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Shunt Faults Detection on Transmission Line by Wavelet

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***Abstract*: Transmission line fault detection is a very important task because major portion of power system fault occurring in transmission system. This paper represents a fast and reliable method of transmission line shunt fault detection. MATLAB Simulink use for modeled an IEEE 9-bus test power system for case study of various faults. In proposed work Daubechies wavelet is applied for decomposition of fault transients. The application of wavelet analysis helps in accurate classification of the various fault patterns. Wavelet entropy measure based on wavelet analysis is able to observe the unsteady signals and complexity of the system at time-frequency plane. The result shows that the proposed method is capable to detect all the shunt faults.**

***Keywords:* Transmission line faults, MATLAB Simulink, Daubechies Wavelet.**

1. INTRODUCTION

Fault detection on transmission lines is very important to safeguard the power system. The most dangerous fault in power system is the short circuit or shunt fault, it results either in an excess current or in the reduction of the impedance between conductors or conductors and earth. In a transmitting system following types of fault possible: i) single line-to-ground (LG) fault which is occurring 85%, ii) line-to-line (L-L) fault which is occurring 8%, and iii) double line- to-ground (L-L-G) fault which is occurring 5%,and iv)triple line (L-L-L)fault having occurrence 2% of all shunt fault possible in transmission line. Faults on power transmission lines need to be detected and located rapidly, classified correctly and cleared as fast as possible for protection purpose which having these requirements : i) fault detection and ii) fault clearing, which involve detection of a fault including determination of the fault location and subsequently fault classification. When the type of fault is correctly identified, the possible remedial action can quickly be sorted out to solve the problem.[1] An ability to detect faults in transmission lines as fast as possible is crucial, since they may compromise the propagation of energy to customers and the functioning of the transmission network. Therefore, efficient fault detection approaches are focused primarily on the analysis of short time intervals, or transient signals. In this context, the use of wavelet transforms has emerged as a powerful tool for feature extraction, mainly due to its ability to focus on short time intervals for the analysis of high-frequency components. Wavelets transforms can use varying time windows in order to extract the coefficients of the mother wavelet. Short time windows are applied for high–frequency components, and long time windows for low-frequency components [8].

In this paper an approach to presented Fault detection with the help of discrete wavelet analysis (DWT) in transmission lines connecting a multi bus system. The use of the Wavelet Transform (WT) in power system analysis constitutes a

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powerful tool for the diagnosis of fault events. The main advantage is that, as opposed to Fourier analysis, the WT has good resolution in both time and frequency [4].

2. WAVELET TRANSFORM

A wavelet is a small wave, which deals with building a model for non-stationary signals, using a set of components. It has become a well-known useful tool since its introduction, especially in signal and image processing [9]. Wavelet analysis is a new development in the area of applied mathematics and was first introduced in seismology to provide a time dimension to seismic analysis which the Fourier analysis lacked. Fourier analysis is ideal for studying stationary data but not well suited for studying data with transient events which cannot be statistically predicted from past history of the data. Wavelets are ideally suited for analysis of such non-stationary data. Wavelet transformation can be broadly categorized as: (i) continuous wavelet transform and (ii) discrete wavelet transform. In the present study, discrete wavelet transform (DWT) has been used as an effective tool for post processing and extraction of valuable features from the fault patterns for discrimination and classification of various fault patterns [3],[6],[7]. Among the DWT family, the Daubechies wavelet is considered to be one of the most effective DWT tool, and this has been used to extract valuable features from the recorded waveforms. Daubechies wavelets are widely used in solving broad range of problems. The wavelets are generated from a single basic wavelet Ψ (t),, namely, mother wavelet, by scaling and translation:

$$\psi_{s,\tau(t)} = \frac{1}{\sqrt{s}}\psi\left(\frac{t-\tau}{s}\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots. \text{eq.}[1]$$

Where s is the scale factor, τ is the translation factor and the factor s-1/2 is the energy normalization across the different scales. To obtain the DWT the parameters s and τ need to discretized. Discretizing $s = 2^j$ and $\tau = 2^j k$ will yield orthogonal basis functions for certain choices of ψ:

$$\psi_{(j,k)}(t) = 2^{-j/2}\psi(2^{-j}t - k) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{eq.}[2]$$

C is a real coefficient, j and k are sets of integer indices and $\psi_{j.k}(t)$ are the wavelet expansion functions. Function $f(t)$can be expressed as a linear decomposition as follows:

$$f(t) = \sum_j \sum_k C_{j,k}\psi_{j,k}(t) = \sum_k A_{J0,k}\varphi_{J0,k} + \sum_{j=Jo}^{\infty}\sum_k D_{j,k}\psi_{j,k}(t) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. eq.[3]$$

Where *Jo* is an integer. Equation [3] is a linear combination of wavelet coefficients, ($A_{J0,k}$,*Dj,k*), a set of functions $\varphi_{J0,k}$called *scalling function* $\psi_{(j,k)}$ and Coefficients $A_{J0,k}$, and *Dj,k* are the *Discrete Wavelet Transform* (*DWT*) of $f(t)$ [12].

The signals can be accurately reproduced with the wavelet analysis using relatively small number of components. The analyzing wavelets are called the "mother wavelets" and it's dilated and translated versions are called the "daughter wavelets". It has a digitally implementable counterpart called the discrete Wavelet transform (DWT). The generated waveforms are analyzed with Wavelet multi resolution analysis (MRA) to extract sub-band information from the simulated transients [3]. Daubechies four (db-4) wavelet is used in this work for the analysis as it closely matches the signal to be processed which is of utmost importance in wavelet applications. Wavelet co-efficient of the signal are obtained by the decomposition of a discrete fault current and voltage signals using Mallat's algorithm [3], [11].

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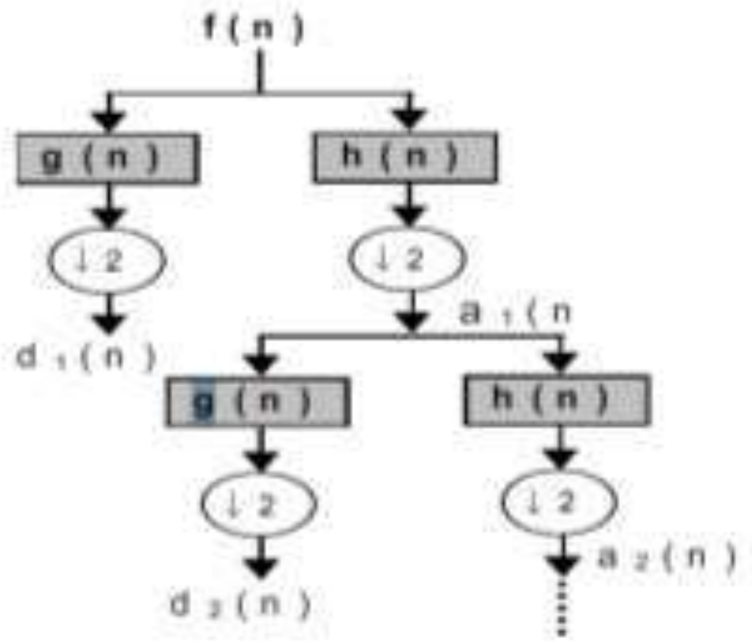

FIGURE 1-SIGNAL DECOMPOSITION BY WAVELET

The DWT acts as two filters defined by a low frequency filter h(n) and a high frequency filter g(n). Both filters have same cut frequency fN/2. The function f(n) is divided into two parts, d1 (the high frequency part) and it is called Detail component, and a1(the low frequency part), and is called Approximation. Decimation by 2 is done for removing redundant information.. The algorithm is iterated for *a1*, obtaining a second level detail component d2 and a second level Approximation a2, the process will be repeated. d1 have the frequency(fN – fN/2*)*, d2 have(fN/2 – fN/4), dk have(fN/2n – fN/2k+1) and an contains the frequencies lower than *fN/2k+1* [4], [5], [13], [16]. Wavelets are functions that satisfy the requirements of both time and frequency localization. The necessary and 16 sufficient condition for wavelets is that it must be oscillatory, must decay quickly to zero and must have an average value of zero. In addition, for the discrete DWT considered here, the Wavelets are orthogonal to each other [10].

3. WAVELET ENTROPY

To identify the transient signal, wavelet entropy measures is a feature, which have some unique capabilities[13]. The non normalized Shannon entropy is as follows .The wavelet energy spectrum at scale j and instant k is:

$$E_{JK} = \left|D_{JK}\right|^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots..eq.[4]$$

The nonnormalized Shannon entropy at scale j, in a moving data window goes through the detail coefficients shifting 128 samples at a time, is

$$\mathrm{E_j} = -\sum_{k=1}^{N_w} E_{jk}\, logE_{jk} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.eq.[5]$$

4. POWER SYSTEM MODEL

A nine bus power system [14] has been modeled in MATLAB Simulink. A schematic single line diagram of the nine bus system under study has been presented in figure 2. The modeled system comprises of three generator, three transformers and active and reactive loads connected to different buses. Detailed specification of the various components of the system are provided in Appendix-I.

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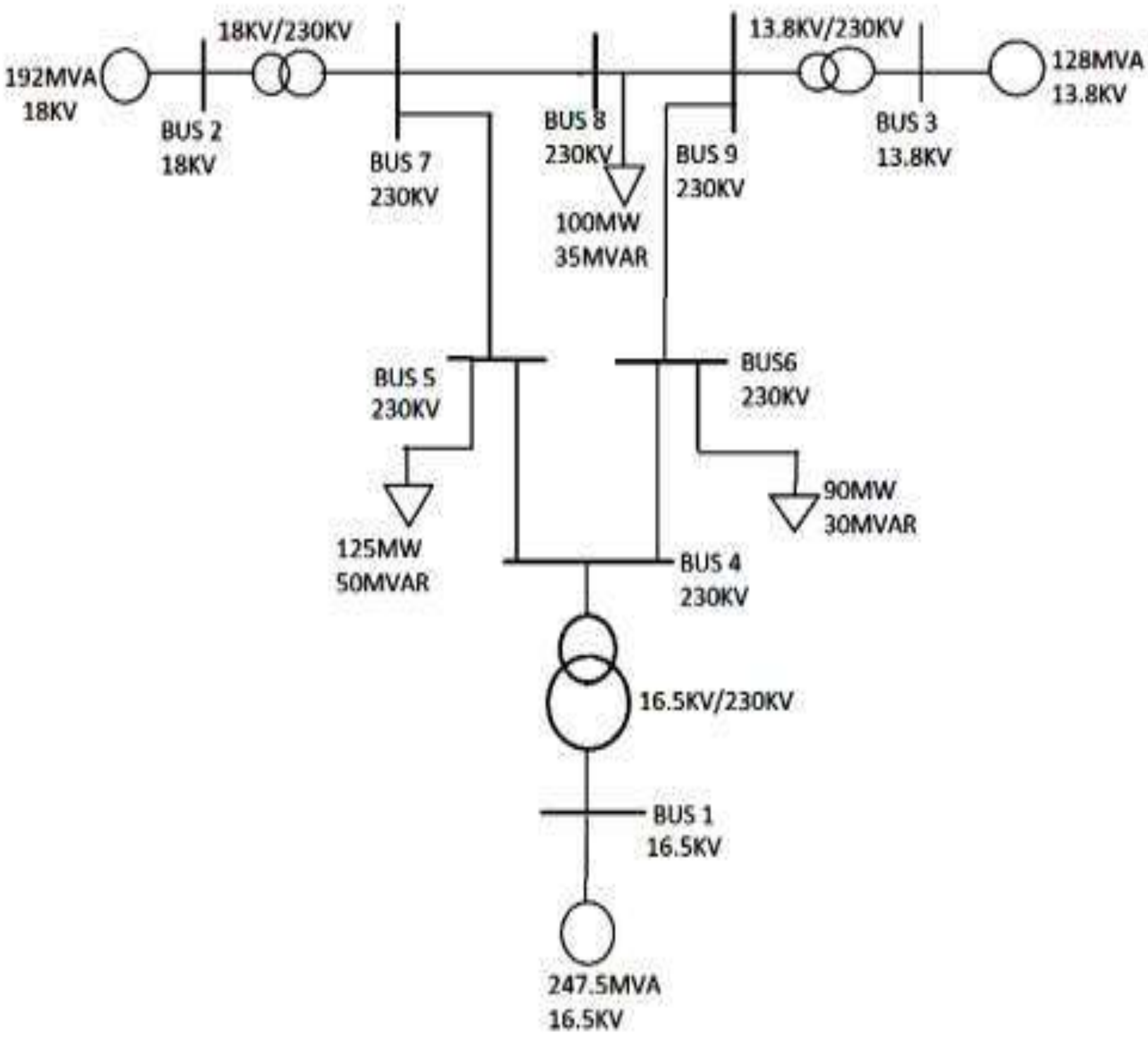

Figure-2 Nine bus power system model

5. SIMULATION OF SHUNT FAULTS

As mentioned earlier different types of faults were simulated using the fault breaker module in the MATLAB Simulink. In the present study, four different types of short-circuit faults were simulated, which include L-G fault, L-L fault, L-L-G fault and symmetrical three phase fault involving all the three phases of transmission lines (L-L-L). The letters A, B, C and G stands for. These faults were simulated at different buses of the system and continuous monitoring and recording of current is carried out at the Bus-6.Inspection and comparison of these results with the healthy waveforms reveals considerable difference between healthy and faulty waveforms. In Figure-3,5,7,9and 11 given the waveform of current and in Figure-4,6,8,10 and 12 given DWT and entropy at different conditions as healthy and different fault condition. Fault timing is taking T1= 0.2sec (in fault time) and T2= 0.3sec (fault out time). It is clear from the waveform at the healthy condition waveforms are regular in shape and DWT and WE shows zero value means no fault detection. Table-I shows statistical data of bus 6 at healthy and different fault conditions. From highlighted area it is clear which type of fault occurring. At healthy condition there is no fault detection shows by zero values. At fault condition only faulted phase gives the reading, no faulty phases gives zero. These differences are helpful in proper identification of the faults. Table-2 and 3 shows statistical data of bus5 and 8. Faulted phase data highlighted in the table.

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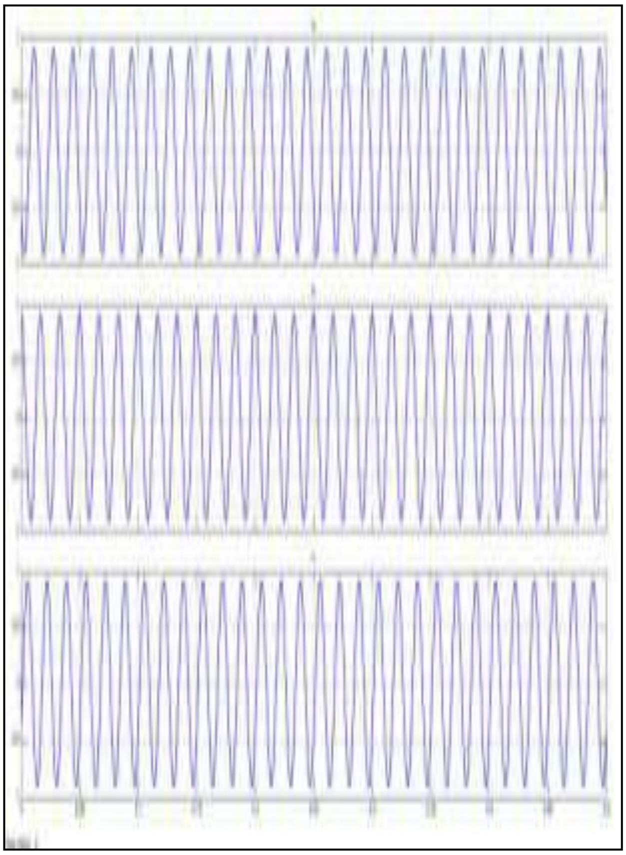

Figure-3 Waveform of current for phase A, B and C at healthy condition

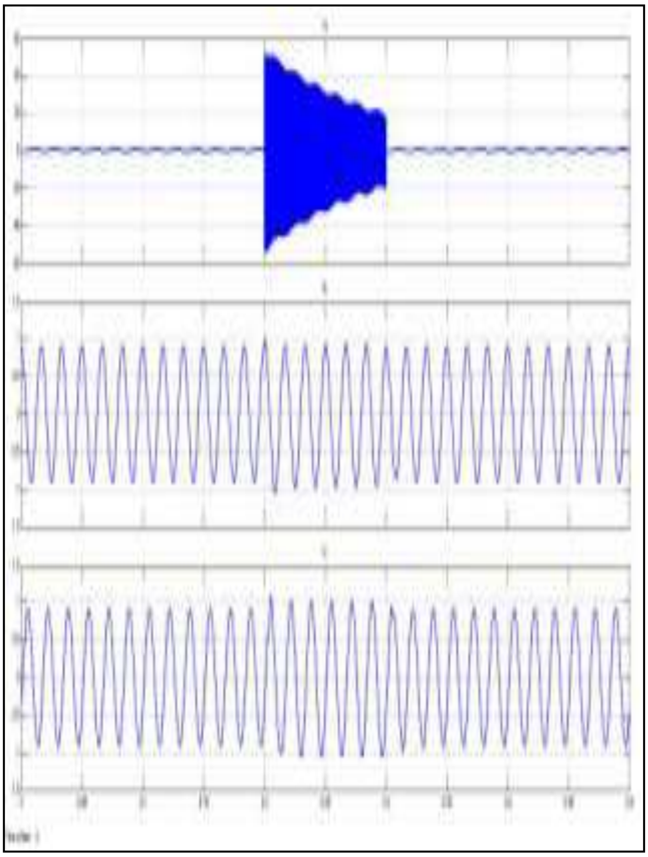

Figure-5 Waveform of current at L-G fault

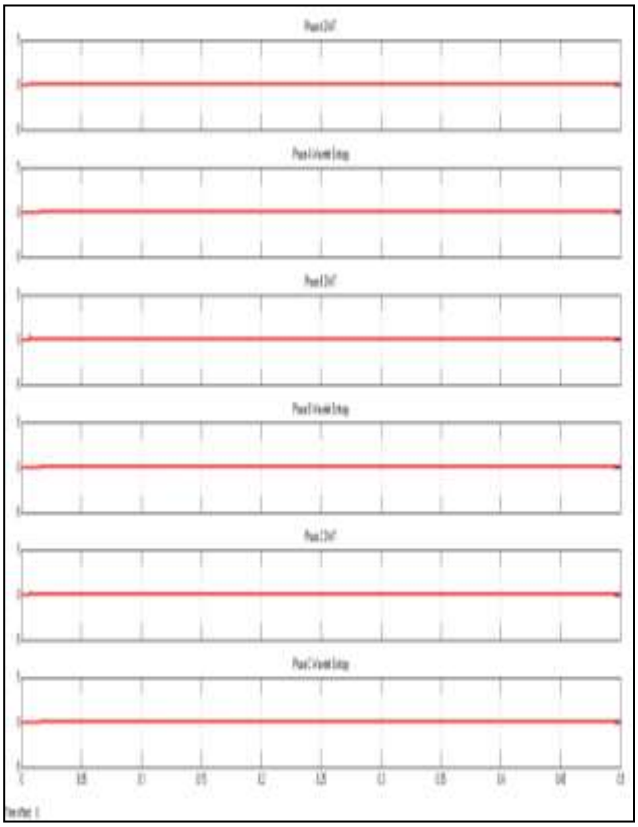

Figure-4 DWT and WE for phase A, B and C at healthy condition

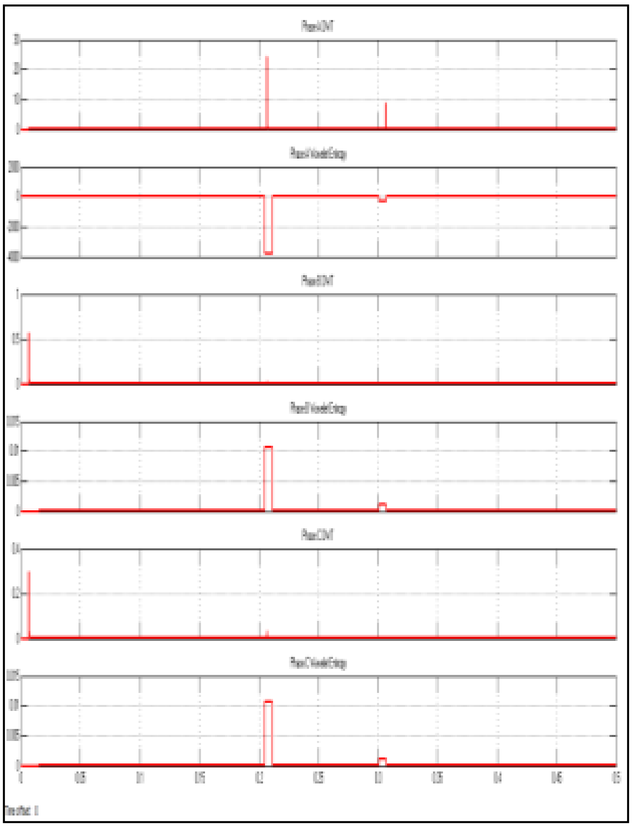

Figure-6 DWT and WE AT L-G fault

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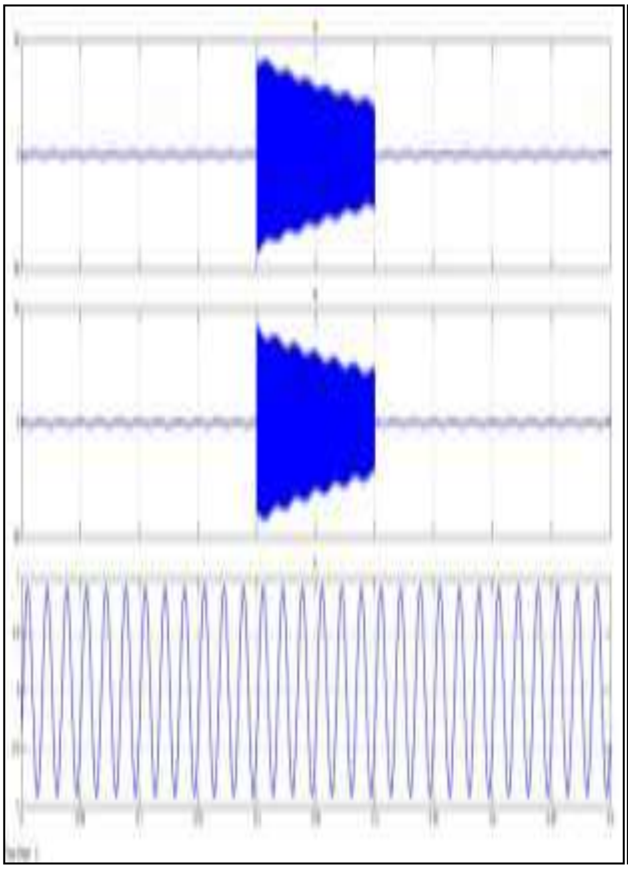

Figure-7 Waveform of current at L-L-G fault

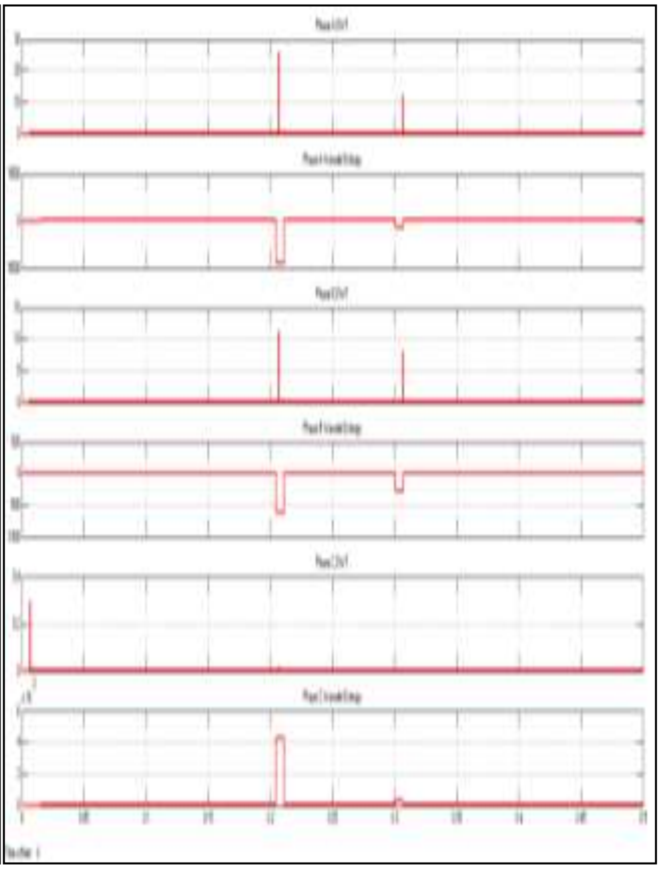

Figure-10 DWT and WE at L-L-G fault

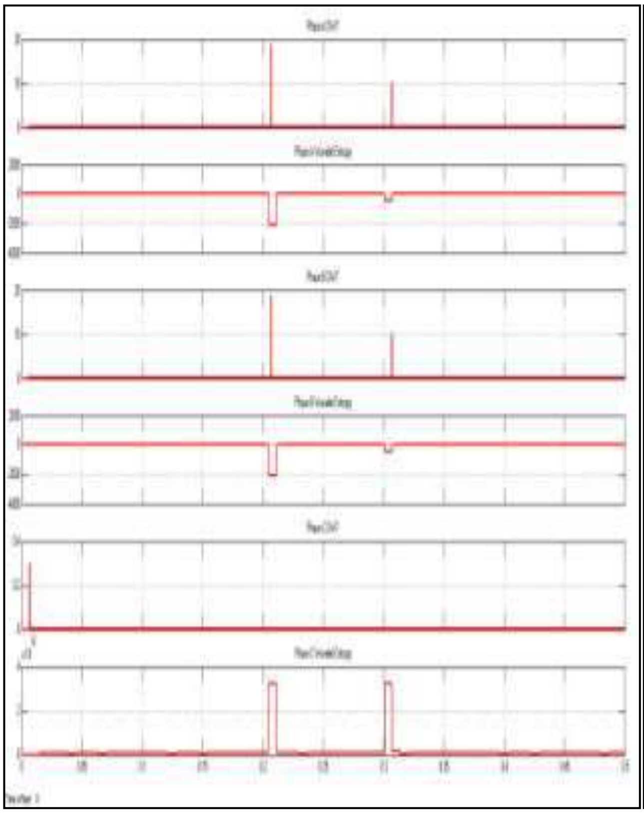

Figure-8 DWT and WE at L-L fault

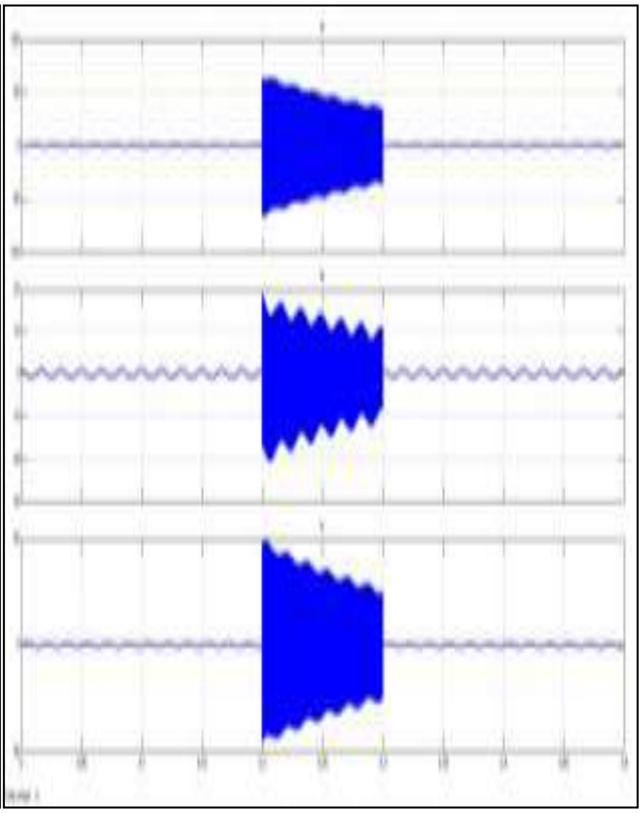

Figure-11 Waveform of current at L-L-L fault

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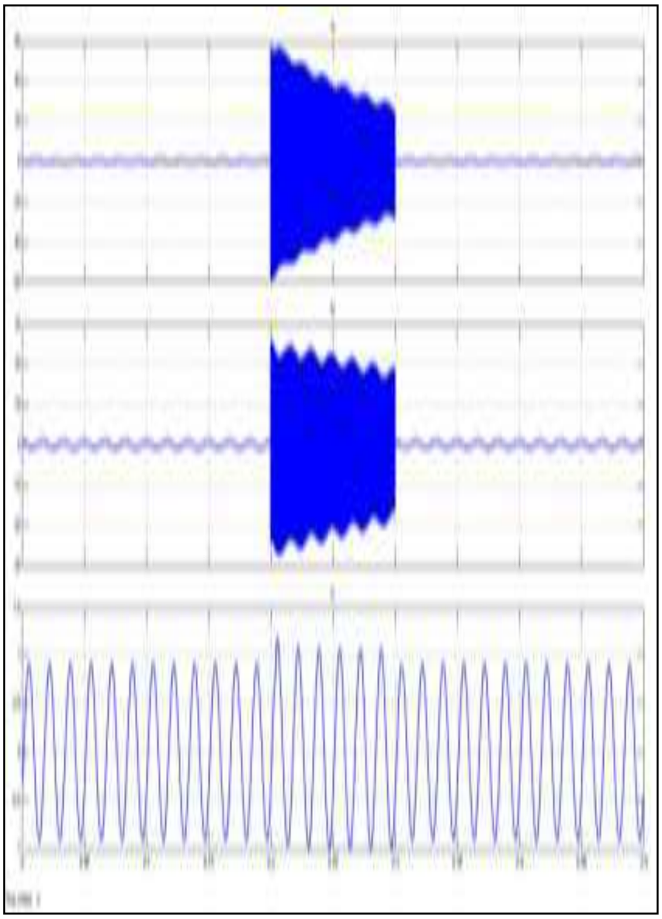

Figure-9 Waveform of current at L-L-G fault

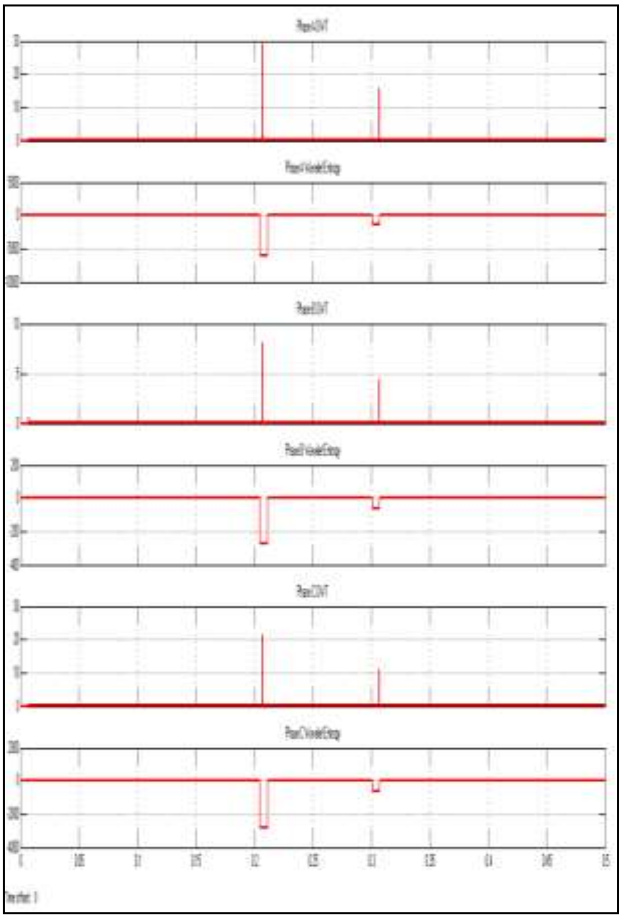

Figure-12 DWT and WE at L-L-L fault

TABLE-I STATISTICAL FAULT CURRENT ANALYSIS AT BUS 6

faults	Phase A				PhaseB				Phase C			
	T1		T2		T1		T2		T1		T2	
	DWT	WE	DWT	WE	DWT	WE	DWT	WE	DWT	WE	DWT	WE
No fault	0	0	0	0	0	0	0	0	0	0	0	0
LG	24	-3793	8.6	-340	0	0	0	0	0	0	0	0
LL	18.5	-2000	10	-500	18.5	-2000	10	-500	0	0	0	0
LLG	26	-4560	12	-800	11	-600	8	-287	0	0	0	0
LLL	29	-6000	15.7	-1400	7.5	-276	4.4	-60	21	-2850	11.2	-600

TABLE-II STATISTICAL FAULT CURRENT ANALYSIS AT BUS 5

faults	Phase A				Phase B				Phase C			
	T1		T2		T1		T2		T1		T2	
	DWT	WE	DWT	WE	DWT	WE	DWT	WE	DWT	WE	DWT	WE

No fault	0	0	0	0	0	0	0	0	0	0	0	0
LG	19	-2200	7.5	200	0	0	0	0	0	0	0	0
LL	15	-1280	8.4	-330	15	-1280	8.4	-330	0	0	0	0
LLG	20	-2750	10	-520	9.3	-400	6.8	-190	0	0	0	0
LLL	23.3	-3584	13.2	-940	6.7	-180	4	-45.6	16.6	-1600	9.2	-400

TABLE-III STATISTICAL FAULT CURRENT ANALYSIS AT BUS 8

Faults	Phase A				PhaseB				Phase C			
	T1		T2		T1		T2		T1		T2	
	DWT	WE	DWT	WE	DWT	WE	DWT	WE	DWT	WE	DWT	WE
No fault	0	0	0	0	0	0	0	0	0	0	0	0
LG	10	-500	5	90	0	0	0	0	0	0	0	0
LL	8	-294	5.4	-100	8	-294	5.4	-100	0	0	0	0
LLG	11	-600	6.5	-175	5.3	-100	4	-50	0	0	0	0
LLL	12.4	-800	8	-292	4	-45	2.7	-15	8.4	-314	5.4	-100

6. CONCLUSION

In this paper a wavelet analysis based approach has been proposed to detect and classify various types of faults in a multi bus power system. A case study has been conducted on IEEE 9-bus test system, where different types of faults LG, L-L, L-L-G and L-L-L fault were artificially simulated in different buses of the network. All these faults could be correctly detected and classified with the help of discrete wavelet analysis and entropy using Daubechie-4 up to level 2 decomposition. The case study the 9-bus system reveals that the proposed technique can yield 100% fault detection and classification accuracy.

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