Classification of Transmission Line Faults Using Discrete Wavelet Transform

Sruti. V.S, Bobin K Mathew

Abstract— This paper proposes a method for classifying Transmission Line faults using Discrete Wavelet Transformation. The method utilizes current travelling wave generated during the fault conditions. Wavelet Transform is used for extracting these transient signals. An algorithm for classification of Transmission line faults is presented which utilizes the modulous maxima of current travelling waves as threshold values. The method is more efficient and accurate for classifying and phase selection of Transmission Line faults.

Index Terms—Transmission line, DWT, Daubechies6 wavelet (Db4), Modulous maxima

I. INTRODUCTION

Fault classification and faulted phase selection plays a very important role in the protection of Transmission line faults. Mainly transmission line faults are classified into balanced and unbalanced fault [1] .Unbalanced faults are again classified into Single Line to Ground Fault (SLG), Double Line to Ground Fault(DLG) and Line to Line Fault(LL). Among these faults single line to ground fault is the most frequently occurring fault, they may be triggered due to Lighting strokes trees may fall across lines, fog and salt spray on dirty insulators may cause the insulator strings to flash over, and ice and snow loading may cause insulator strings to fail mechanically. Whereas the fault due to simultaneous short circuit between all the three lines, known as three-phase fault (L-L-L) is least likely. The severity of the fault can be expressed in terms of the magnitude of the faults current and hence it's potential to cause damage in the power system. The three –phase faults is the most severe where as single line to ground faults is the least severe.

Modern power systems involve large amount of investment. Proper operation and protection of power systems is necessary to minimize the consequences of faults. Devices, called protective relays, are installed at various places in the power system to detect faults and isolate the faulted part from the remaining system. Depending on the application, relays receive voltages and/or currents as inputs from a power system via voltage and current transformers.

Relays continuously monitor the power system and operate when the inputs deviate from their normal levels. Each relay, used for power system protection, performs a pre-defined function and responds to change in pre-specified parameters. Therefore Fault classification and faulted phase selection is important inorder to identify the type of fault and to identify the faulted phase to satisfy he faulted phase to satisfy the single pole tripping and auto reclosure.

Manuscript received August, 2013.

Sruti VS, EEE, IES College of Engineering, Chittilappilly affiliated to Calicut University, India.

Bobin K Mathew, EEE, Amal Jyothi College of Engineering Kanjirapally affiliated to MG University, India.

Most commonly used protective relays in EHV/MV lines are distance relays [2]. Distance relays works on the principle of change in impedance of the line during fault condition. Using distance relays only a particular zone at which fault occurs are identified. Thus the accuracy of fault location is reduced which will in turn affects fast clearance of fault. Also the performance of distance relay under power swing condition is not satisfactory. The disadvantages of distance relays are eliminated with the use of travelling wave principle for fault location and classification [3]. Travelling waves propagates at the velocity of light. Fault location is achieved by knowing the time of arrival of reflected current or voltage waves during fault condition. The energy level of transient signals are used for fault classification [5]

The fault classification based on travelling waves involves following steps [4].

1. Detecting the travelling waves: Travelling waves are detected either from one end of the transmission lines or from both ends of the transmission line. In this paper travelling waves are recorded from one end of the transmission line. Traditional voltage transducers cannot transform transient signals with high frequency therefore coupling devices or optical voltage transducers are necessary.
2. Sampling of travelling waves: A high sampling rate is necessary since the speed of travelling wave is very close to the speed of light.
3. Extracting transient waves: Since travelling waves posees high frequency components it is very difficult to extract the features of the signal also it is difficult to adopt a mathematical model to describe it.

Most commonly used transformation technique is Fourier transformation technique which gives only the spectral information of the signal. Time domain information of the signal cannot be extracted using Fourier transformation. The travelling wave is a function of both time and frequency. Therefore a method which extracts both time and the frequency information has to used.

Wavelet transformation method analysis a signal in its time and frequency domain. It investigates what spectral component exists in a given interval of time. It utilizes multiresolution technique ie. it analysis the signal at different frequencies with different resolution. The method for classifying and locating the faults utilizing wavelet transformation technique is described in [5]-[10].

In this paper a method for fault classification and faulted phase selection using wavelet transform is proposed. The method utilizes single ended recording algorithm in which the current transients generated during the fault conditions are recorded from one end of the transmission line. The three phase current transients are decoupled using model transformation and are sampled at a rate of 400KHz. Wavelet transform is applied to these sampled signals. Karrenbeur transformation is applied to the current travelling waves for decoupling. For fault classification the energy levels of wavelet decomposed signal is used.

II. WAVELET TRANSFORM

Wavelet transform is a new mathematical technique developed in the year 1980. It eliminates the resolution problem and provides a time frequency representation of signal. . It was developed to overcome the short coming of the Short Time Fourier Transform (STFT) and Fourier transforms (FT). Both the STFT and FT suffers from resolution problems. Wavelet transform techniques does not have any resolution problem since it uses multiresolution technique. Also it is the most suitable method for processing non- stationary signals. In this technique the signal to be analyzed is multiplied with a wavelet function and then the transform is computed for each segment generated. The width of the wavelet function changes with each spectral component. The Wavelet Transform, of high frequencies, gives good time resolution and poor frequency resolution, while at low frequencies; it gives good frequency resolution and poor time resolution. Both STFT and Fourier transforms provide only the frequency information of the signal. But wavelet transform technique is localized both in time and frequency. Wavelet transform techniques are divided into two Continuous wavelet transform and Discrete wavelet transform. In this paper discrete wavelet transform is used.

In DWT a time- scale representation of a discrete signal is obtained using digital filtering technique. The signal to be analyzed is passed through different filters having different cut off frequencies at different scales. In discrete wavelet transform the scale is changed by upsampling and down sampling. Normally half band high pass and low pass filters are used. The DWT is computed by successive lowpass and highpass filtering of the discrete time-domain signal as shown in figure1. This is called the Mallat algorithm or Mallat-tree decomposition. Its significance is in the manner it connects the continuous-time mutiresolution to discrete-time filters. In the figure, the signal is denoted by the sequence x[n], where n is an integer. The low pass filter is denoted by G_0 while the high pass filter is denoted by H_0. At each level, the high pass filter produces detail information,d[n], while the low pass filter associated with scaling function produces approximations, a[n].

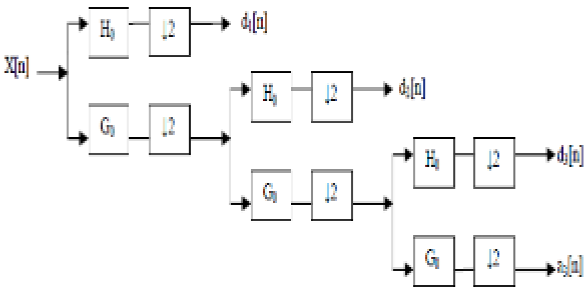

Fig 1.Three level decomposition tree

The major wavelet families which we use commonly are Daubechies, Biorthogonal, Symlets, Coiflets, Mexican Hat, Morlet, Meyer and complex wavelets. Among these wavelets Daubechies wavelets are commonly used for observing the fault transients since the characteristics shape of daubechies wavelets are similar to the shape of fault transients. Daubechies wavelets are normally designated as dbN where N represents the order. The ten daubechies wavelet function is as shown in figure2.

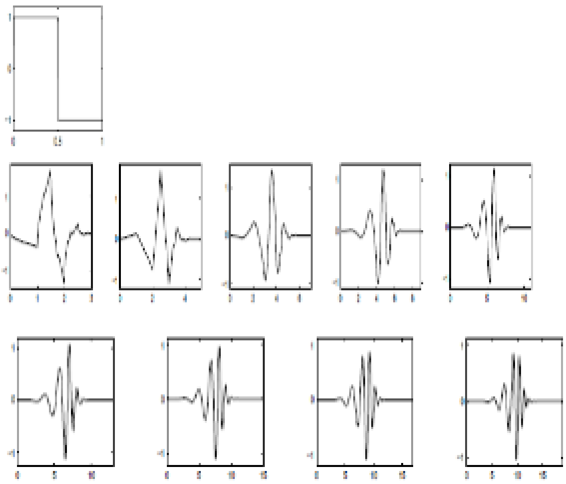

Figure 2. Daubechies wavelet functions.

III. TEST RESULTS

The system studied is composed of 220 KV transmission circuit . The single line diagram of the line is shown in Fig.3. Short circuit capacity of the equivalent thevenin sources on each sides of the line is considered to be 1.25 GVA and X/R ratio is 10.The transmission line is simulated with distributed parameter line model using MATLAB software. The fault classification is done by using wavelet transform.

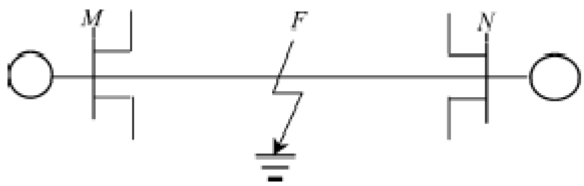

Figure 3. Single line diagram of the network

A. Fault Classification Algorithm

The initial current travelling waves are used for fault classification. The initial current travelling waves are recorded at one end of the transmission line. These three phase fault current are decoupled using Karrenbeur transformation and are sampled at 400KHz frequency. These signals are analyzed using Daubecheis 6 (db6) wavelet at level 4 decomposition. The fault classification is performed by analyzing ∝ modal, ß modal, γmodal and 0model at each fault.

$$\begin{bmatrix} \propto \\ \beta \\ 0 \\ \gamma \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & -1 & 0 \\ 1 & 0 & -1 \\ 1 & 1 & 1 \\ 1 & 1 & -1 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \end{bmatrix} \quad (1)$$

The matrix of the Karrenbauer transform is a full-order matrix. a-modal represents the “linemodal” between phase A and phase B; *ß-modal* represents the “line-modal” between phase A and phase C. In order to represent the “line-modal” between phases B and phase C, the γ-modal can be constructed. So that the transformation matrix becomes a redundancy matrix. Then the characteristics of various faults can be described by ∝-modal, ß- modal, γ-modal and 0-modal. The characteristics of various faults using Karrenbeur transformation is given below.

TABLE.I.CHARACTERISTICS OF VARIOUS FAULTS

Type of Fault	α-Modal	γ - Modal	β - Modal	0 – Modal
AG	iA	0	iA	iA
BG	-iB	iB	0	iB
CG	0	-iC	-iC	iC
AB	2iA	-iA	iA	0
BC	-iB	2iB	iB	0
CA	-iC	-iC	-2iC	0
ABG	iA-iB	iB	iA	iA+iB
BCG	-iB	iB-iC	-iC	iB+iC
CAG	iA	-iC	-(iC-iA)	iA+iC
ABC(G)	iA-iB	iB-iC	iA-iC	0

The initial current travelling wave are recorded at one end. These signals are decoupled using Karrenbeur transformation and are sampled at 400 KHz frequency. These signals are analyzed using daubechies6 (db6) wavelet at level one decomposition. The fault classification is performed by analyzing the ∝-model, ß-model,0-model and γmodel at each fault. The algorithm for fault classification and detection is given below.

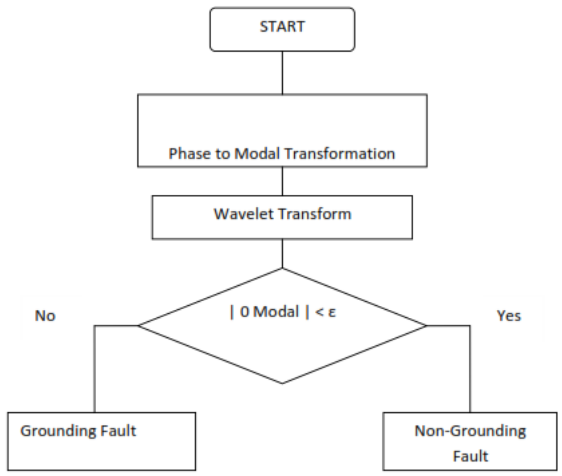

Figure 4 Flowchart for classification of grounding and non grounding fault

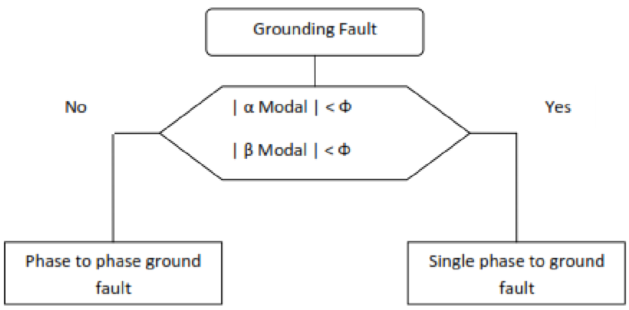

Figure 5. Flowchart for classification of SLG and DLG fault

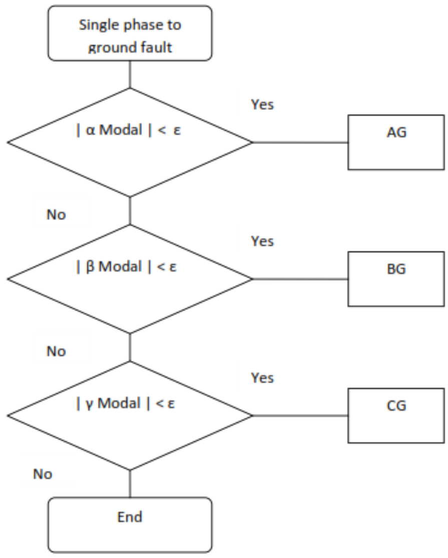

Figure 6. Flowchart of Phase selection in SLG fault

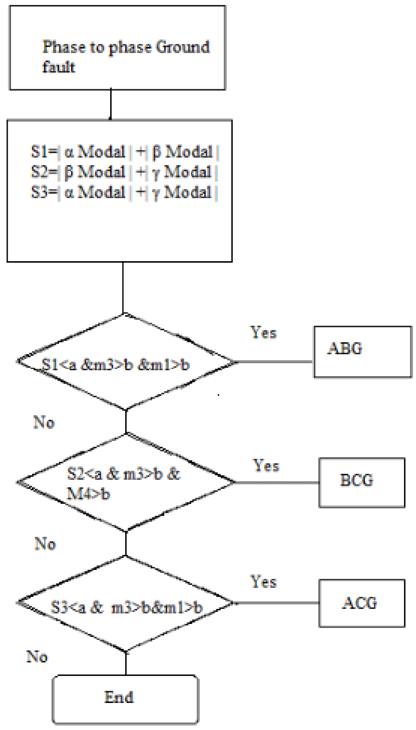

Figure7. Flowchart for phase selection in DLG fault

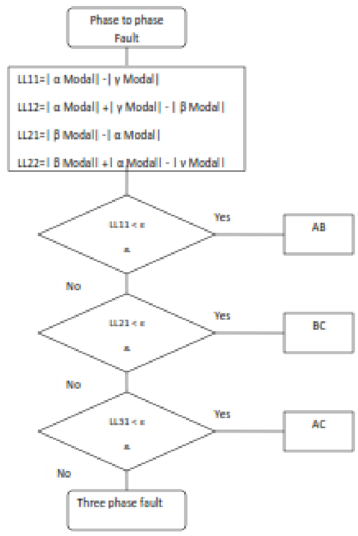

Figure 8. Flowchart for Phase selection in LL fault

The alphabets A,B,C and G represents phase A,phase B , phase C and ground.The value of ϕ , e, a and b are chosen according to the conditions of the system (The values are analysed by inserting all types of fault at different distances of transmission line).In this paper value of ϕ is chosen as 0.0001, e =0.001, a= 0.05 and b=0.02.

TABLE. 11.TEST RESULTS

Sl No	Fault Distance (Km)	∝	ß	Γ	0	Fault type
1	10	0.00065	0.0060	0.000420 2	0.007 0	AG
2.	50	0.0003201 6	0.0228	0.0159	0.015 9	CG
3.	100	0.0351	0.0176	0.0123	0	AB
4.	25	0.0343	0.0239	0.0479	0	AC
5.	189	0.0351	0.0234	0.0479	0	ABC
6.	170	0.0076	0.0243	0.000019	0.017 5	ABG
7.	70	0.00006	0.0023 6	0.0217	0.031 6	BCG

IV. CONCLUSION

A method for fault classification and faulted phase selection using wavelet transform technique is described in this paper. The current travelling waves which are decoupled using Karrenbeur transformation is used for fault classification. Since these travelling waves are of high frequency sampling rate of 400KHz is used and ar e analyzed using Daubechies 6 wavelet. The method is tested for all types of fault at different distance and different fault resistance. The method proves to be more accurate upto a fault resistance of 100Ω. Also the accuracy is effected in case of close in faults due to multiple reflection. In order to improve the accuracy at all conditions a methodology that combines Discrete Wavelet Transform and Artificial Neural Network is proposed.

REFERENCES

[1] DP Kothari and I J Nagrath, "*Modern Power system Analysis*," Tata Mcgraw Hill,New Delhi, 2009. pp.328-414

[2] Y.G Paithankar and S.R Bhide, "*Fundamentals of Power system Protection"*, PHI publications.

[3] A.T John and J.R Platts, "*Digital Protection of Power System"* , IEEE power series 15.

[4] Xinzhou Dong, *Senior Member, IEEE*, Wei Kong, and Tao Cui, " Fault classification and faulted phase selection based on initial current travelling wave", *IEEE Transactions on Power Delivery,* 24(2), 552 – 559, April 2009.

[5] D. Chanda, N.K Kishore, A.K Sinha, A wavelet multiresolution analysis for location of faults on transmission line‟ , *Science direct*, 29, 59-69, 2003.

[6] Yang Chun-wen1,2, DuanMu Yong-guang1, Ma Dong-juan1, Li Lingling, „The Method of precise timing of grounding fault in power system based on wavelet theory‟ , Science Direct,17, 1754- 1760, 2012.

[7] Jipin Lu, Jian Li, Wenyuan Li, Ying Li, Yi Xue, „A new approach of identifying faulty lines in distribution system based on travelling wave refraction and coupling‟ , 78, 353-360, 2008.

[8] X Z Dong , M A Redfern , Z Bo and F Jiang , "Application of wavelet transform of Travelling Wave phenomena for transient based protection", International conference on Power system transients, 2003.

[9] Zhengyou He, Ling Fu, Sheng Lin, and Zhiqian Bo, „Fault detection and classification in EHV transmission line based on wavelet singular entropy‟ ,IEEE transactions on Power Delivery,25(4),2156-2163, 2010.

[10] Mehrdad Mallakia,, Rahman Dashtib, " Fault locating in transmission networks using Transient voltage data", *science direct*, pp no: 173-180.

[11] Robi Polikar,*Wavelet Tutorial.*.