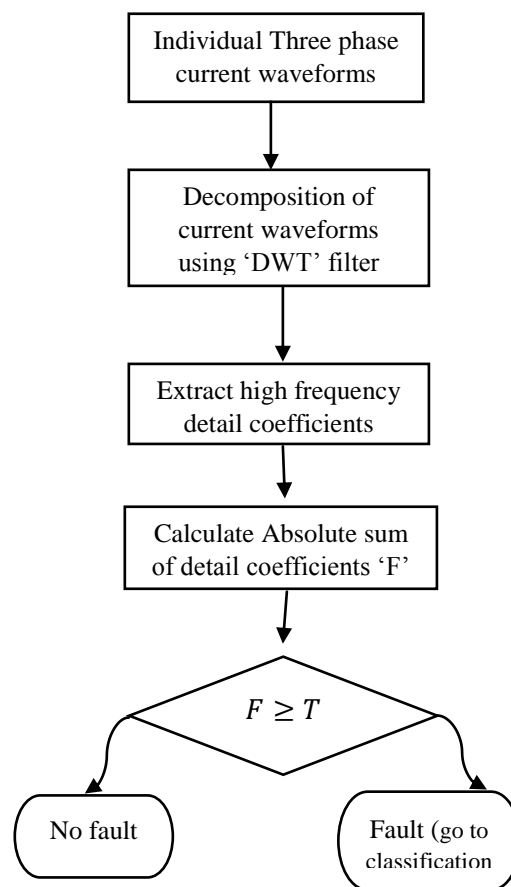

Fig.4.2: Algorithm for Fault Detection

Let **aA**, **aB**, **aC** are absolute sums of detail coefficients of individual phase currents.
Where

$$aA = |sum| \text{ of } 1^{st} \text{ level details of } I_A$$
$$aB = |sum| \text{ of } 1^{st} \text{ level details of } I_B$$
$$aC = |sum| \text{ of } 1^{st} \text{ level details of } I_C$$
$$F = aA + aB + aC$$

If 'F' greater than the threshold value 'T', fault will be exist. The steps involved in this algorithm is shown in figure 4.2.

3.3 Fault Classification

When the algorithm identify fault in system, after that it classify the type of fault, it can be performed by individual phase threshold values. The flow chart of classification is shown in figure 4.3. The algorithm starts from last step of fault detection.
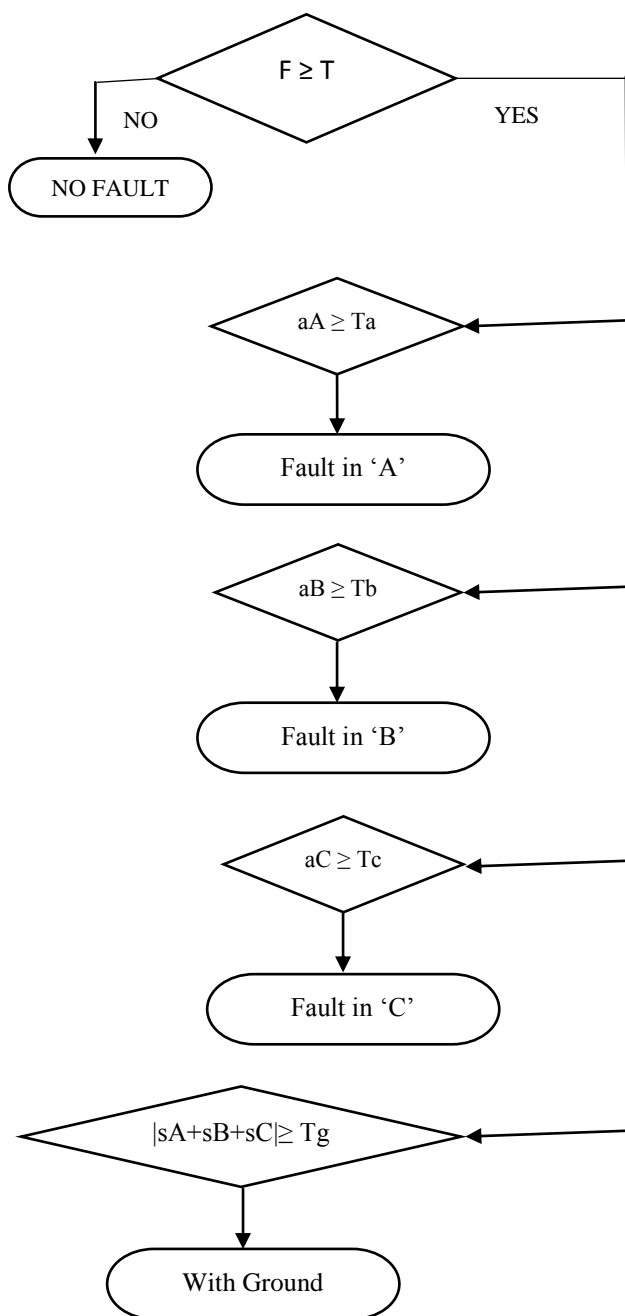
Where

         Ta= Threshold Value of phase 'A'
         Tb= Threshold Value of phase 'B'
         Tc= Threshold Value of phase 'C'
         sA= Details sum of phase 'A'
         sB= Details sum of phase 'B'
         sC= Details sum of phase 'C'
         Tg= Threshold Value of ground

V. TEST SYSTEM

The test system was modelled in SIMULINK and various fault conditions are generated. The test system is composed of 220KV transmission lines with length of 300Km connect one end to load section and another end to generating station, a generating station consists of two generator in parallel with capacity of 247MVA, 15.75KV each. The one line diagram of test system is shown in figure 5.1.
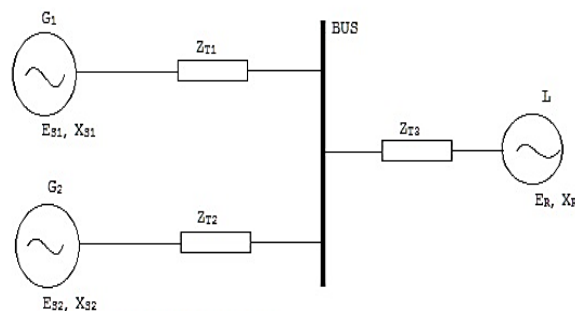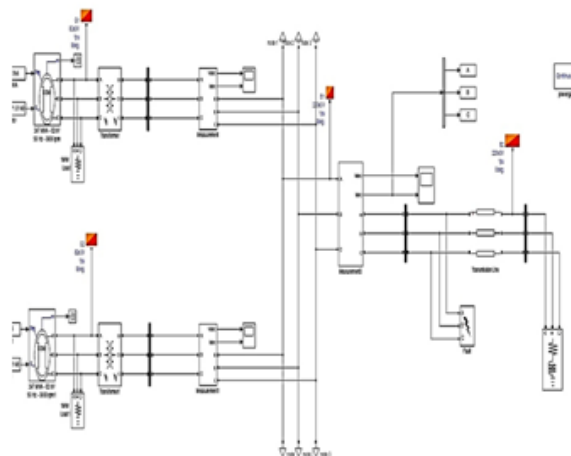

Fig.5.1 : TEST POWER SYSTEM

The Simulink model of test model is shown in below figure 5.2.

The power system transmission parameter are shown in Table-1. The negative sequence parameters are assumed to negligible.

Power Frequency in Hz	50
Transmission line Length in Km	300
Positive Sequence Resistance R_1, Ω/Km	0.01273
Zero Sequence Resistance R_0, Ω/Km	0.3864
Positive Sequence Inductance L_1, H/Km	0.93e-3
Zero Sequence Inductance L_0, H/Km	4.12e-3
Positive Sequence Capacitance C_1, F/Km	12.7e-9
Zero Sequence Capacitance C_0, F/Km	7.75e-9

Table-1: Transmission Line Parameters

VI. SIMULATION RESULTS

The proposed work was first created in SIMULINK atmosphere. The phase currents are imported to MATLAB atmosphere by workspace, these current signals are given as input to the algorithm which is made exclusively by discrete wavelet transform. The algorithm check the accuracy of Threshold values, further these threshold values used as parameters of Relaying elements.
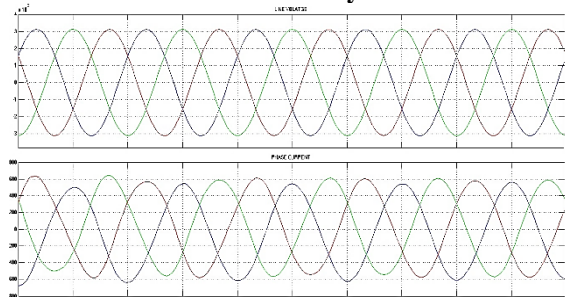
3.4 When no Fault in Power System

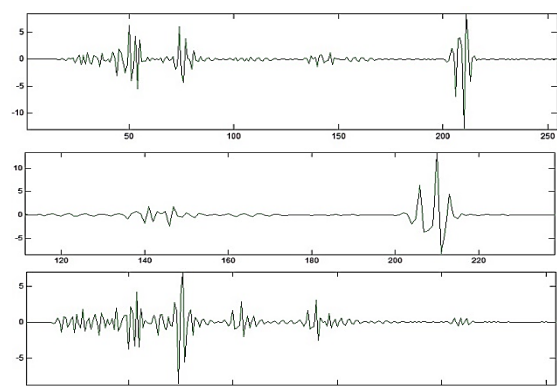Fig.6.1: Line Voltage & Phase Current

Fig.6.2: High Freq. Details of A, B, C Currents
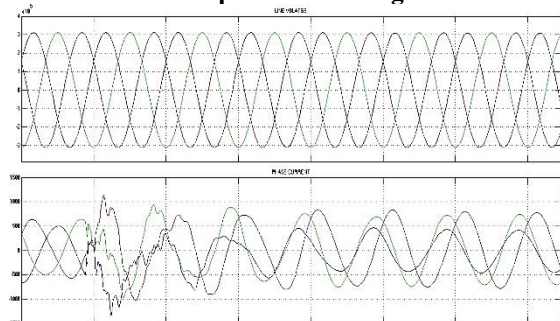
3.5 When Fault in phase 'A' with ground

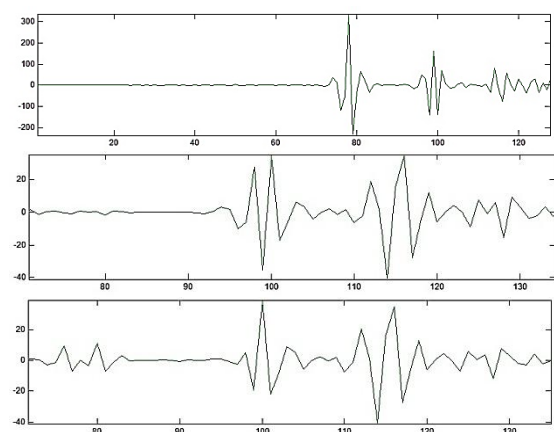Fig.6.3: Line Voltage & Phase Current when phase 'A' fault

Fig.6.4: High Freq. Details of A, B, C Currents in phase 'A' Fault

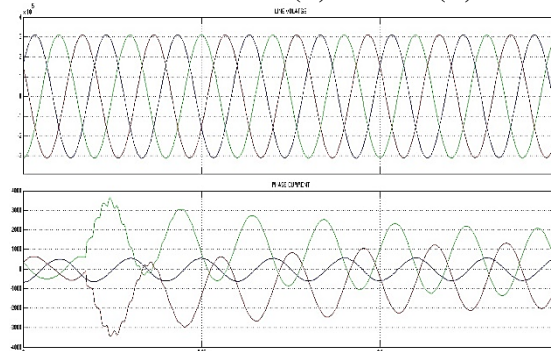## 3.6 When Fault in Phase (B) & Phase (C)

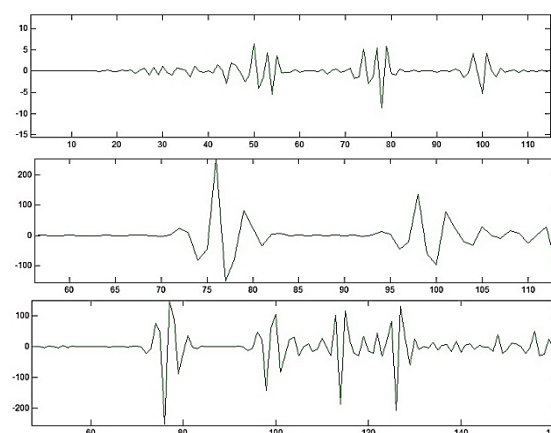Fig.6.5: Line Voltage & Phase Current when phase 'B' & Phase 'C' fault

Fig.6.5: High Freq. Details of A, B, C Currents in phase 'B' & Phase 'C' Fault

The parameters of Relay element is shown in Table-2 and these are nothing but threshold values which are calculated in algorithm.

VII. CONCLUSION

For reliable operation of power system, continuity in transmission of electricity from generating station to load centre is must, in general so many faults are occurred in transmission system.

In order to maintain stability we have to make use of relay element which disconnects the faulty sections until the fault is cleared, for proper operation of relay we pre-determine the fault levels *i.e.* parameters of relay.

Discrete Wavelet Transform have certain advantages over there, vig. Less time required for detection of fault and accuracy concern.

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BIOGRAPHIES

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