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POWER FAULT DETECTION BY VOLTAGE MEASUREEMNT METHOD

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Abstract: Fault location is very important in power system engineering in order to clear fault quickly and restore power supply as soon as possible with minimum interruption. In this study a 300km, 330kv, 50Hz power transmission line model was developed and simulated using power system block set of MATLAB to obtain fault current waveforms. The waveforms were analysed using the Discrete Wavelet Transform (DWT) toolbox and DCT by selecting suitable wavelet family to obtain the pre-fault and post-fault coefficients for estimating the fault distance. This was achieved by adding non negative values of the coefficients after subtracting the pre-fault coefficients from the post-fault coefficients. It was found that better results of the distance estimation, were achieved using Daubechies 'db4'wavele.

KEYWORDS: Transmission line, Fault location, Wavelet transforms, signal processing

I. INTRODUCTION

Fault location and distance estimation is very important issue in power system engineering in order to clear fault quickly and restore power supply as soon as possible with minimum interruption. This is necessary for reliable operation of power equipment and satisfaction of customer. In the past several techniques were applied for estimating fault location with different techniques such as, line impedance based numerical methods, travelling wave methods and Fourier analysis [1]. Nowadays, high frequency components instead of traditional method have been used [2]. Fourier transform were used to abstract fundamental frequency components but it has been shown that Fourier Transform based analysis sometimes do not perform time localisation of time varying signals with acceptable accuracy. Recently wavelet transform has been used extensively for estimating fault location accurately. The most important characteristic of wavelet transform is to analyze the waveform on time scale rather than in frequency domain. Hence a Discrete Wavelet Transform (DWT) is used in this paper because it is very effective in detecting fault- generated signals as time varies [8]. This paper proposes a wavelet transform based fault locator algorithm. For this purpose, 330KV,300km,50Hz transmission line is simulated using power system BLOCKSET of MATLAB [5].The current waveform which are obtained from receiving end of power system has been analysed. These signals are then used in DWT. Four types of mother wavelet, Daubechies (db5), Biorthogonal (bio5.5), Coiflet (coif5) and Symlet (sym5) are considered for signal processing.

II. WAVELET TRANSFORM

Wavelet transform (WT) is a mathematical technique used for many application of signal processing [5].Wavelet is much more powerful than conventional method in processing the stochastic signal because of analysing the waveform in time scale region. In wavelet transform the band of analysis can be adjusted so that low frequency and high frequency components can be windowing by different scale factors. Recently WT is widely used in signal processing application such as de noising, filtering, and image compression [3]. Many pattern recognition algorithms were developed based on the wavelet transform. According to scale factors used the wavelet can be categorized into different sections. In this work, the discrete wavelet transform (DWT) was used. For any function (f), DWT is written as.

$$DWT_{\varphi} f(m,k) = \frac{1}{\sqrt{a_o{}^m}} \sum_n x(n)\varphi[\frac{k-n_o b_o a^m}{a_o^m}] \quad (1)$$

Where φ is the mother wavelet [3], $a_o^m$is the scale parameter, n_o , b_o , a^m are the translation parameters.

III. TRANSMISSION LINE EQUATIONS

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A transmission line is a system of conductors connecting one point to another and along which electromagnetic energy can be sent. Power transmission lines are a typical example of transmission lines. The transmission line equations that govern general two-conductor uniform transmission lines, including two and three wire lines, and coaxial cables, are called the telegraph equations. The general transmission line equations are named the telegraph equations because they were formulated for the first time by Oliver Heaviside (1850-1925) when he was employed by a telegraph company and used to investigate disturbances on telephone wires [1]. When one considers a line segment __ with parameters resistance (*R*), conductance (*G*), inductance (*L*), and capacitance (*C*), all per unit length, (see Figure 3.1) the line constants for segment dx are Rdx, Gdx, Ldx, and Cdx. The electric flux and the magnetic flux Φ created by the electromagnetic wave, which causes the instantaneous voltage U(x,t), & and current i(x,t) are:

$$d\psi(t) = u(x,t)Cdx \quad (2)$$

$$d\phi(t) = i(x,t)Ldx \quad (3)$$

Calculating the voltage drop in the positive direction of *x* of the distance __ one obtains

$$u(x,t) - u(x+dx,t) = -du(x,t) = -\frac{\partial u(x,t)}{\partial x}dx = \left(R + L\frac{\partial}{\partial t}\right)i(x,t)dx$$

(4)

If __ '1 cancelled from both sides of equation (4), the voltage equation becomes

$$\frac{\partial u(x,t)}{\partial x} = -L\frac{\partial i(x,t)}{\partial t} - Ri(x,t) \quad (5)$$

Similarly, for the current flowing through *G* and the current charging *C*, Kirchhoff's current law can be applied as

$$\frac{\partial i(x,t)}{\partial x} = -C\frac{\partial u(x,t)}{\partial t} - Gu(x,t) \quad (7)$$

The negative sign in these equations is caused by the fact that when the current and voltage waves propagates & will decrease in amplitude for increasing .

The expressions of line impedance, Z and admittance Y are given by

$$Z = R + \frac{\partial L(x,t)}{\partial t} \quad (8)$$

$$Y = G + \frac{\partial C(x,t)}{\partial t} \quad (9)$$

Differentiate once more with respect to *x*, the second-order partial differential equations

$$\frac{\partial^2 i(x,t)}{\partial x^2} = -Y\frac{\partial u(x,t)}{\partial t} = YZi(x,t) = \gamma^2 i(x,t)$$

$$\frac{\partial^2 u(x,t)}{\partial x^2} = -Z\frac{\partial u(x,t)}{\partial t} = ZYu(x,t) = \gamma^2 u(x,t)$$

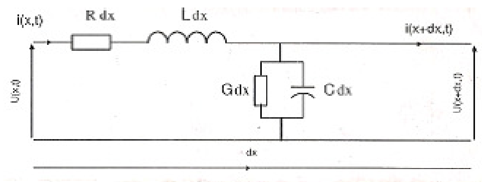

Figure 1 Single phase transmission line model

In this equation, 8 is a complex quantity which is known as the propagation constant, and is given by

$$\gamma = \sqrt{ZY} = \alpha + j\beta \quad (12)$$

Where, ; is the attenuation constant which has an influence on the amplitude of the wave, and the phase constant which has an influence on the phase shift of the wave. Equations (7) and (8) can be solved by transform or classical methods in the form of two arbitrary functions that satisfy the partial differential equations. Paying attention to the fact that the second derivatives of the voltage > and current 'functions, with respect to *t* and *x*, have to be directly proportional to each other, so that the independent variables *t* and *x* appear in the form [1]

$$u(x,t) = A_1(t)e^{\gamma x} + A_2(t)e^{-\gamma x}$$

$$i(x,t) = \frac{1}{Z}\left[A_1(t)e^{\gamma x} + A_2(t)e^{-\gamma x}\right] \quad (14)$$

Where *Z* is the characteristic impedance of the line and is given by

$$Z = \sqrt{\frac{R + L\frac{\partial}{\partial t}}{G + C\frac{\partial}{\partial t}}} \quad (15)$$

A1 and A2 are arbitrary functions, independent of x

To find the constants A1and A2 it has been noted that when x=0, u(x) = u_R and i(x) = i_r from equations (13) and (14) these constants are found to be

$$A_1 = \frac{VR + ZI_R}{2}$$

$$A_2 = \frac{VR - ZI_R}{2} \quad (17)$$

Upon substitution in equation in (13) and (14) the general expression for voltage and current along a long transmission line become

$$u(x) = \frac{V_R + ZI_R}{2}e^{\gamma x} + \frac{V_R - ZI_R}{2}e^{-\gamma x}$$

$$i(x) = \frac{\frac{V_R}{Z} + I_R}{2}e^{\gamma x} - \frac{\frac{V_R}{Z} - I_R}{2}e^{-\gamma x} \quad (19)$$

The equation for voltage and currents can be rearranged as follows

$$u(x) = \frac{e^{\gamma x}+e^{-\gamma x}}{2}V_R + Z\frac{e^{\gamma x}-e^{-\gamma x}}{2}I_R$$

$$i(x) = \frac{1}{z}\frac{e^{\gamma x}-e^{-\gamma x}}{2}V_R + \frac{e^{\gamma x}+e^{-\gamma x}}{2}I_R \qquad (21)$$

$$u(x) = cosh\gamma x V_R + Zsinh\gamma x I_R$$

$$i(x) = \frac{1}{z}sinh\gamma x V_R + cosh\gamma x I_R \qquad (23)$$

$$V_s = cosh\gamma l V_R + Zsinh\gamma l I_R$$

$$I_s = \frac{1}{z}sinh\gamma l V_R + cosh\gamma l I_R \qquad (25)$$

Rewriting the above equations (24) and (25) in term of ABCD constants we have

$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix} \qquad (26)$$

IV. RESULTS & DISCUSSION

A MATLAB simulink model for that is shown figure 1. To determine the fault location DCT-DWT algorithm has been used in my case. The current before and after fault occurrence is given to the DCT block which after that passes through DWT. A four level DWT is used with mother wavelet db4 for best results.

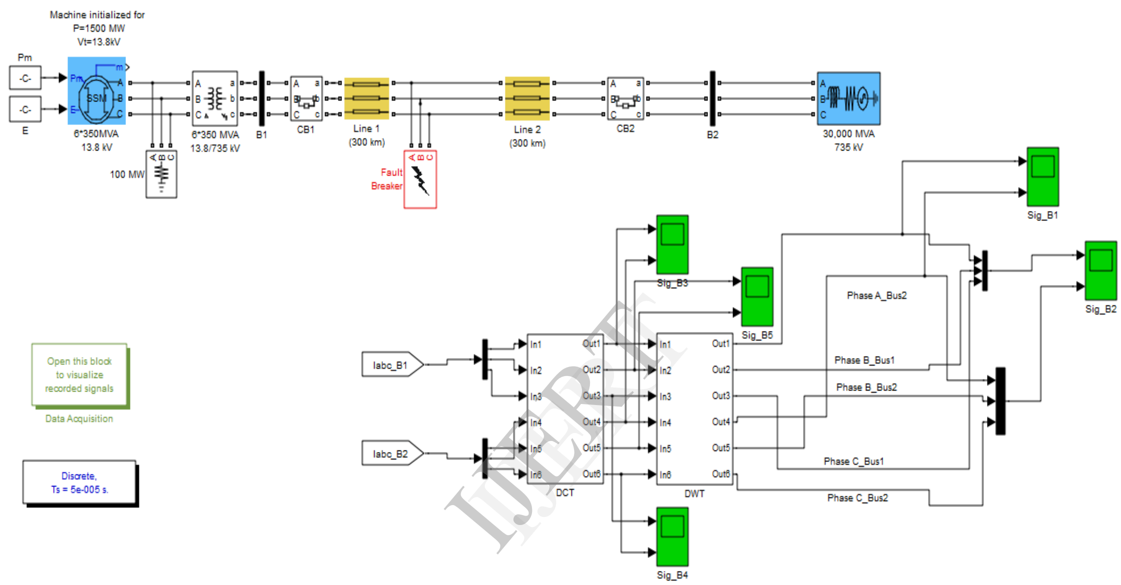

Figure 1: Complete MATLAB model for proposed algorithm

In my work results for fault location algorithm will be checked with all types of faults along with for different mother wavelets function. Initially a three phase fault is given at a distance of 97 km from sending end. The DWT of fault current for three types of faults: three phase, double phase to ground, single phase to ground is shown in following graphs. The four level discrete wavelet transform is used with mother wavelet db6. These graphs are shown when fault was at a distance of 97 km from the sending end.

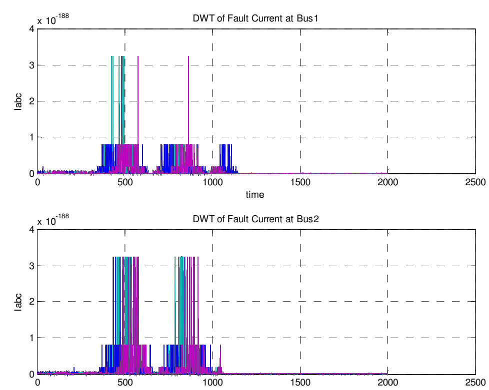

Figure 2: DWT of three phase fault current using db6 for three phase fault

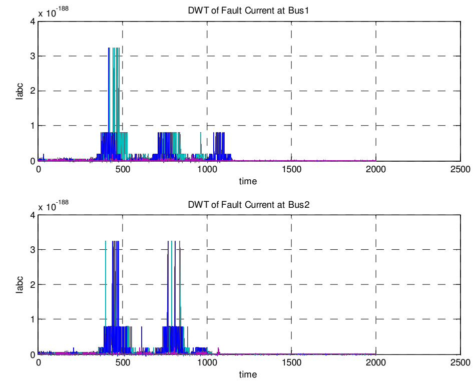

Figure 3: DWT of double phase fault to ground current using db6

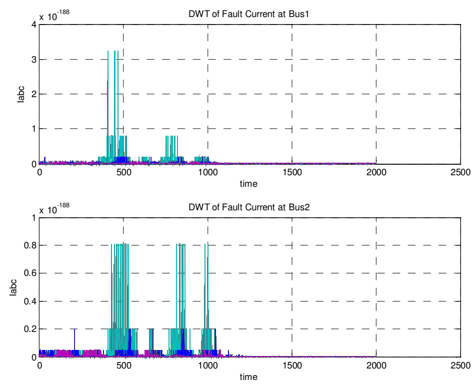

Figure 4: DWT of single phase fault to ground current using db6

The above graphs for different faults classify the types of faults by using DWT. In three phase faults the wavelet magnitude of all three phases is highest at some points as shown in figure by three different colors indicating three phases, whereas in two phase only two phase wavelet magnitudes is highest at some points because of fault occurrence at that location and for single phase only single coloured magnitude is showing its highest value at the time of fault occurrence. This is the way to classify and detect the type of fault in transmission line.

The fault location is found out by travelling wave formula as given

$$d = \frac{L - v(t_r - t_s)}{2}$$

Where d = fault distance from the sender end

V = velocity of travelling wave

t_r = time at the receiving end

t_s = time at the sending end

L = total length of line

To measure the time of fault occurrence in DWT-DCT transform, the time of first peak of fault is checked. For that the time period taken by fault in reaching to bus 2 is calculated. In our above case that time taken is 0.00044. A table given below shows all factors.

Table1: Fault Location for fault at various positions

Travelling wave speed	Sender Time	Receiver Time	Real Location	Calculated Location	Error(Km)
296688	0.02105	0.0219	35	34.6	-0.4
296688	0.0209	0.0215	73	73.4936	0.4936
296688	0.02156	0.022	97.50	97.23	-0.27
296688	0.02005	0.0204	111	110.58	-0.42
296688	0.0242	0.02421	160	161	1

Fault location has been found out at various locations as shown in above table. The results for three phase faults are shown in above table. By using DWT-DCT and even for four scaling of DWT our algorithm works well. A graph between real location and calculated location by our proposed method is shown in figure below.

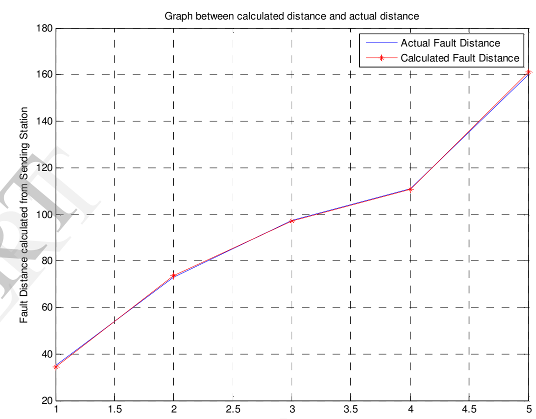

Figure 6.4: Graph between calculated fault distance and real fault distance

Above graph clearly shows that our proposed algorithm DWT-DCT fault location detection with the help of travelling wave calculates fault location almost exactly to the actual fault location. These all results classifiy the various types of faults and calculates the fault location from the sending end considering the first peak of wavelet transform.

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