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Fault Classification in Power DistributionSystem with Distributed Generation

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Abstract: *The primary aim of Power System is to provide uninterrupted power supply to consumers but the performance of Power System is frequently affected by Power Distribution System faults. In order to maintain the continuity of supply and to improve the efficiency of Power System the Power Distribution System fault should be rapidly diagnosed and treated accurately. This paper describes the development of Wavelet-Artificial Neural Network method for classification of Faults in Power Distribution System with Distributed Generation. The disturbances characterized are events from an IEEE 14 bus test system with Distributed Generation. The main purpose of the algorithm is to classify the unsymmetrical faults, single-line-to-ground fault (LG), double line fault (LL) and double line to ground fault (LLG). Along with this some other parameters are also discussed in this work like impact of DG on voltage regulation, impact of DG on harmonics, impact of DG on losses and the impact on short circuit level of the network.*

Keywords*:* Distributed Generation (DG), IEEE 14 bus, ANN, PSCAD

I. INTRODUCTION

Electrical power system is the backbone of developing and developed nations. It has become a basic necessity in the lives of humans. It is a complex system comprising a large number of interconnected electrical components with the sole global aim of allowing the electrical power produced at various locations to reach the customers. Over the last few decades, and particularly in 21st century, renewable energy has constitute large part of that new distributed generation. Renewable energy sources such as solar, wind, biomass, hydro and fuel cell have shown great potential for viable utilization in distributed generation systems. The production of power from renewable energy is both desirable and beneficial as it provides a sustainable alternative that significantly reduces the rate of environmental pollution in comparison with production from fossil fuels. But the integration of renewable energy into the power system can potentially cause severe challenges for the control and protection of large central generators and the distribution system.

1.1 Objective of Work

The share of renewable energy is rapidly increasing in total energy generation.
Today large scale integration of wind turbine and other renewable energy sources is done with the Grid by high power density and controllability. Due to integration of DG, the detection and classification of faults in distribution system has become more and more difficult. The objective of this paper is to classify the faults like LG, LL, and LLG in Power Distribution System with Distributed Generation.

1.2 Organization

The paper is organized as follows:
Section II deals with Distributed Generation (DG) and its classification. It also includes the impact of DG on Power System while section III mainly focuses on fault theory along with the probability of occurrence and severity of Fault. Section IV contains description of Wavelet Transform. Section V provides the detail information of classification tool i.e. Artificial Neural network (ANN). Section VI describes algorithm of this work. Section VII includes system under study on which various unsymmetrical faults are created. The section VIII discusses results and IX section presents the conclusion of work done along with the future scope followed by references.

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II. DISTRIBUTED GENERATION

Distributed Generation has many definitions as some countries define DG with respect to the voltage level; others define it as generation present in the distribution system and finally some others define it based on characteristics such as renewable, cogeneration and non-dispatched (DG cannot be controlled from the system operator). DG is also defined as a generation that is directly connected to the distribution network regardless of its generation capacity level and its primemover [3].

2.1 Classification of Distributed Generation

- Renewable (Wind, Photo Voltaic cell, Hydro) or non-renewable (diesel) DG
- Intermittent (Photo Voltaic cell, Wind energy, Ocean wave) or steady (Diesel, Hydro, Fuel) DG
- Grid connected or Isolated DG
- Inverter based and rotating machine DG
- Dispatch able (Diesel, Micro/small hydro) or not-dispatch able DG

III. FAULT THEORY

During unsymmetrical faults the, the voltages of the three phases are unbalanced and power flow is diverted towards the faultand the supply to neighboring zone is affected.

Reasons of Fault Occurrence

Failure of insulation due to ageing, overheating.
Breakage of conductor due to overstretching.
Accidents.
Short circuit on overhead line.
Lightning surges.

Types of Faults

Faults are generally of two types viz. symmetrical and asymmetrical or unsymmetrical.

Symmetrical faults: These are balanced and most severe faults. However, they occur very rarely. They are of two type namely tripleline to ground fault (L-L-L-G) and three phase fault (L-L-L).

Unsymmetrical faults:

These faults occur frequently in power system. These are categorized as, line to ground (L-G), line to line (L-L) and double line toground (L-L-G) faults.

IV. WAVELET TRANSFORM

The transform of a signal is just another form of representing the signal. It does not change the information content present in the signal. The Wavelet Transform provides a time-frequency representation of the signal. It was developed to overcome the short coming of the Short Time Fourier Transform (STFT), which can also be used to analyze non-stationary signals. While STFT gives a constant resolution at all frequencies, the Wavelet Transform uses multi-resolution technique by which different frequencies are analyzed with different resolutions. [16]

The wavelet analysis is done similar to the STFT analysis. The signal to be analyzed is multiplied with a wavelet function just as it is multiplied with a window function in STFT, and then the transform is computed for each segment generated. However, unlike STFT, in Wavelet Transform, the width of the wavelet function changes with each spectral component. The Wavelet Transform, at high frequencies, gives good time resolution and poor frequency resolution, while at low frequencies; the Wavelet Transform gives good frequency resolution and poor time resolution.

V. ARTIFICIAL NEURAL NETWORK

Artificial neural network consists of many artificial neurons that are linked together according to a specific network architecture. The purpose of the neural network is to transform the inputs into meaningful outputs. [1]. Here, the artificial neural network, which is designed for detection and classification of faults is feed forward back-propagation network. The algorithm (back propagation) effectively divides the contribution of every connection weight. For neural

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network training, Leven berg Marquardt (LM) algorithm is used, because it is found to be one among the fastest methods employed for training the neural networks [2]. Basically, here the network consists of three different layers, namely the input, the output and the intermediate layer or the hidden layer. All these layers consist of neurons that are interconnected to form a broad network of neurons. Weights which are assigned to the connections marks the signal strength. These weight values are updated based on the backpropagation algorithm

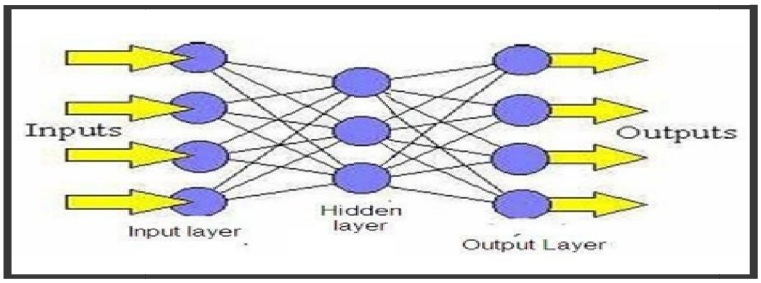

Fig.1 Architecture of ANN

VI. METHODOLOGY

In this paper classification of Power Distribution System fault is carried out in the presence of DistributedGeneration (DG) by using following steps.

Simulation of IEEE 14 bus Test system in PSCAD software.

Unsymmetrical faults namely L-G, L-L, L-L-G are created on bus 12 and 14 with DG at different fault inception angle 0°, 45° and 90°.

Captured fault current signals from overhead transmission lines with project duration of run 0.5 sec at 4 kHz sampling frequency.

Output files of Simulation are converted into excel sheets.

Excel sheet data is imported to MATLAB program for DWT analysis

Discrete Wavelet Transform is applied to current signals and decomposed up to 5 levels.

Calculation of energy of decomposed current signals, by Parseval's theorem is done. The Energy of signal can be calculated as

$$E = \sum_{n=-\infty}^{\infty} |x(n)|^2$$

Where, n is the number of samples

Excel sheet data is prepared for ANN input.

This sheet is given as input to ANN for classification of unsymmetrical faults.

SYSTEM UNDER STUDY

The IEEE 14 bus test system represents a simple approximation of the American Electric Power system as of February 1962 [13].

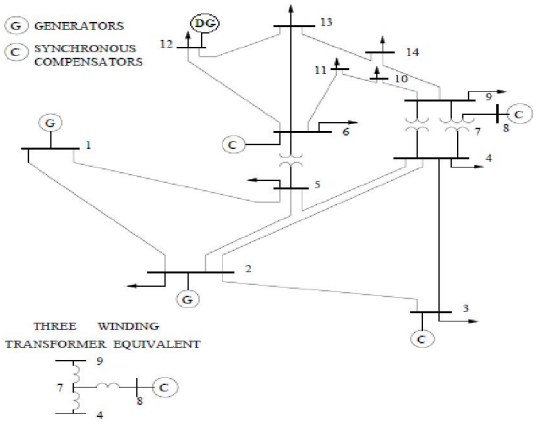

Fig.2 IEEE 14 Bus System with DG at Bus 12

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VII. RESULTS AND DISCUSSION

Important observations are made after creating the unsymmetrical faults on test system in presence of DG.

Voltage and Current Signals

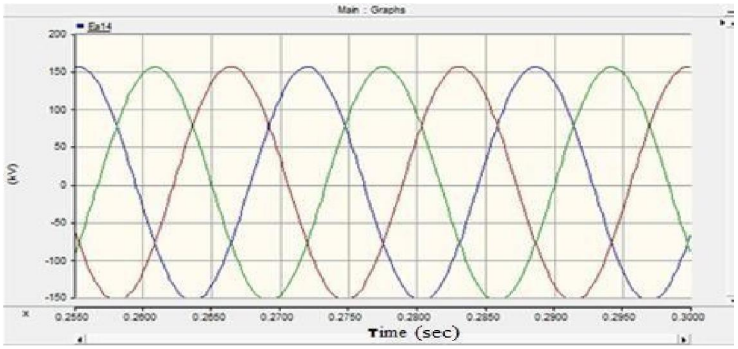

Fig.3 Voltage signal measured at bus 14 during normal condition

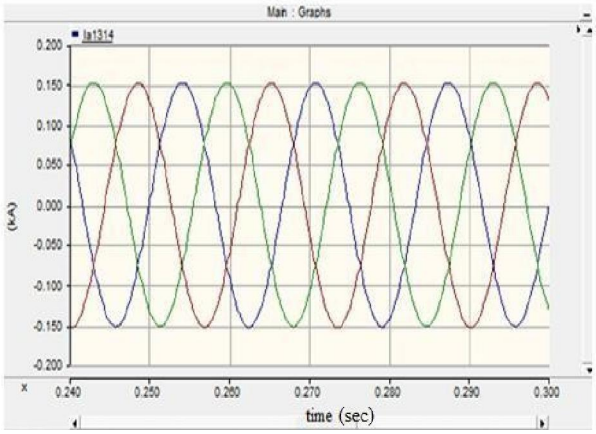

Fig. 4 Current signal of transmission line no.20 during normal condition

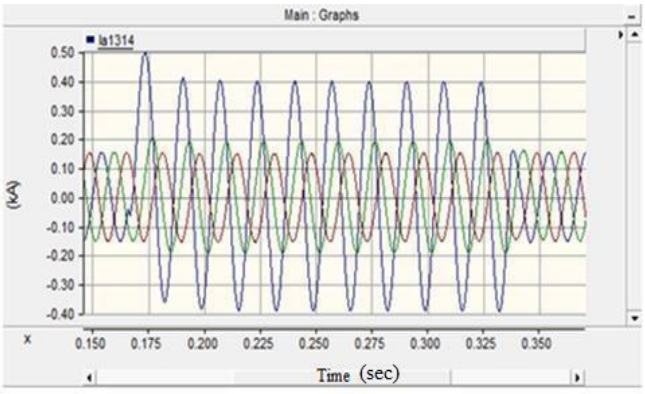

Fig.5 Current Signal for L-G (A-G) fault on bus 14

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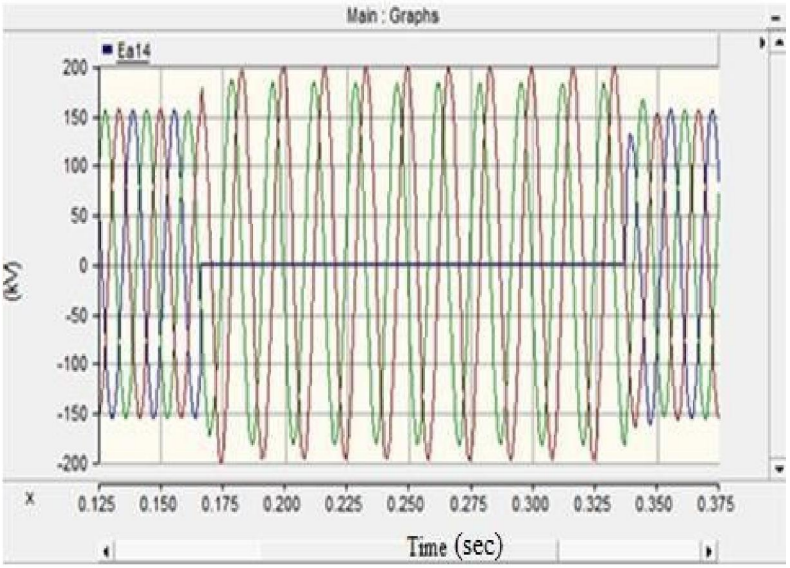

Fig. 6 Voltage signal for L-G (A-G) fault on bus 14

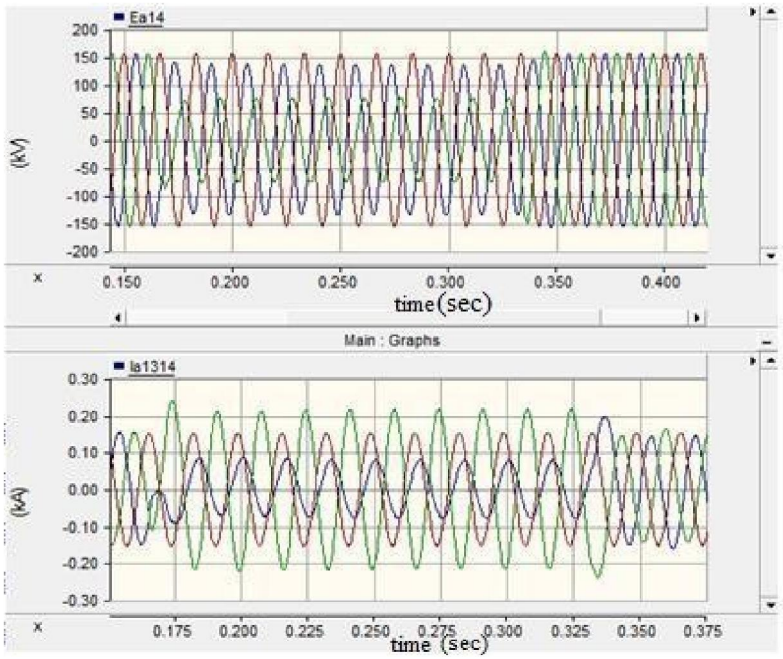

Fig. 7 Voltage and Current signals for L-L (A-B) fault on bus 14

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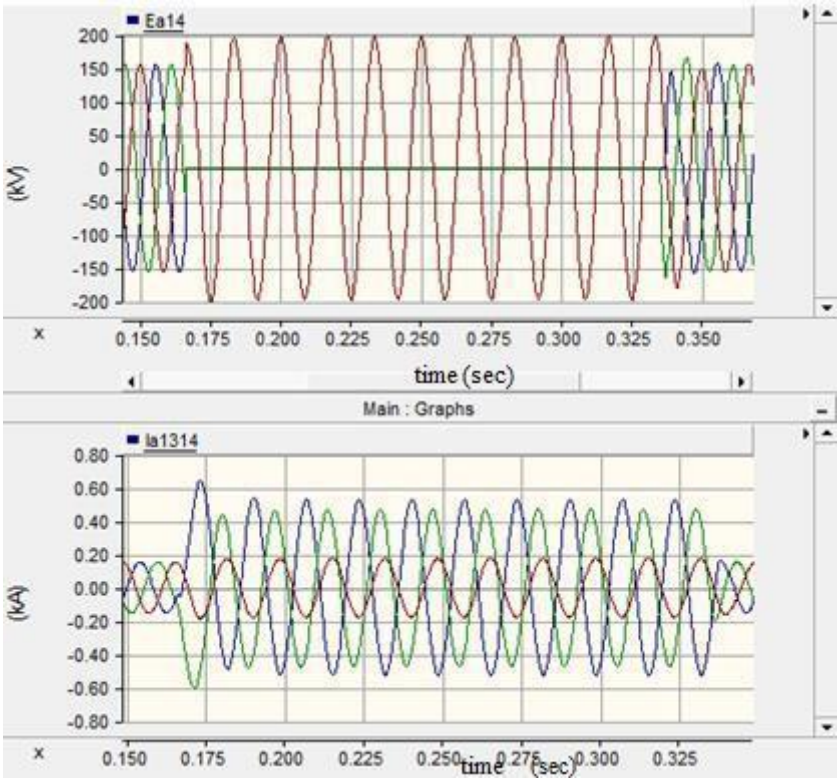

Fig. 8 Voltage and Current signals for L-L-G (A-B-G) fault on bus 14

Comparison between fault current with & without DG when L-G fault is on DG bus i.e. bus 12.

In this case current through transmission lines 14, 15, 16 and 19 are measured with DG (at bus 12) and without tDG. LG faultis at bus number 12 and the results with analysis are given in table 1.

Table I Comparison between Fault Current with & Without DG When L-G Fault is on Bus 12

L-G Fault is on bus 12			
Line	Fault CurrentWithout DG (KA)	Fault Current with DG(KA)	% Change
14	0.127	0.1324	4.07
15	0.345	0.3762	8.29
16	0.1443	0.1536	6.05
19	0.2365	0.2576	8.19

DWT Waveforms

After capturing the current signal from transmission lines, DWT analysis of current signal for L-G, L-L and L-L-Gat 0^o, $45^o$and 90^o instant are shown in Discrete Wavelet waveforms.

Figure 9. shows wavelet decomposition of current signal when L-G(A-G) fault is on bus 14 at 0^o instant upto 5 detail levelusing Daubechies (Db), Db3 mother wavelet.

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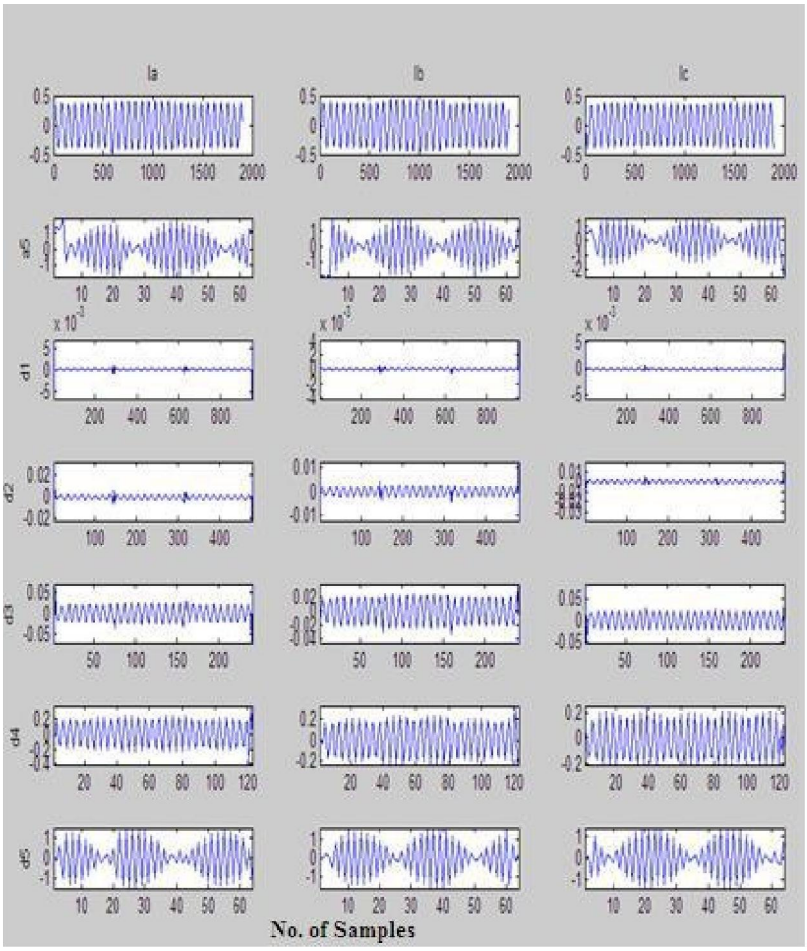

Fig.9 DWT waveform of current signal for L-G (A-G) fault at 0^{o} instant

Figure 10. shows wavelet decomposition of current signal when L-L (A-B) fault is on bus 14 at 0^{o} instant upto 5 detail levelusing Daubechies (Db), Db3 wavelet.

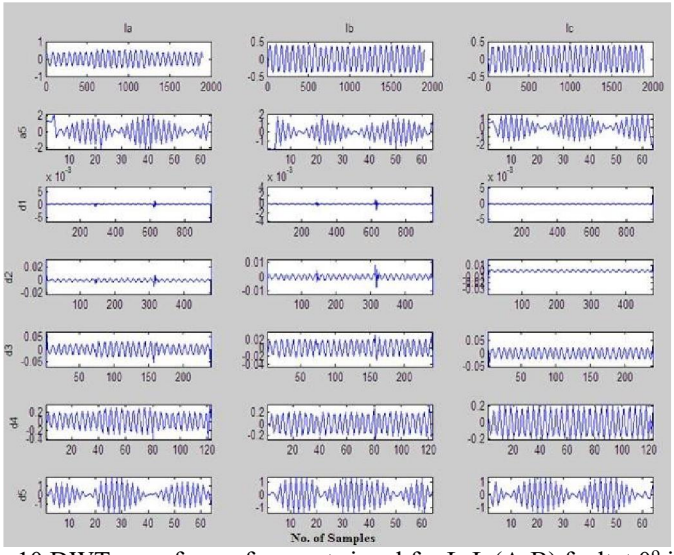

Fig.10 DWT waveform of current signal for L-L (A-B) faultat 0^{o} instant

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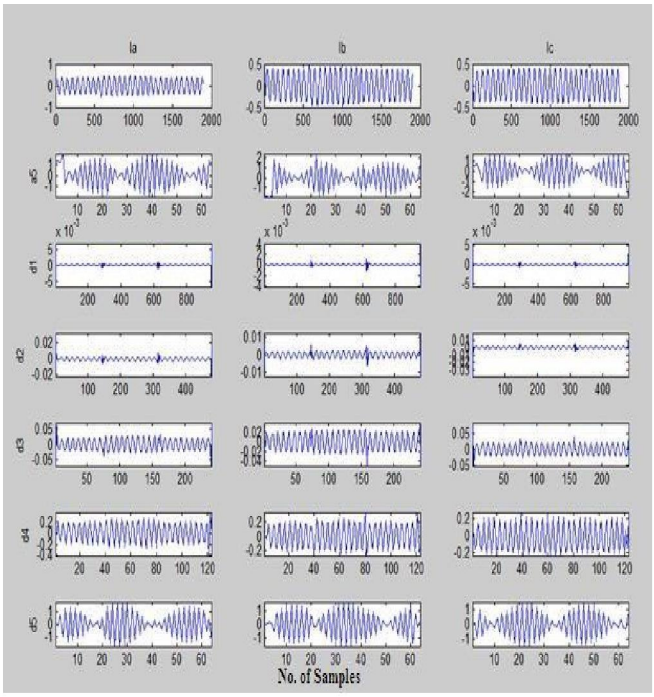

Fig.11 DWT waveform of current signal for L-L-G (A-B-G)fault at 0° instant

Figure 12. shows wavelet decomposition of current signal when L-G (A-G) fault is on bus 14 at 45° instant upto 5detail levelusing Daubechies (Db), Db3 wavelet.

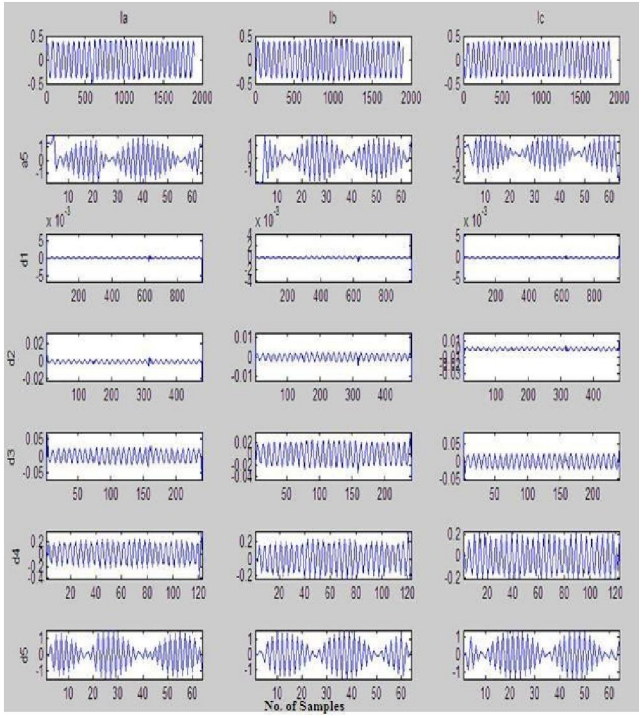

Fig. 12 DWT waveform of current signal for L-G (A-G) fault at 45° instant

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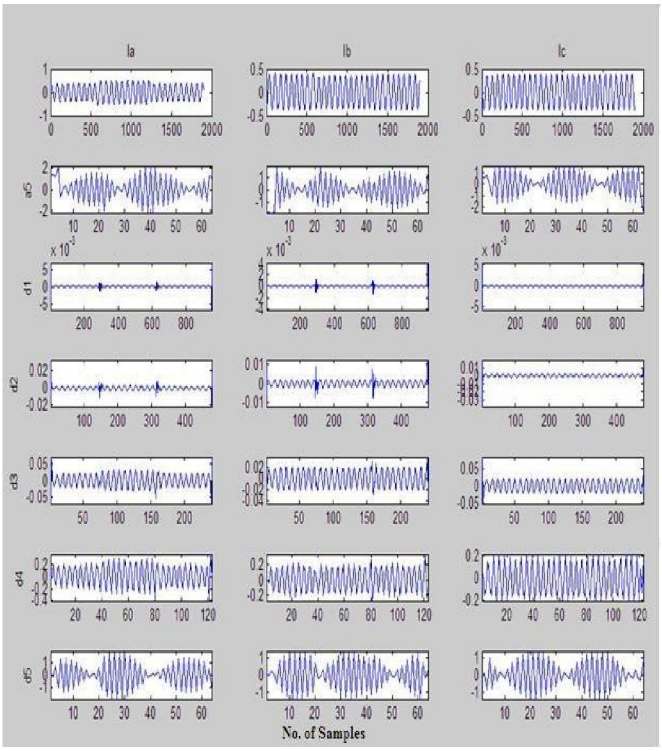

Fig.13 DWT waveform of current signal for L-L (A-B) faultat 45° instant

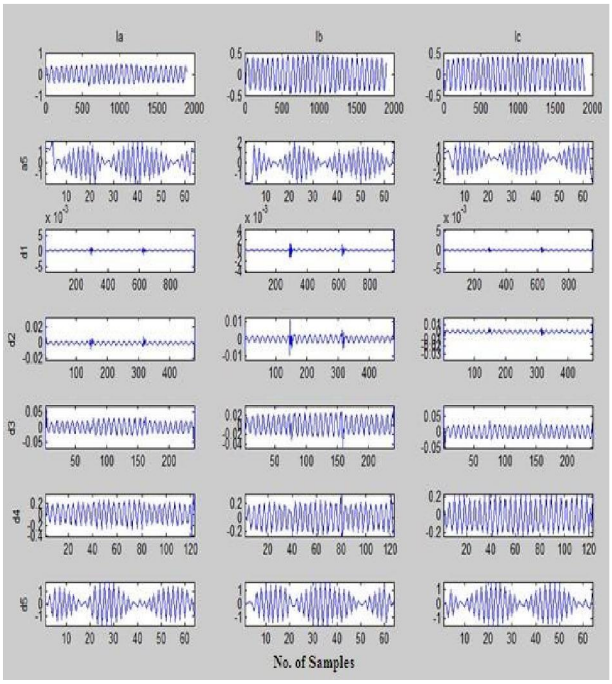

Fig.14 DWT waveform of current signal for L-L-G (A-B-G)fault at 45° instant

Figure 15. shows wavelet decomposition of current signal when L-G (A-G) fault is on bus 14 at 90° instant up to 5detail level using Daubechies (Db), Db3 wavelet

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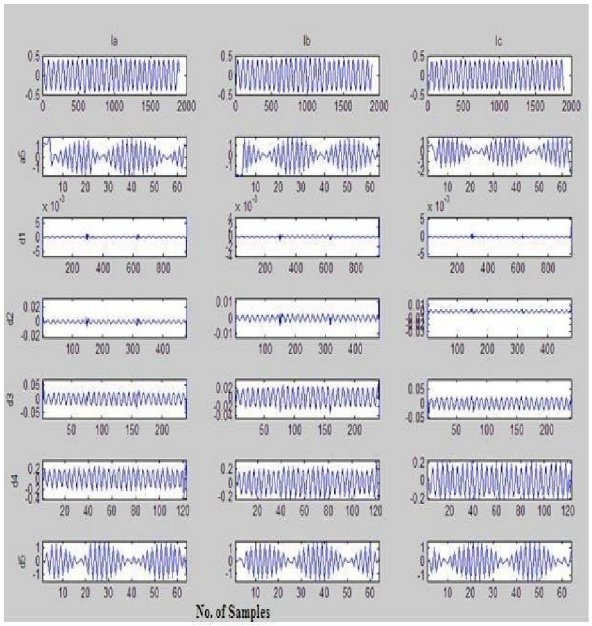

Fig.15 DWT waveform of current signal for L-G (A-G) fault at 90° instant

Figure 16. shows wavelet decomposition of current signal when L-L fault is on bus 14 at 90° instant up to 5 detail level using Daubechies (Db), Db3 wavelet.

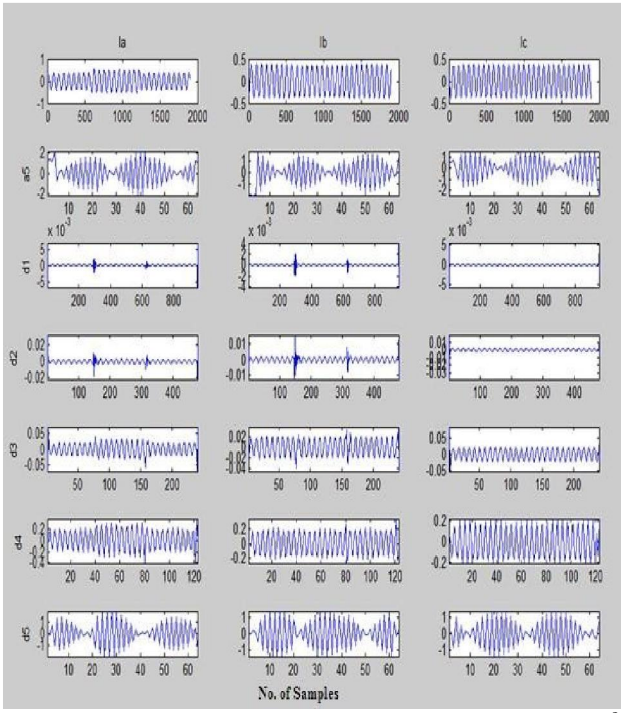

Fig.16 DWT waveform of current signal for L-L (A-B) fault at 90° instant

Figure 17. shows wavelet decomposition of current signal when L-L (A-B) fault is on bus 14 at 90° instant up to 5detail levelusing Daubechies (Db), Db3 wavelet

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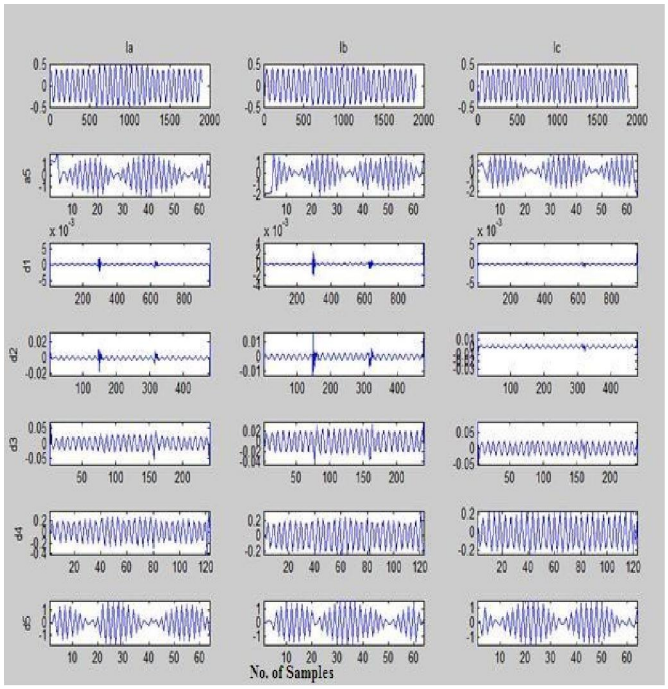

Fig.17 DWT waveform of current signal for L-L-G (A-B-G) fault at 90° instant

Classification Using ANN

In this paper Artificial Neural Network is used and trained with supervised learning. The neural network is provided with three input layers, three hidden layers and three output layers during fault classification process as shown in figure 18. Energy of current signal in the feature extracted data sheet is fed to neural network in MATLAB and number of iterations are varied and decided by trial-and-error method [10].

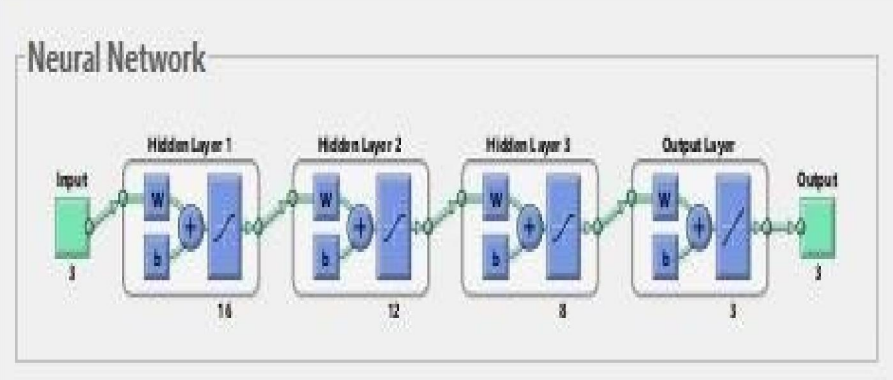

Fig.18 Neural network training

Figure 19 shows the training performance plot, the overall mean square error of the trained neural network is approximated to the pre-defined value. Hence the architecture which is shown in figure 18 is chosen as final for given input andoutput.

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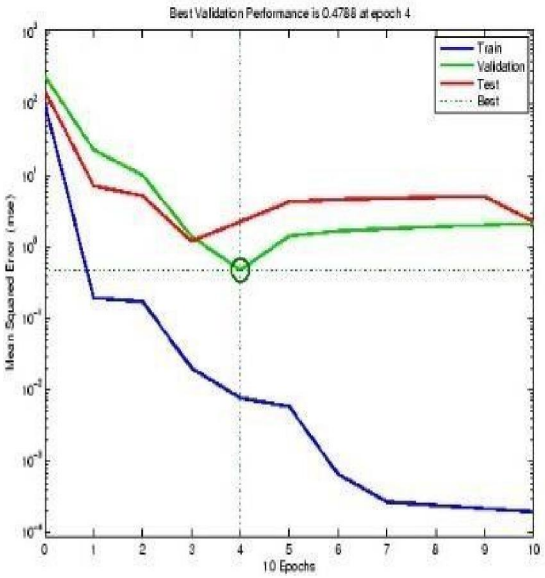

Fig. 19 Mean square error performance of the network

Another means of testing the performance of the neural network is to plot the confusion matrices for the various types of errors that occurred for the trained neural network. Fig.20 shows the confusion matrix for the three phases of training, testing and validation. The diagonal cells in green indicate the number of cases that have been classified correctly by the neural network and the off-diagonal cells which are in red indicate the number of cases that have been wrongly classified by the ANN. The last cell in blue in each of the matrices indicates the total percentage of cases that have been classified correctly. The boxes in green colour indicate the correct classification of faults and red colour boxes indicate incorrect classification of faults. It can be seen that the chosen neural network has 95.6 percent accuracy in fault classification.

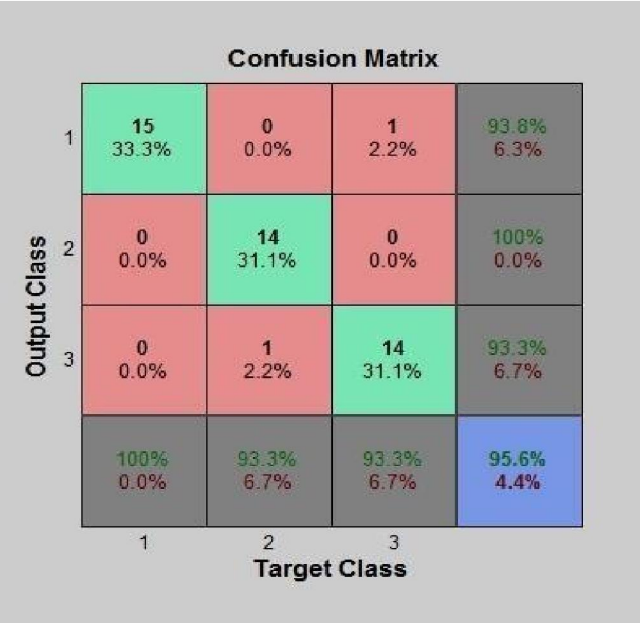

Fig.20 Confusion matrix for training, testing and validation phases

VIII. CONCLUSION

In this paper, IEEE 14 bus test system is simulated. A DWT-ANN approach is used to classify unsymmetrical faults in Power Distribution System with DG. DWT with its inherent time frequency localization property is employed to extract

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disturbance features in Power signal. A backpropagation neural network classifier is then used for identification of fault type. Faults with various types, and location have been tested with overall 95.6% correct classification accuracy.
From the analysis it is also observed that there is an increment in short circuit level with Distributed Generation which affects the existing protection system. The results obtained with the use of DWT-ANN based algorithm are promising and suggest that this approach could lead to useful application in an actual power system.

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