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Current Signal Based Classification of Fault In Transmission Line Using DWT

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***Abstract*—The demand for electrical energy is rising continuously. The electrical network is expanding on a large scale to meet the increasing demand. Thus it increases the possibility of faults occurring on the transmission lines. To prevent severe damages caused by it and improve the reliability of the network, it becomes necessary to detect and isolate the faulted part of the system. This paper presents DWT (Discrete Wavelet Transform) method using signal analysis for detection of three phase faults. The analysis is carried out in MATLAB Simulink environment for unsymmetrical faults like Single Line to Ground (LG) fault, Double Line to Ground (LLG) fault, Line to Line (LL) fault and symmetrical three phase fault (LLL) and three phase to ground fault (LLLG). This method is based on determining the maximum value of coefficients of three phase currents using signal decomposition technique. Based on the maximum value of coefficients calculated for phase currents, the faults types are identified and distinguished from each other.**

***Keywords*— Faults, Wavelets, MATLAB/Simulink, Decomposition Coefficients**

I. Introduction

The occurrence of a fault in power system gives rise to transient and hence should be followed by quick detection of fault and disconnection of healthy circuit from the rest part of the system. Hence we have to look for efficient techniques to detect, classify and locate faults. There are various methods to detect and classify the line faults. The approaches include impedance based methods, travelling wave techniques and the methods using synchronized phasors [1]. Direction traveling wave is used for fault line section identification [2]. The travelling wave method needs higher cost compared to impedance based method [3]. The synchronized phasor measurements (SPM) using PMUs is found to be very effective in real-time monitoring at both ends of the transmission line with respect to wide area awareness [4].The other methods need the signal analysis. The occurrence of faults gives rise to the transient currents, which are characterized by the harmonics in them. The fault analysis is done according to the information extracted from these signals. The signal analysis include Fourier and wavelet analysis methods [5]. Figure 1 and 2 shows the signal conversion using Fourier transform and short time Fourier transform respectively.

Fig. 1. Fourier Analysis[5]

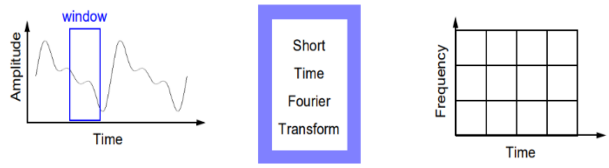

Fig. 2. Short Time Fourier analysis [5]

II. LITERATURE REVIEW

The discrete Fourier analysis has been used to detect and classify fault making use of voltage signal data from either end of line [6]. The wavelets are further classified into continuous wavelets and discrete wavelets. Fourier transform gives the information about various components of frequency that are there in the signal, but it will provide no information about time during which these signals existed. In contrast to FT, WT provides non-uniform frequency domain division, i.e., WT utilizes short windows at high frequencies and long windows at low frequencies. WT also examines the signal in frequency bands. This facilitates both frequency and time domain analyses of the signal. [7]. Figure 3 shows the signal conversion using wavelet transform.

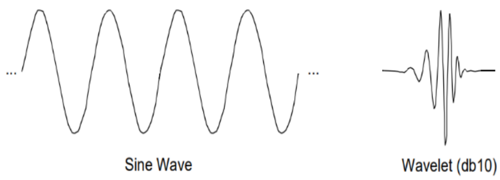

Fig. 3. Wavelet Analysis [5]

With a large reduction in calculation time, the discrete wavelet transform (DWT) offers enough data for the original signal's analysis and synthesis[8]. An effective instrument for signal coding is the DWT. It uses discrete samples of the signal to operate. Since it has been successfully utilized in a variety of domains, including image compression, biological signal identification, speech processing, acoustics, power systems, and power quality, the WT technique has established itself as a potent instrument for signal analysis[9][10]. One of the extra capabilities included with WT is called Multi Resolution Analysis (MRA), which analyzes signals at various frequencies and in various resolutions[11].

Using dilation equations, the scaling functions and wavelets are defined iteratively. A two-scale or dyadic difference equation makes up the fundamental equation for dilation. [12]

$$\phi(x)=\sqrt{2}\sum_{k=0}^{N-1}c_k\phi(2x-k) \qquad (1)$$

$\phi(x)$ denotes the scaling function also called as father wavelet.

Above equation determines $\phi(x)$ up to certain constant. The scaling function is normalized by:

$$\int\phi(x)d(x)=1 \qquad (2)$$

The relation between mother wavelet and scaling function is

$$\psi(x)=\sqrt{2}\sum_{k=0}^{N-1}c_{N-1-k}\phi(2x-k) \qquad (3)$$

III. METHOD

The three phase current signals are obtained from the Simulink model and measured at a particular distance from the sending terminal of transmission line. The Daubechies (db4) mother wavelet is used for extracting the features[13] since it has proven to be the most efficient among all other wavelets. The current signal *I(n)* is passed through high pass and low pass filter. The signal as a result is decomposed into two sets of coefficients i.e. approximation coefficient (A1) and detail coefficient (D1), that forms the output of the filter. These coefficients values are calculated for level 1. This technique is implemented for the current signals for no-fault and for different types of three phase faults, the faults occurring at 0.016 second and getting cleared at 0.083 second.

The coefficients of signal *I(n)* at different levels are calculated by following equations [14].

$$A(k)=\sum_n I(n).h(2k-n) \qquad (4)$$

$$D(k)=\sum_n I(n).g(2k-n) \qquad (5)$$

Under no-fault condition, the coefficients and their maximum value is determined. From these values a threshold value 'T' is selected. It's comparison is done with each of the maximum coefficient value of every phase current. If all values are below the value 'T', then it's a normal system otherwise the fault persists in the system. Depending on the maximum values of coefficients of respective phases the fault type is identified. Figure 4 shows the decomposition of signal using DWT.

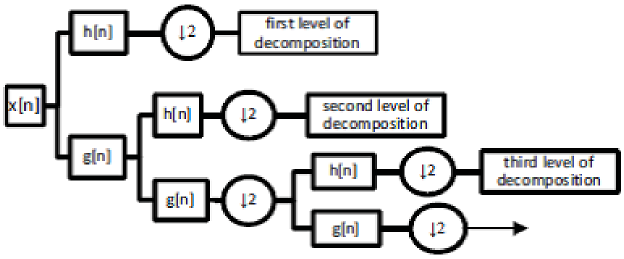

Fig. 4. Filter bank decomposition in discrete wavelet transform [15]

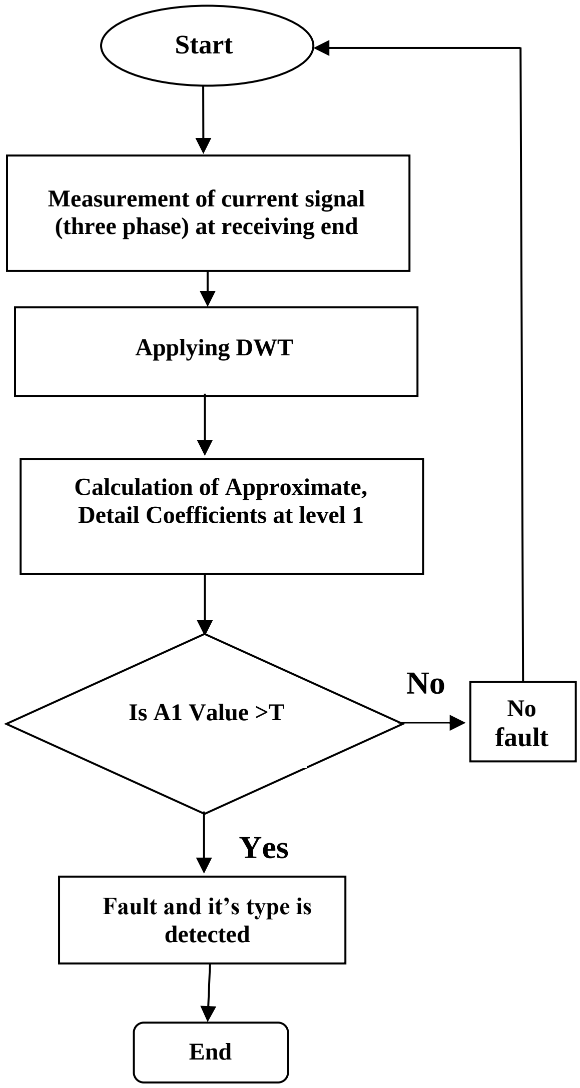

Fig. 5. Flowchart of the System

The proposed system consists of 132 kV and 100 km length line as shown in figure 6. [16]

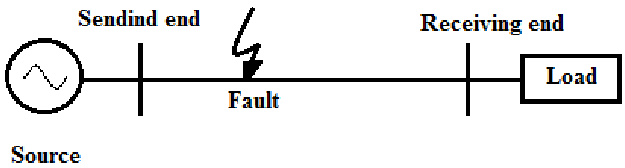

Fig. 6. A two-bus system

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The specifications of above system are mentioned in table I.

TABLE I. THE SPECIFICATIONS OF TRANSMISSION LINE

Variable	Value
Positive sequence resistance	100.045 Ohms/km
Zero sequence resistance	0.1124 Ohms/km
Positive sequence inductance	1.009e-3H/km
Zero sequence inductance	2.019e-3H/km
Positive sequence capacitance	7.469e-9F/km
Zero sequence capacitance	4.395e-9F/km

IV. RESULTS AND DISCUSSION

A. *No-Fault Condition*

The three phase current waveforms are obtained for the given power system network under normal condition as shown in figure 7. They all have equal amplitudes.

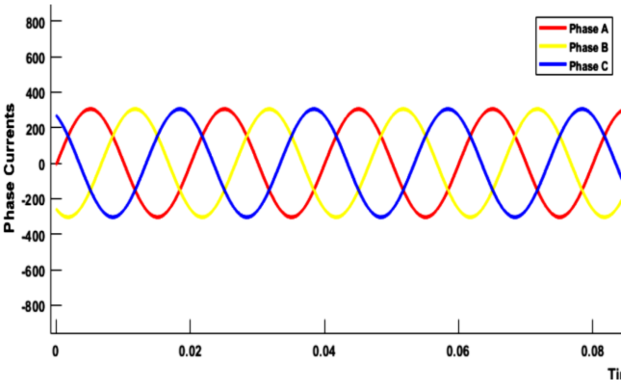

Fig. 7. No-fault current waveform

The approximation as well as detail coefficients are obtained for all the three phases under normal condition as given in table II. Under this condition they have the minimum values.

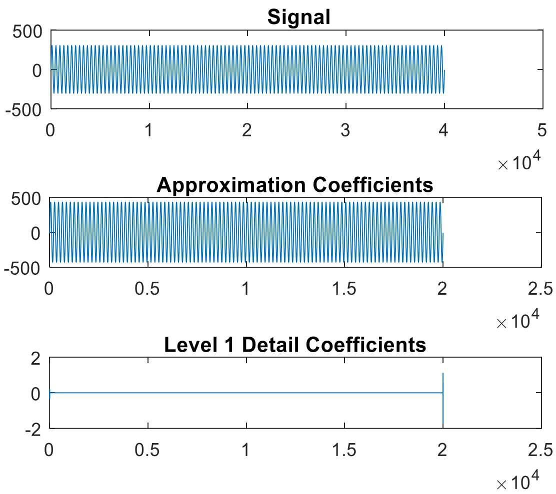

Fig. 8. Phase-A approximation, detail coefficients

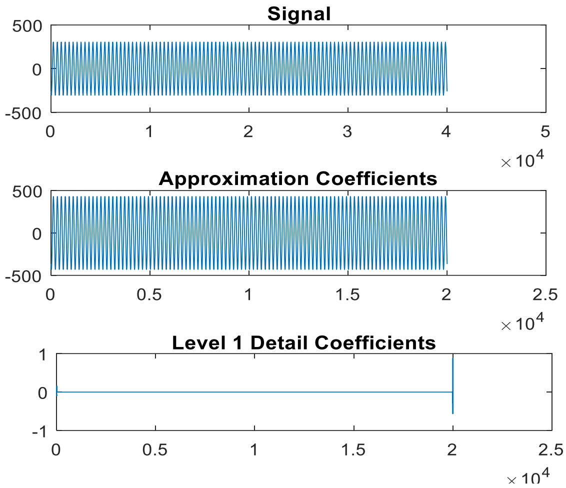

Fig. 9. Phase-B approximation, detail coefficients

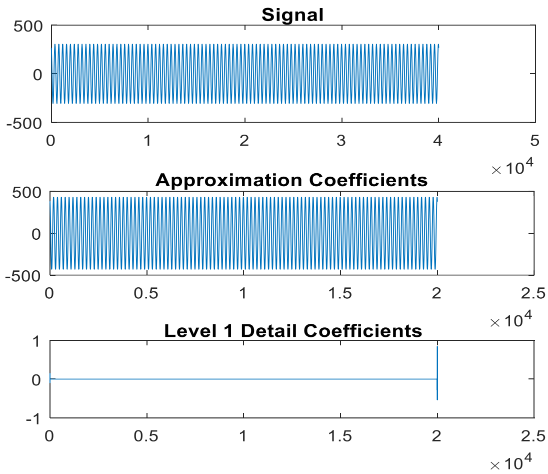

Fig. 10. Phase-C approximation, detail coefficients

TABLE II. THE APPROXIMATION AND DETAIL COEFFICIENTS UNDER NO-FAULT CONDITION

Phase	A1	D1
A	430.4528	1.1014
B	430.4607	0.8874
C	430.4213	0.8426
G	1.0302e-11	1.9637e-12

The approximation coefficient for all healthy phases is 430, which is the minimum value. But to avoid treating the healthy system as faulted system [14], the threshold value ‘T’ is selected as,

$$T = 1.5*430 \approx 645$$

B. *Single Line to Ground Fault*

The fault is made to occur on phase A. The simulation is carried out in MATLAB. Figure 11 shows the current waveforms of all the three phases during this fault. It is seen that the fault current on phase-A increases while it is normal for the other phases.

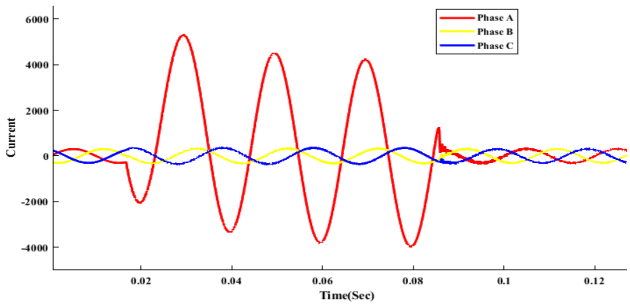

Fig. 11. SLG fault current waveform

All the phase currents are decomposed to obtain approximation as well as detail coefficients with the help of DWT using db4 wavelet up to level 1. Table III gives the maximum values of all the coefficients obtained at respective phases. The value of approximation coefficients for phase A and ground are greater than the threshold value. This indicates the fault occurrence on phase A involving ground, which is single line to ground (SLG) fault and also indicates the faulted phase.

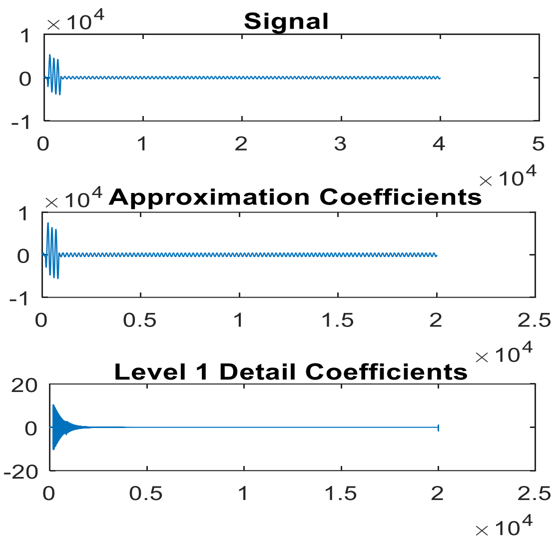

Fig. 12. Phase-A approximation, detail coefficients

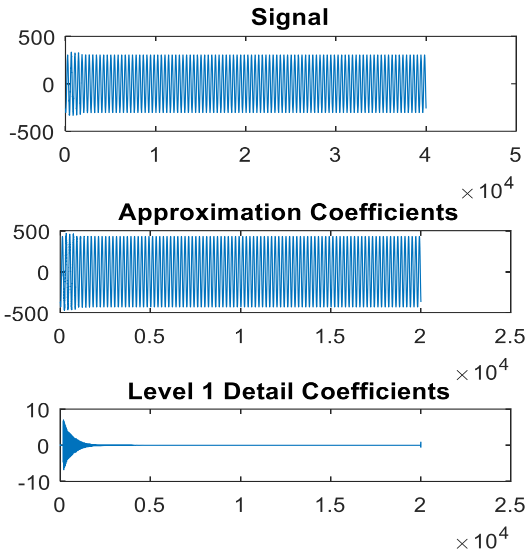

Fig. 13. Phase-B approximation, detail coefficients

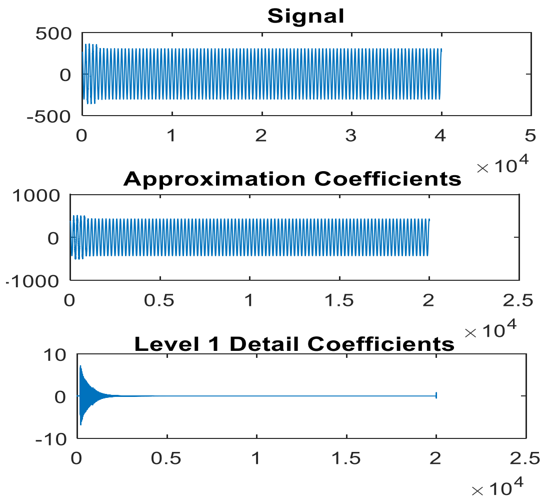

Fig. 14. Phase-C approximation, detail coefficients

TABLE III. THE APPROXIMATION AND DETAIL COEFFICIENTS FOR A-G FAULT

Phase	A1	D1
A	7.5046e+03	10.4191
B	469.9375	7.0151
C	511.457	7.2011
G	5.4705e+03	11.761

C. *Double Line to Ground Fault*

The fault is made to occur on phase-A and B through ground. Figure 15 shows the current waveforms of all the three phases during this fault. It is seen that the fault current on phase A, phase B increases whereas phase C has a normal value.

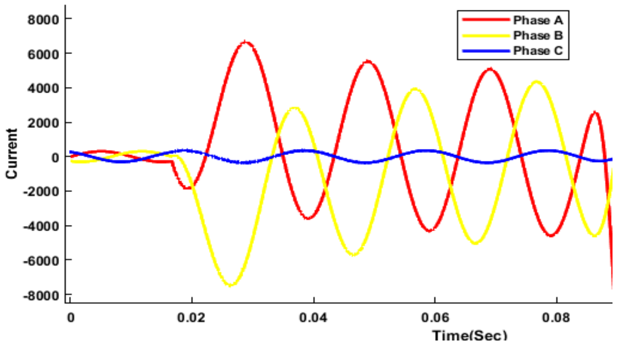

Fig. 15. DLG fault current waveform

The value of approximation coefficients for phases A and B including the ground are greater than threshold value as shown in table IV. This indicates that the fault occurred on phases A and B including ground, which is double line to ground (DLG) fault and also indicates the faulted phases.

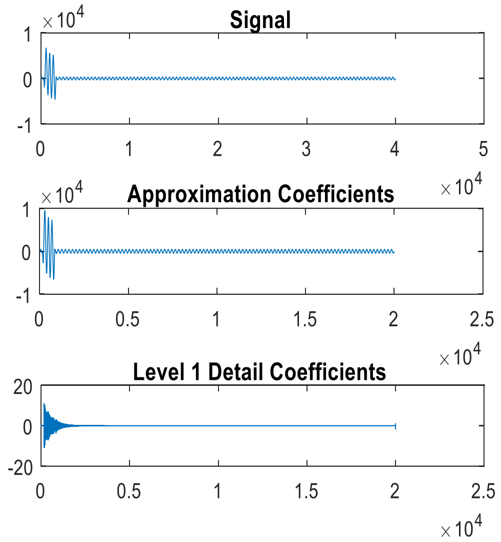

Fig. 16. Phase-A approximation and detail coefficients

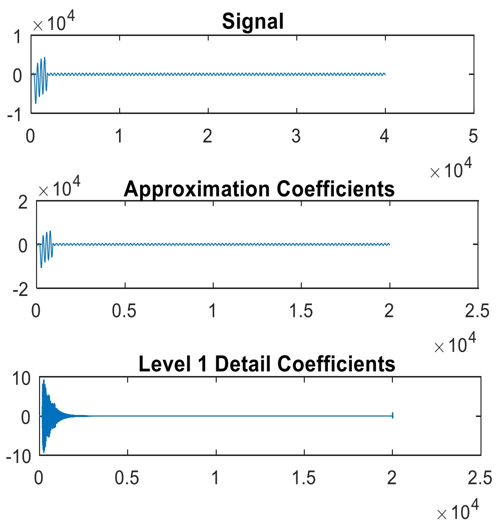

Fig. 17. Phase-B approximation and detail coefficients

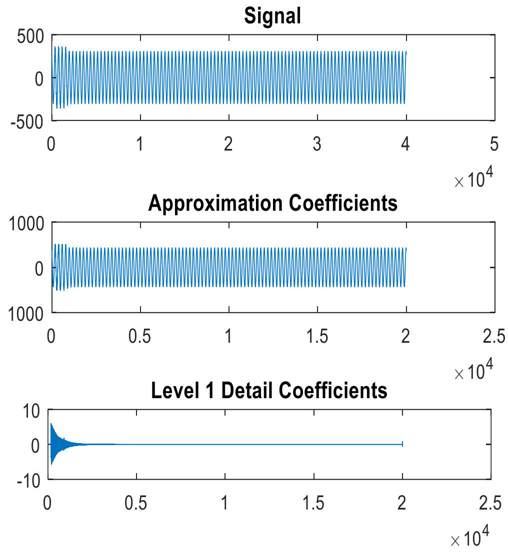

Fig. 18. Phase-C approximation, detail coefficients

TABLE IV. THE APPROXIMATION AND DETAIL COEFFICIENTS FOR A-B-G FAULT

Phase	A1	D1
A	9.4313e+03	11.0543
B	6.1502+03	9.2332
C	507.8853	6.0177
G	6.0468e+03	9.3634

D. Line to Line Fault

The fault is made to occur on phases A and B. Figure 19 indicates the current waveforms of all the three phases at the time of this fault. It is seen that the fault current on phases A and B increases while for phase-C it has a normal value.

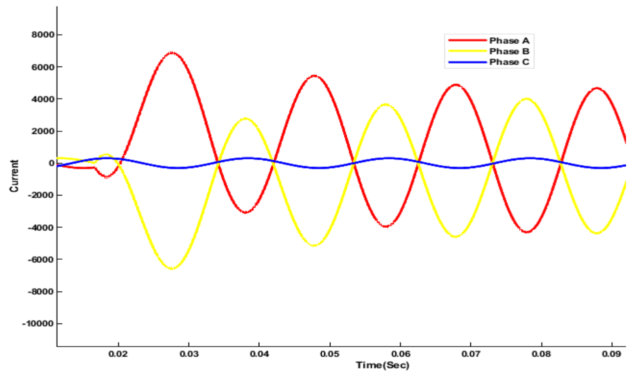

Fig. 19. LL fault current waveform

The value of approximation coefficients for phase-A, phase-B are greater than threshold value given in table V. This indicates that the fault has occurred on phases A, B including ground, which is double line to ground (DLG) fault and also indicates the faulted phases

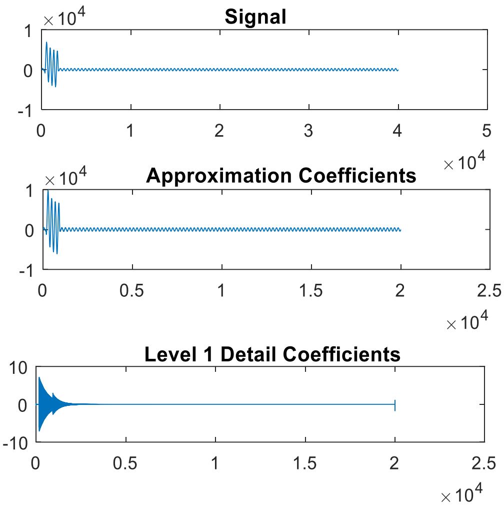

Fig. 20. Phase-A approximatio, detail coefficients

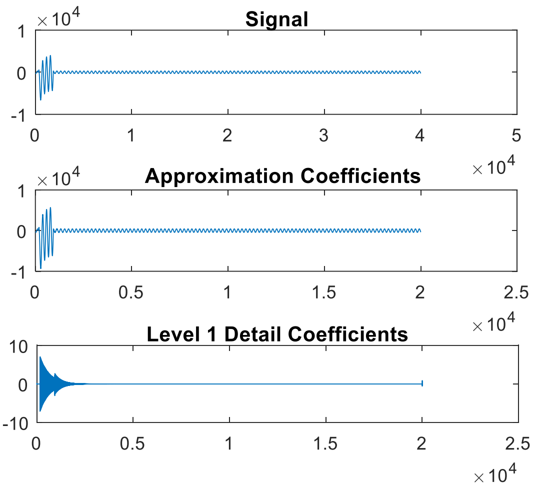

Fig. 21. Phase-B approximation, detail coefficients

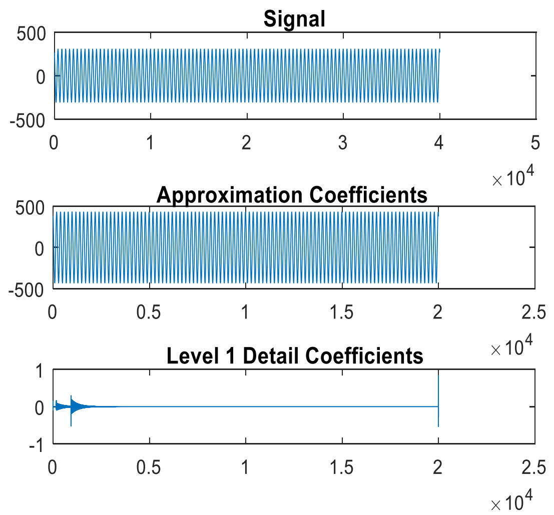

Fig. 22. Phase-C approximation,detail coefficients

TABLE V. THE APPROXIMATION AND DETAIL COEFFICIENTS FOR A-B FAULT

Phase	A1	D1
A	9.737e+03	7.151
B	5.6685e+03	7.0678
C	430.9033	0.8426
G	0.0783	0.0010

E. *Three Phase Fault*

The fault is made to occur on all the phases. Figure 23 shows the current waveforms of all the three phases. It is seen that the fault current on all phases increases while for the ground it has minimum value.

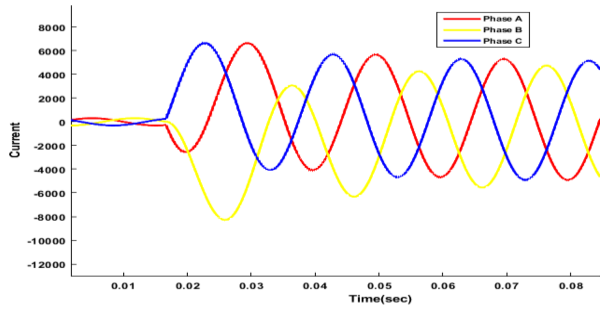

Fig. 23. LLL fault current waveform

Wavelet decomposition is done for all the phases including ground. Table VI shows the maximum values of all the coefficients obtained for respective phases. The value of approximation coefficients is highest for phases A, B and C. This indicates that fault occurred on all the three phases which is the three phase (LLL) fault and also indicates the faulted phases.

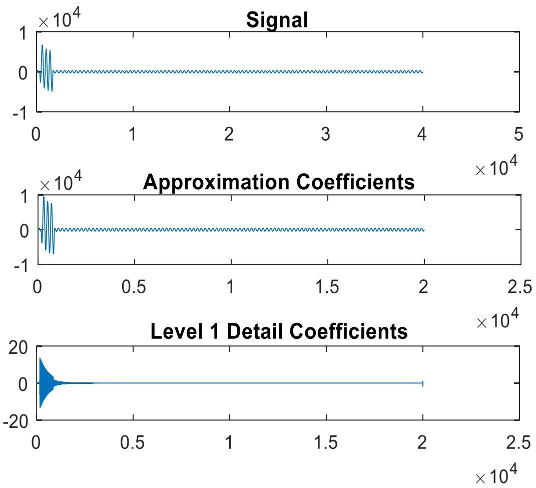

Fig. 24. Phase-A approximation, detail coefficients

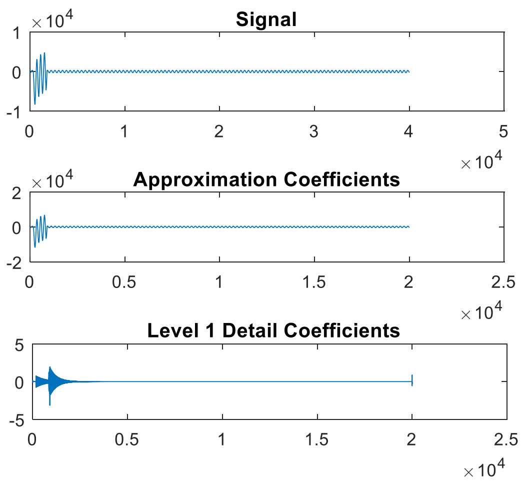

Fig. 25. Phase-B approximation, detail coefficients

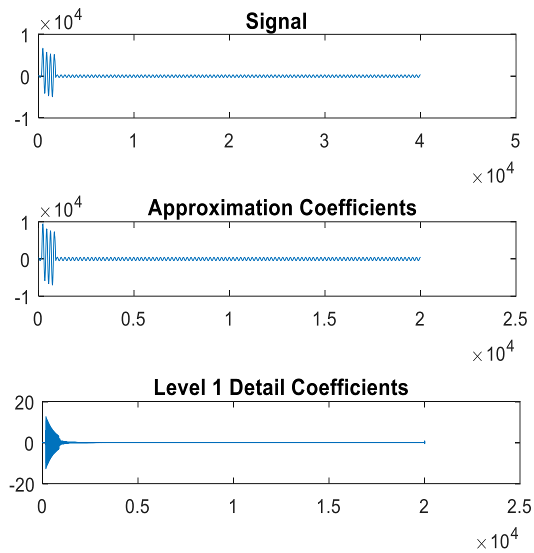

Fig. 26. Phase-C approximation, detail coefficients

TABLE VI. THE APPROXIMATION AND DETAIL COEFFICIENTS FOR A-B-C FAULT

Phase	A1	D1
A	9.4415e+03	13.4846
B	6.7144e+03	1.9753
C	9.4281e+03	12.6332
G	0.0824	3.9321e-04

F. Three Phase to Ground Fault

The fault is made to occur on all the phases including ground. Figure 27 shows the current waveforms of all the three phases during this fault. The fault current on all phases including ground it has greater value than the threshold.

Fig. 27. LLLG fault current waveform

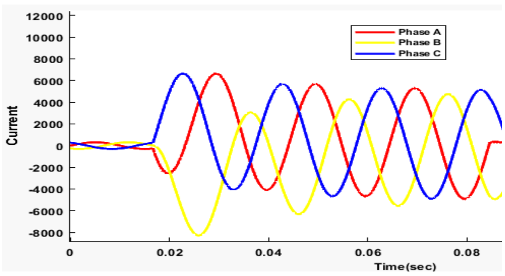

Table 7 shows the maximum values of all the coefficients for respective phases. The value of approximation coefficients is highest for all the phases including ground. This indicates that the fault is three phase to ground fault (LLLG).

TABLE VII. THE APPROXIMATION AND DETAIL COEFFICIENTS FOR A-B- C-G FAULT

Phase	A1	D1
A	9.4415e+03	13.4846
B	6.7144e+03	1.4239
C	9.4281e+03	12.6332
G	4.3809e+03	1.5058

V. CONCLUSION

The fault identification technique using discrete wavelet transformation technique of signal analysis has been implemented. The current waveforms are obtained using MATLAB/Simulink. The detail along with approximation coefficients for different faulted phases at level 1 have been obtained using Daubechies (db4) wavelet. With respect to different fault types, the comparison of maximum values of approximation coefficient for phase currents is done with the threshold value. The comparison is used to differentiate between faulted and healthy phases. There by the fault classification is done effectively. The method is tested for unsymmetrical and three phase symmetrical faults for a two bus 100 km, 300 kV transmission line. The results obtained are highly satisfactory and thus we can effectively use this method for fault identification and designing a relaying system for the protection.

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