# WAVELET TRANSFORM APPLICATION TO FAULT CLASSIFICATION ON TRANSMISSION LINE

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***Abstract*—This paper presents the development of an algorithm for classifying the power system faults. The algorithm devised is based on Discrete Wavelet Transform (DWT) analysis of transient current signals recorded in the event of a short circuit on a transmission line. The DWT analysis of line currents are carried out for normal and various fault condition. Few parameters are defined using detailed coefficients of DWT analysis. Fault identification is done by comparing values of these parameters during fault with those in normal condition.**

***Index Terms*—Transmission line faults, Wavelet Transform, Discrete Wavelet Transform**

## I. INTRODUCTION

Electromagnetic transients in power systems result from a variety of disturbances on transmission lines, such as faults, are extremely important [1] .A fault occurs when two or more conductors come in contact with each other or ground in three Phase systems, faults are classified as Single line-to-ground faults, Line-to-line faults, Double line-to-ground faults, and Three phase faults. For it is at such times that the power system components are subjected to the greatest stresses from excessive currents

These faults give rise to serious damage on power system equipment. Fault which occurs on transmission lines not only effects the equipment but also the power quality. So, it is necessary to determine the fault type and location on the line and clear the fault as soon as possible in order not to cause such damages. Flashover, lightning strikes, birds, wind, snow and ice-load lead to short circuits. Deformation of insulator materials also leads to short circuit faults. It is essential to detect the fault quickly and separate the faulty section of the transmission line.

Locating ground faults quickly is very important for safety, economy and power quality. Wavelet theory is the mathematics, which deals with building a model for non-stationary signals, using a set of components that look like small waves, called wavelets. It has become a well-known useful tool since its introduction, especially in signal and image processing [2].

## II. DISCRETE WAVELET TRANSFORM

The DWT is easier to implement than Continuous Wavelet Transform CWT because CWT is computed by changing the scale of the analysis window, shifting the window in time, multiplying the signal and the information of interest is often a combination of features that are well localized temporally or spatially This requires the use of analysis method sufficiently, which are versatile to handle signals in terms of their time-frequency localization. Frequency based analysis has been common since Fourier's time; however frequency analysis is not ideally suited for transient analysis, because Fourier based analysis is based on the sine and cosine functions, which are not transients. These results in a very wide frequency spectrum in the analysis of transients Fourier techniques cannot simultaneously achieve good localization in both time and frequency for a transient signal. [3].The main advantage of WT over Fourier Transform is that the size of analysis window varies in proportion to the frequency analysis. WT can hence offer a better compromise in terms of localization

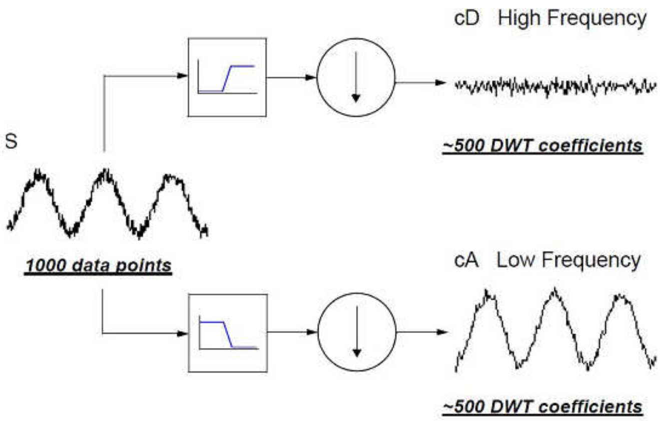



Fig. 1. Analyses of signal using wavelet transform

The wavelet transform decomposes transients into a series of wavelet components, each of which corresponds to a time domain signal that covers a specific octave frequency band containing more detailed information. Such wavelet components appear to be useful for detecting, localizing, and classifying the sources of transients. Hence, the wavelet transform is feasible and practical for analyzing power system transients [1-5].

The discrete wavelet transform (DWT) is normally implemented by Mallat's algorithm its formulation is related to filter bank theory.
Wavelet transform is largely due to this technique, which can be efficiently implemented by using only two filters, one high pass (HP) and one low pass (LP) at level (k). The results are down-sampled by a factor two and the same two filters are applied to the output of the low pass filter from the previous

stage. The high pass filter is derived from the wavelet function (mother wavelet) and measures the details in a certain input. The low pass filter on the other hand delivers a smoothed version of the input signal and is derived from a scaling function, associated to the mother wavelet. The idea is illustrated in Figure 2 which mathematically is expressed as

$$y_{high}[k] = \sum_n x[n].H[2k-n]$$

$$y_{low}[k] = \sum_n x[n].L[2k-n]$$

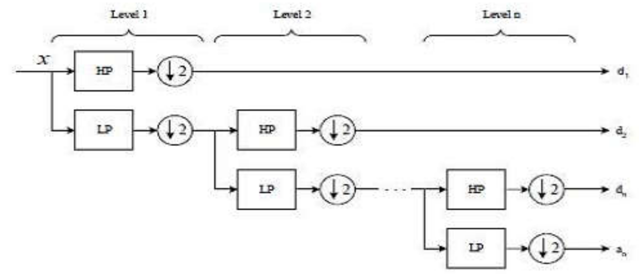



**Fig.2.** DWT multi filter bank framework.

## III. POWER SYSTEM MODEL AND DETAILS

A simple 3-phase power system network as shown in Fig. 2 was simulated to test the performance of proposed scheme. The prototype system consists of a 3-phase power supply, a transmission line represented by lumped parameters connecting a load. Faults were created at different places on the transmission line.

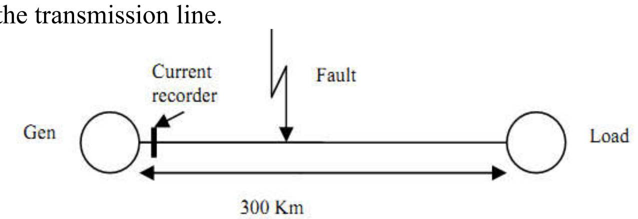



Fig. 3. Sample power system network

*Generator*

500 MVA, 13.8 KV, 60 Hz. Rpu: 0.22/15, Xpu: 0.22.

*Transformer*

500 MVA, 60 Hz, 13.8KV/735KV, R1pu=0.002, X1pu=0.08 R2pu=0.002, X2pu=0.08

*Transmission Line*

Positive and negative sequence resistance / unit length = 0.01273 Ω /km.

Zero sequence resistance/unit length = 0.3864 Ω /km.

Positive and negative sequence inductance / length = 0.9337 mH /km.

Zero sequence inductance per unit length =4.1264 mH / Km.

Positive and negative sequence capacitance / unit length = 12.74 nF /km.

Zero sequence capacitance / unit length =7.751 nF /km. *Load* 330 MVA

## IV. IMPLEMENTATION OF PROPOSED FAULT CLASSIFICATION METHOD

Line currents Ia, Ib, Ic at a frequency of 60 Hz are measured at the sending end of the line to classify the types of the fault among LG, LL, LLG, LLL and healthy (normal) conditions. For N-level decomposition, 2N samples are required. These current signals are being decomposed in 9–levels using MRA algorithm. So in this work, the current signals with 512 samples at a sampling period of Ts = 5 ×10-5 sec are used. The input contains 512 (12.77 kHz) samples which are passed through HPF and LPF, and corresponding approximate and detailed coefficients are recorded. The high frequency noise signals are filtered and corresponding $7^{th}$ level detailed wavelet coefficients are calculated to know the $2^{nd}$ and $3^{rd}$ order harmonic components in the faulted current signals. During fault condition, the detailed (HPF) coefficients of $7^{th}$ level with the frequency band of (99-199 Hz) have higher magnitudes due to presence of $2^{nd}$ and $3^{rd}$ order harmonic content in the line currents. From the previous studies, it is found that, daubechies mother wavelet is having good capability to capture the time of transient occurrence and extraction of frequency features during power system faults and disturbance. In the proposed algorithm, “Db3” mother wavelet is used to get the DWT coefficients for classification of different type of faults.

With the use of these detailed coefficients, various parameters i.e. Sa, Sb, Sc, Sr, Qa, Qb, Qc and Qr are calculated,

Where

Sa = Sum of $7^{th}$ level detailed coefficients of line current Ia.

Sb = Sum of $7^{th}$ level detailed coefficients of line current Ib.

Sc = Sum of $7^{th}$ level detailed coefficients of line current Ic.

Sr = Sum of Sa, Sb, Sc.

Qa = Sum of absolute values of $7^{th}$ level detailed coefficients of line current Ia.

Qb = Sum of absolute values of $7^{th}$ level detailed coefficients of line current Ib.

Qc = Sum of absolute values of $7^{th}$ level detailed coefficients of line current Ic  Qr = Sum of Qa, Qb, Qc.

After calculating above parameters, following steps are performed to classify various types of faulty as well as normal operating conditions.

*Step 1) Detection of faulty and healthy conditions*

Check the ratio (Qa/2Qna), (Qb/2Qnb), (Qc/2Qnc).

If any of these ratio is grater then 2 then there is fault otherwise there is no fault.

Where Qna, Qnb, Qnc are for normal condition and Qa, Qb, Qc are for present condition.

*Step 2) Detection of LG fault*

If only one from ratio (Qa/2Qna), (Qb/2Qnb), (Qc/2Qnc) is grater then 2 then there is LG fault

*Step 3) Detection of LLG and LL fault*

If only two from ratio (Qa/2Qna), (Qb/2Qnb), (Qc/2Qnc) are grater then 2 then there is double line fault.
If (0<Qr<2) then it is LL fault Otherwise LLG fault.

*Step 4) Detection of LLL fault*

If all ratio (Qa/2Qna), (Qb/2Qnb), (Qc/2Qnc) are grater then 2 then there is LLL fault.
Flow chart for fault classification algorithm is shown in Fig 4.
Value of Sa, Sb, Sc Sr, Qa, Qb, Qc, and Qr for healthy condition and for various faults are shown in TABLE 1
Figure 5 to Figure 8 shows Line current signals and its DWT decomposition for phase a, b and c for normal operating condition and for various types of faults

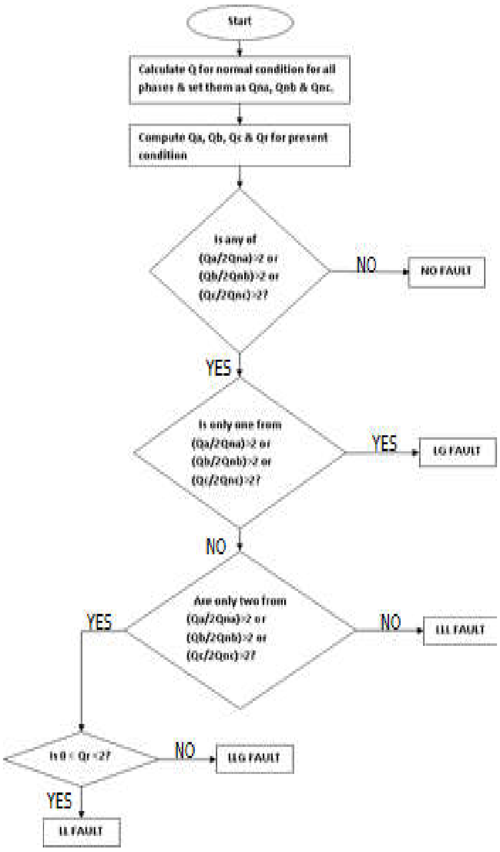



Fig. 4 Flow chart for fault classification algorithm

**LG FAULT**

| | healthy | AG | BG | CG |
|---|---|---|---|---|
| Sa | -888.837 | 10541.26 | -384.317 | 749.7151 |
| Sb | -328.583 | -2471.66 | 13394.5 | 1309.969 |
| Sc | 1217.42 | -925.652 | 1721.94 | -23935.8 |
| Sr | -4.97E-10 | 7143.955 | 14732.12 | -21876.1 |
| Qr | 4.97E-10 | 7143.955 | 14732.12 | 21876.08 |
| Qa | 8724.393 | 41822.43 | 10402.01 | 9804.199 |
| Qb | 8747.419 | 11914.12 | 90803.89 | 8226.53 |
| Qc | 9172.678 | *8439.799* | 12114.88 | 58379.38 |

**LL FAULT**

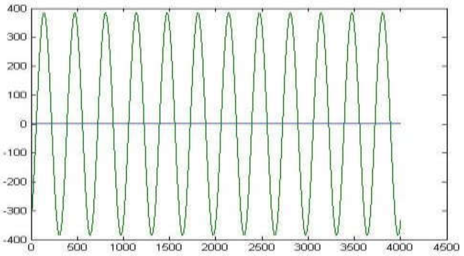
| | healthy | AB | BC | CA |
|---|---|---|---|---|
| Sa | -888.837 | -1132.1 | -888.774 | 14803.61 |
| Sb | -328.583 | -84.5937 | 15609.07 | -328.466 |
| Sc | 1217.42 | 1217.24 | -14719 | -14477 |
| Sr | -4.97E-10 | 0.547243 | 1.274055 | -1.8213 |
| Qr | 4.97E-10 | 0.547243 | 1.274055 | 1.821298 |
| Qa | 8724.393 | 53630.53 | 8724.37 | 24172.33 |
| Qb | 8747.419 | 47195.17 | 56080.16 | 8746.91 |
| Qc | 9172.678 | 9173.03 | 63049.95 | 27576.39 |

**LLG FAULT**

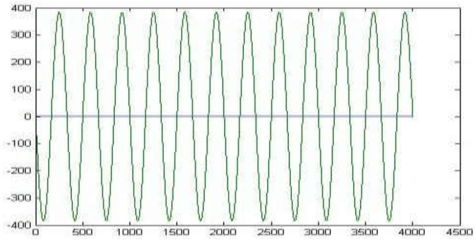
| | healthy | ABG | BCG | CAG |
|---|---|---|---|---|
| Sa | -888.837 | 15354.44 | 2953.958 | 4942.991 |
| Sb | -328.583 | 16401.95 | 8983.146 | -3007.67 |
| Sc | 1217.42 | 53.71438 | -21344.9 | -24337.6 |
| Sr | -4.97E-10 | 31810.1 | -9407.83 | -22402.3 |
| Qr | 4.97E-10 | 31810.1 | 9407.833 | 22402.27 |
| Qa | 8724.393 | 38839.11 | 12253.55 | 53160.12 |
| Qb | 8747.419 | 83977.83 | 81355.92 | 5257.221 |
| Qc | 9172.678 | 9899.038 | 40161.27 | 71450.96 |

**LLL FAULT**

| | healthy | ABC |
|---|---|---|
| Sa | -888.837 | 9411.024 |
| Sb | -328.583 | 10458.53 |
| Sc | 1217.42 | -19869.6 |
| Sr | -4.97E-10 | -1.60E-09 |
| Qr | -4.97E-10 | 1.60E-09 |
| Qa | 8724.393 | 33779.42 |
| Qb | 8747.419 | 70999.78 |
| Qc | 9172.678 | 48164.95 |



Ia



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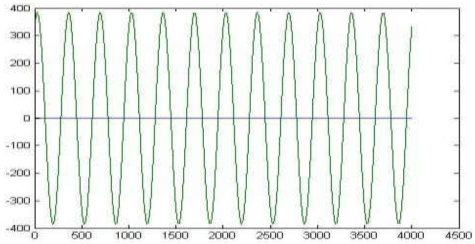

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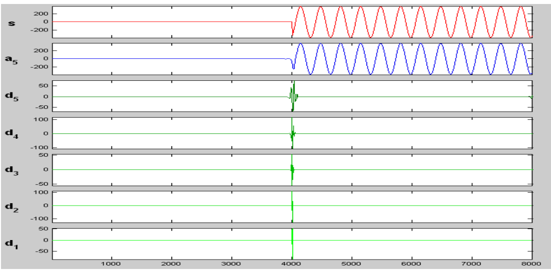

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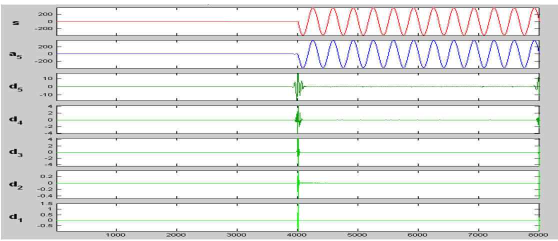

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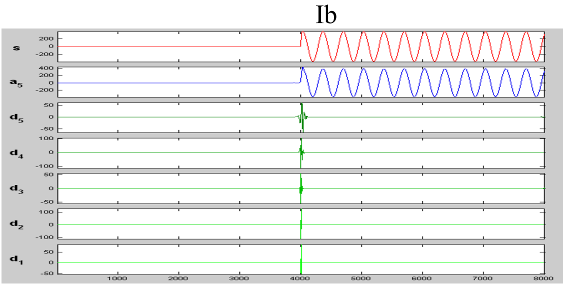
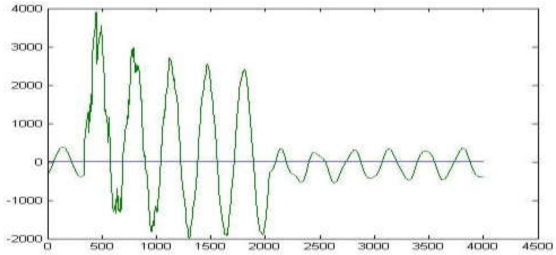


Ic

Fig. 5. Line current signals and its DWT decomposition for phase a, b and c for normal condition



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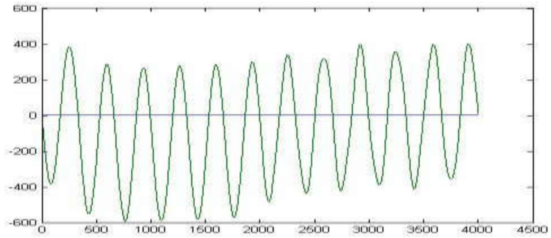

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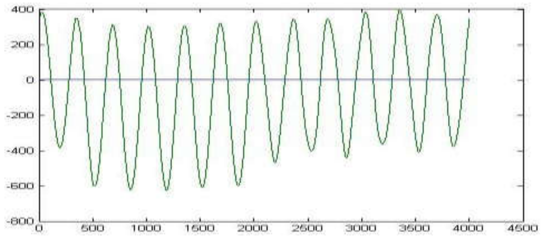

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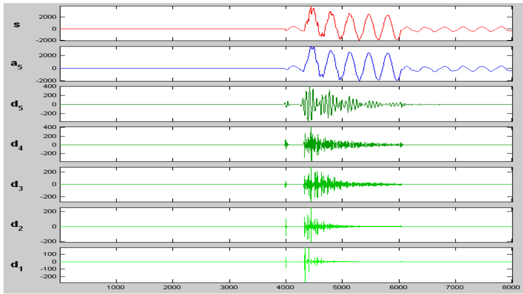

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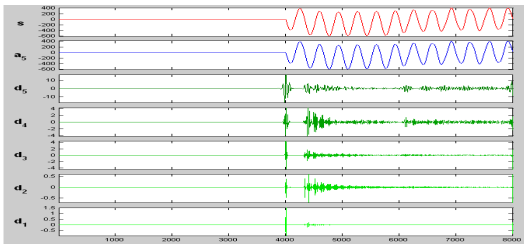

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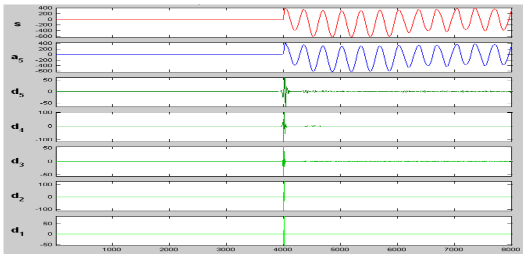

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Fig. 6. Line current signals and its DWT decomposition for phase a, b and c for LG fault in phase A.

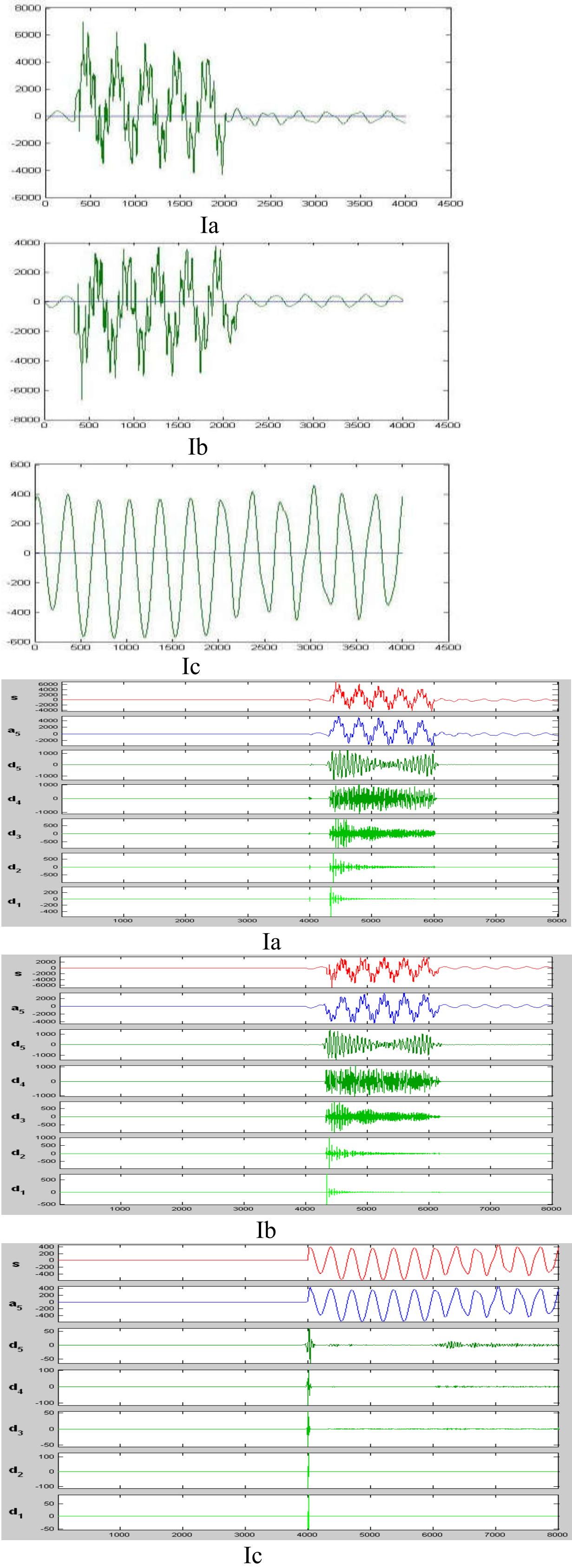


Fig. 7. Line current signals and its DWT decomposition for phase a, b and c for LLG fault in phase A and B.

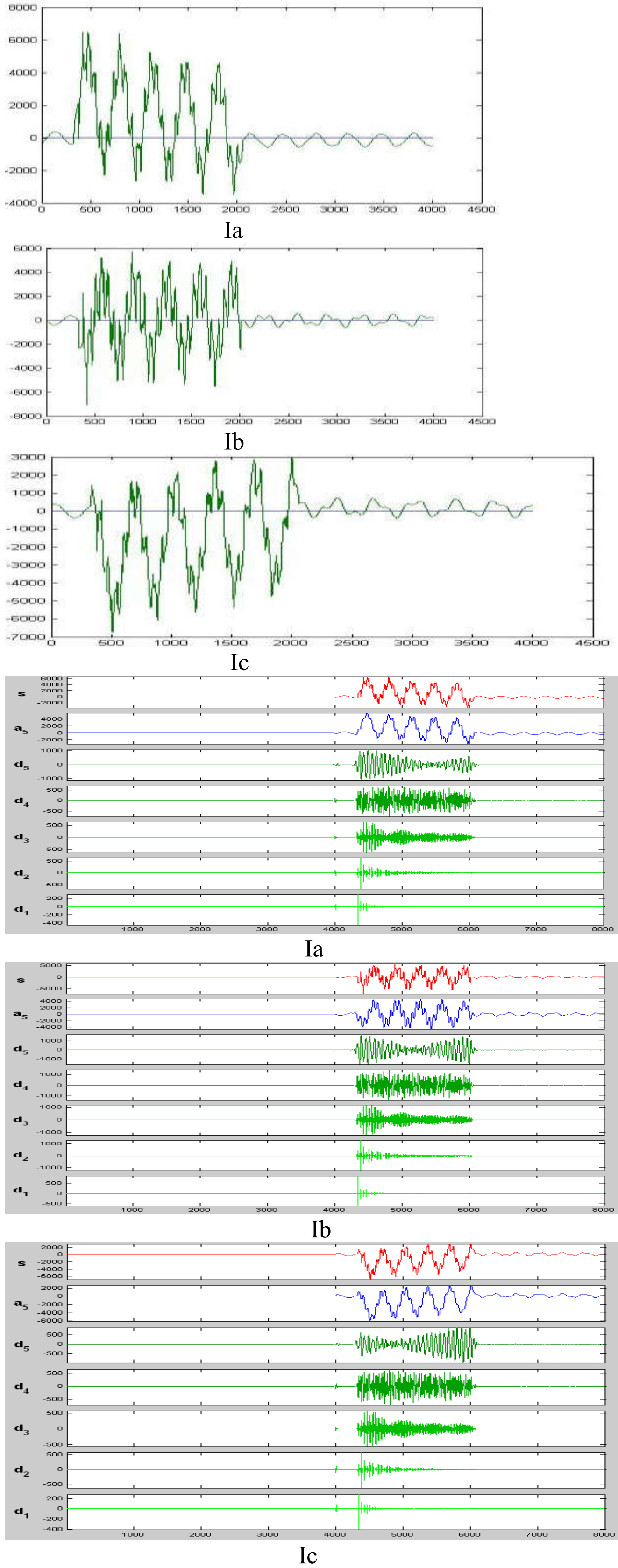


Fig. 8. Line current signals and its DWT decomposition for phase a, b and c for LLL fault in phase A, B and C

# I. CONCLUSION

Analysis using various wavelets was carried out for fault classification. Comparison of detailed coefficient for various waveforms was done for identification of fault with respect to healthy condition. A criterion for fault classification was developed.

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