Analysis of Transmission Line Fault by Using Wavelet

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Abstract— **Power Transmission line fault identification and classification requires fast and accurate analysis. The action of tripping mainly depends on the voltage and current waveforms obtained during the fault at the relay location. Wavelet analysis which is a mathematical tool for signal analysis is used to detect and classify the type of fault occurring on the transmission line. The coefficient of discrete approximation of the dyadic wavelet transform with different wavelets are used to be an index for transmission line fault detection and faulted – phase selection and select which wavelet is suitable for this application. The Discrete Wavelet Transform (DWT) is used for the analysis of current waveform during the fault. MATLAB/Simulation is used to generate fault signals. Simulation results reveal that the performance of the proposed fault detection indicator is promising and easy to implement for computer relaying application.**

***Keywords*— Transmission line, Fault detection, Faulted phase selection, Haar wavelet, Wavelet transform.**

I. INTRODUCTION

In power transmission line protection, faulty phase identification, classification and location are very important issues which need to be addressed in reliable and accurate manner for the analysis [1]-[2]. The wavelet transform normally uses both the analysis and synthesis in pair. Synthesis is used for waveform reconstruction; the original signal is decomposed in to its constituent wavelet sub-bands or levels. Each of these levels represents that part of the original signal occurring at that particular time and in that particular frequency band. These individual frequency bands are logarithmically spaced rather than uniformly spaced as in Fourier analysis. The decomposed signals posses a powerful time-frequency localization property, which is one of the benefits provided by the wavelet transform, and hence resulting signal can analyzed in both time and frequency domains [3]. In this paper the approach base on the wavelet transform of the fault transients, is presented. Wavelet transform having some unique features that make it suitable for the particular application that it maps given function from time domain in to time- scaling domain unlike the function used in Fourier analysis, the wavelet not only localized in frequency but also in time this allows to detect the time of occurrence of disturbance. The approach adopted here for detection and classification of all types of fault which occurs on transmission line. The line currents at the relay location are having transient of non periodic nature when there is fault on the line and hence were utilized for the wavelet analysis.

Application areas of wavelet transform in power systems include power quality, power system transients, power system protection, condition monitoring, partial discharge and transformer. But the area that the wavelet transforms covers largely is power quality and power system protection [4]. Comparison of Fourier Transform method with Wavelet transform method for detection and classification and location of transmission line fault was done in [5]. The Discrete Wavelet Transform based technique that include wavelet decomposition of signal and considering normal operation of system as reference analysis is used. The severity of disturbance is depends on the type of fault and by performing wavelet decomposition, taking maximum value of approximation coefficient as base value and comparing with decomposed current the type of fault were clearly detected was proposed in [6]. A new technique based on traveling wave for fault location on line with branches is based on the detection of fault generated high frequency transient wave at one end of line was presented in [7]. The concept of Wavelet Entropy not only for transient signal feature analysis but also for fault detection and transmission line diagnosis is presented in [8]. The power quality related issues like voltage sag, swell, momentary interruption and oscillatory transient using Morlet wavelet were presented in [9]-[12]. Power system relaying related domain and application of wavelet to resonant grounded power distribution network was presented in [13].

II. SIGNAL ANALYSIS USING WAVELET TRANSFORM

Wavelet transform was introduced at the beginning of 1980s by attracting in the field of speech and image processing. However its application to power sector has been introduced in [5]-[13].It is linear transformation like Fourier transform, with one difference that it allows time localization of different frequency component of given signal.

Short time Fourier transforms achieve partially same thing but with a limitation of using a fixed width windowing function. In case of wavelet transform, the analyzing functions, which are called wavelets, will adjust their time-width to their frequency in such a way that, higher frequency wavelet will be very narrow and lower frequency wavelet will be broader. This property of multi resolution is particularly useful for analyzing fault transients which contains localized high frequency component superposed on power frequency signals. Thus wavelet transform is better suited for analysis of signal containing short lived high frequency disturbance superposed on lower frequency continuous waveforms by virtue of this zoom in capability.

Given function x(t), its continuous wavelet transform will be calculated as follows:

$$WT(a,b) = \frac{1}{\sqrt{a}} \int_{-\infty}^{\infty} x(t)\psi\left(\frac{t-b}{a}\right)dt \qquad (1)$$

Where, a and b are the scaling (dilation) and translation (time shift) constants, and ψ is the wavelet function which may not be real as assumed in above equation for simplicity.

The Discrete wavelet transform (DWT) is defined as

$$DWT(m,k) = \frac{1}{\sqrt{a_o^m}} \sum_n x[n] g\left[\frac{k - na_o^m}{a_o^m}\right] \qquad (2)$$

Where x[n] is the mother wavelet and the scaling and translation parameter a and b are function of an integer parameter m, a= a_o^m and b= na_o^m .

Discrete wavelet transform is very useful technique for analyzing the transient phenomenon related with the transmission line faults. Multiresolution analysis (MRA) is one of the tool of Discrete wavelet transform, which decomposes original signal typically non-stationary signal in to low frequency signal called Approximations and high frequency signal called Details, with different levels or scales of resolution, specially uses prototype function called mother wavelet . At each level the signal like approximation signal is obtained by convolving signal with low pass filter and detailed signal is obtained by convolving the signal by high pass filter and both signal are followed by dyadic decimation.

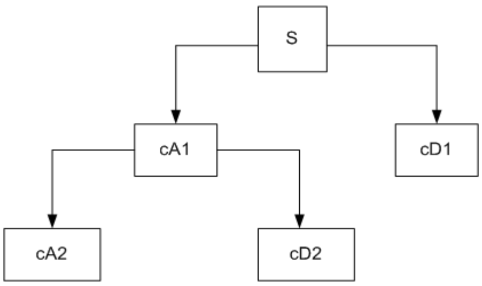

Fig. 1 Wavelet decomposition of Signal

III.POWER SYSTEM MODEL

In order to investigate the applicability of proposed algorithm, a 400 KV-60Hz power system is considered for the purpose. The power system model is shown in Fig.2. The system is simulated using MATLAB/Simulink software. The sending end (SE) is modeled as an equivalent machine and the receiving end (RE) is modeled as an infinite bus. In normal condition, power is transferred from SE to RE through a line having two section, each of 140-km length. Lines are modeled with distributed parameters in the simulation.

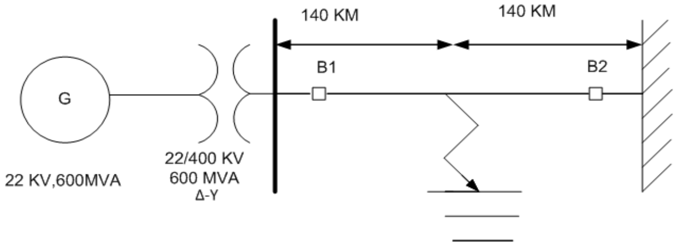

Fig. 2 Simulated System.

The parameters of the system used for simulation are given in table below.

Equivalent Generator G: 600MVA, 22KV, 60Hz, Inertia constant 4.4MW/MVA.

Xd=1.81p.u,Xd'=0.3p.u,Xd"=0.23p.u,Tdo'=8s,Tdo"=0.03s, Xq=1.76p.u,Xq"=0.25p.u,Tqo"0.03s,Ra=0.003pu,Xp=0.15pu

Transformer: 600MVA, 22/400KV, 60Hz, Δ/Y, X=0.163p.u, Xcore=0.33p.u, Rcore=0, Pcopper=0.00177p.u.

Transmission lines: Z1=0.12+j0.88 ohm/km.
Z0=0.309+j1.297ohm/km.
C1=1.0876*10^-8 F/km.

Figure above shows the basic simulated system with generator connected to infinite bus and line is divided in to two section having length of 140km. Initially while developing model that is with using generator, the voltage and current waveforms are obtained having swing in both voltage and current waveform. So in order to obtain smooth waveform generator load flow and machine initialization is done, which gives normal voltage and current signal. Fig 3 shows the voltage and current signal of phase A during the swing, waveforms shows the stable swing. This swing is obtained when the difference between sending end and receiving end angle is 45 degree that is when the power angle is 45 degree.

After the swing generator load flow and machine initialization is done so that we obtained normal voltage and current waveform as shown in Fig 4. The figure shows the voltage and current signal during normal condition that is system does not have any fault. Fig 5 and 6 shows the waveform during phase to ground fault and during three phase fault.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 5, May - 2014

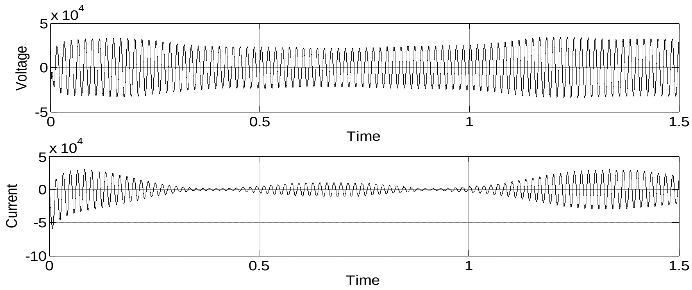

Fig: 3 Voltage and current waveform during power swing.

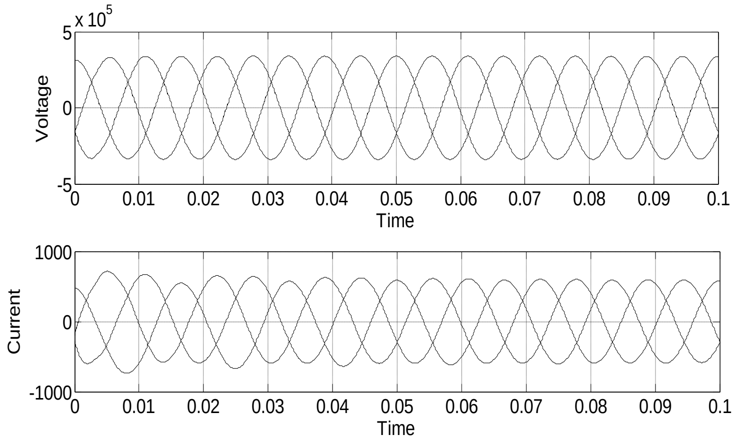

Fig: 4 Voltage and current waveform during normal condition.

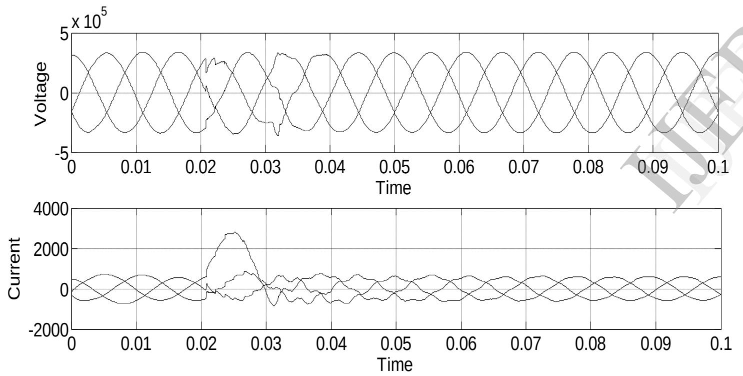

Fig: 5 Voltage and current waveform during a-g Fault.

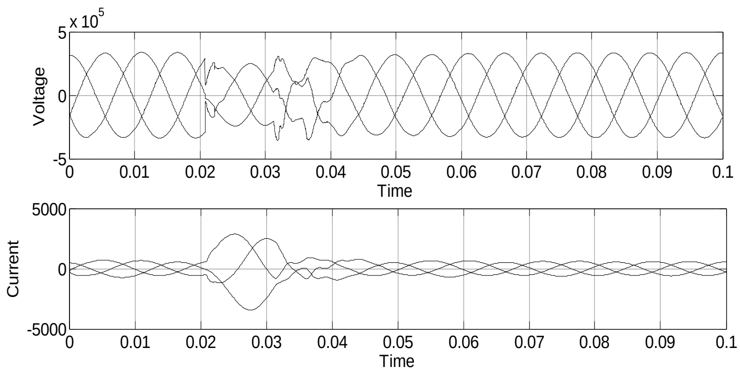

Fig: 6 Voltage and current waveform during a-b-c Fault.

IV. DETECTION METHODOLOGY

Since the facility to allow the use of variable window length, the wavelet transform is useful in analyzing transients those associated with the line faults or switching operations. Unlike Fourier transform, wavelet analysis has ability to analyze a localized area of signal and can reveal aspects of data like break points, discontinuities, etc. Wavelet transform is thus useful in detecting onset of fault and realizing non stationary signals comprising both low and high frequency components. Fault detection can be obtained from details of first decomposition level of the measured current signal using haar and db1 wavelet. This level contains high frequencies that are associated with the faults. A fault can be detected by observing the norm of DWT coefficient of these fundamental frequency components. If the norm of DWT coefficient for line current less than certain threshold, the lines are healthy. Once the norm of one or more current DWR coefficient exceeds the threshold value then disturbance is selected. Six level decomposition is performed for fault classification.

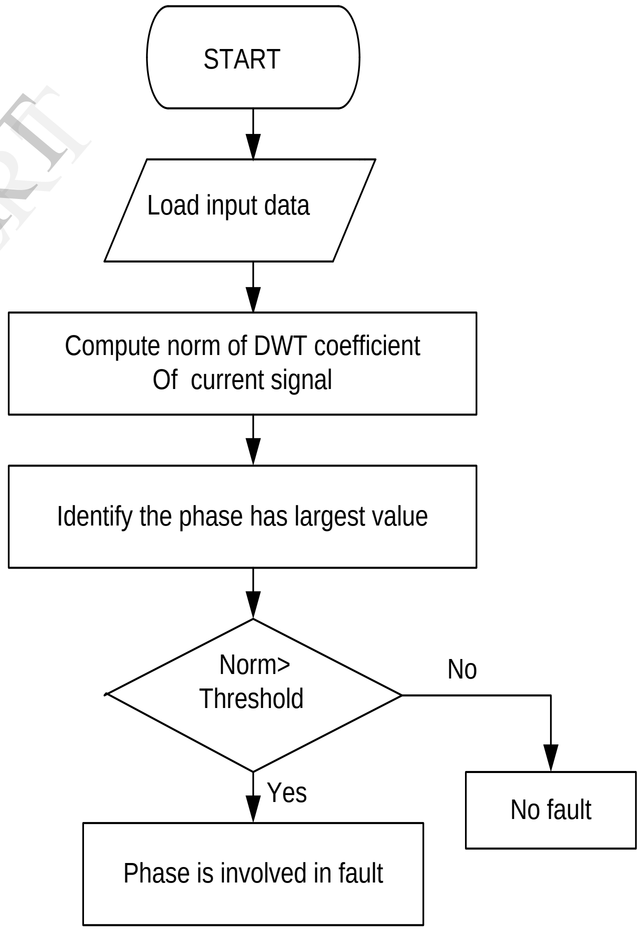

Fig: 7 Flowchart for fault identification.

To illustrate how fault can be detected and classified using wavelet transform a different types of fault created and obtained the norm value of each phase and compared with threshold values clearly classify the fault. Table 1 below shows the normalized value calculated by using DWT for every phase current for normal and faulty condition clearly classifies the type of fault. All this normalized values are calculated by using Haar wavelet with different fault condition with simulation time of 0.1s and fault time of 0.01s. Normal value is threshold value and all other values are with different faulty condition.

Table: 1 Norm value of every phase current by using Haar wavelet.

CONDITION	dA	dB	dC
NORMAL	26129	25812	26005
A-G Fault	43847	26321	25496
B-G Fault	25509	42891	26681
C-G Fault	26447	25258	52290
A-B Fault	41507	33218	26546
B-C Fault	26499	47438	42717
C-A Fault	44709	26118	49696
A-B-G Fault	44604	39135	26215
B-C-G Fault	25945	46115	51441
C-A-G Fault	44667	25550	54539
A-B-C Fault	45725	40595	53894
A-B-C-G Fault	45732	41894	53384

Table: 2 Norm value of every phase current by using db1 wavelet.

CONDITION	dA	dB	dC
NORMAL	26129	25812	26005
A-G Fault	43847	26321	25496
B-G Fault	25509	42891	26681
C-G Fault	26447	25258	52290
A-B Fault	41507	33218	26546
B-C Fault	26499	47438	42717
C-A Fault	44709	26118	49696
A-B-G Fault	44604	39135	26215
B-C-G Fault	25945	46115	51441
C-A-G Fault	44667	25550	54539
A-B-C Fault	45725	40595	53894
A-B-C-G Fault	45732	41894	53384

Table 1 and 2 shows the calculated norm values during fault and normal condition with fault time of 0.01s.

Table: 3 Norm value of every phase current by using Haar wavelet with fault time of 0.02s.

CONDITION	dA	Db	dC
NORMAL	26129	25812	26005
A-G Fault	53855	27149	24645
B-G Fault	25220	46110	27121
C-G Fault	27222	24464	61753
A-B Fault	47123	35684	26887
B-C Fault	26708	48549	42271
C-A Fault	50909	26705	60290
A-B-G Fault	54016	41839	25836
B-C-G Fault	26643	47537	60062
C-A-G Fault	53780	25880	64933
A-B-C Fault	54202	43417	60595
A-B-C-G Fault	53838	43219	62958

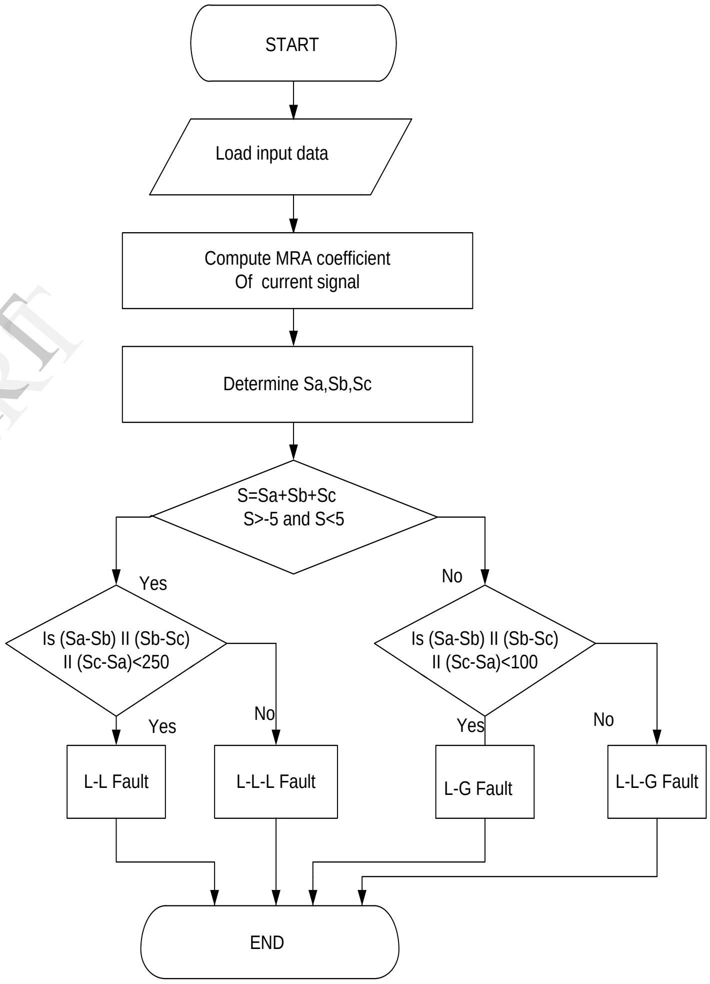

Fig: 8 Algorithm for fault classification.

METHODOLOGY FOR FAULT CLASSIFICATION

Fig 8 above shows the algorithm for fault classification, in this wavelet decomposition of six level considered for obtaining the absolute values of all the three phases of current signal for classifying the fault. The sampling frequency is 12.5 KHz, twelve level decomposition of signal is considered and out of that six level decomposition of signal is considered for fault classification. Each level of signal contains frequency to that level like first level decomposition of signal contains frequency, from 3.125 KHz to 6.25 KHz and so on.

CONCLUSION

This paper presents a wavelet transform based approach for transmission line fault classification that is a simple and effective fault detecting approach based on wavelet transform. The abrupt change of current component of fault current for power system can be detected by using Haar and db1 wavelet. The fault detection indicator also can achieve the task of faulted phase selection. The simulation studies demonstrate that the proposed algorithm is feasible for transmission line protection to the fault such as L-G, L-L, L-L-G, L-L-L, and L-L-L-G faults in different location.

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