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An Algorithm Based On Discrete Wavelet Transform For Faults Detection, Location and Classification in Radial Distribution System

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***Abstract*: An electric power distribution system is the final stage in the delivery of electric power; it carries electricity from the transmission system to individual consumers. Fault classification and location is very important in power system engineering in order to clear fault quickly and restore power supply as soon as possible with minimum interruption. Hence, ensuring its efficient and reliable operation is an extremely important and challenging task. With availability of inadequate system information, locating faults in a distribution system pose a major challenge to the utility operators. In this paper, a faults detection, location and classification technique using discrete wavelet multi-resolution approach for radial distribution systems are proposed. In this distribution network, the current measurement at the substation have been utilized and is demonstrated on 9-bus distribution system. Also in this work distribution system model was developed and simulated using power system block set of MATLAB to obtain fault current waveforms. The waveforms were analyzed using the Discrete Wavelet Transform (DWT) toolbox by selecting suitable wavelet family. It was estimated and achieved using Daubechies 'db5' discrete wavelet transform.**

***Keywords*: Fault detection, Fault location, Fault classification, Multi-resolution analysis, Discrete wavelet transform, Distribution system**

I. INTRODUCTION

An important objective of all the power systems is to maintain a very high level of continuity of service, and when abnormal conditions occur, to minimize the outage times. It is practically impossible to avoid effects of natural events, physical accidents, failure of equipment or mis-operation which results in the loss of power, voltage dips on the power system.

The very important issue in power system engineering is to locate the fault and estimate the distance in order to clear fault quickly and restore power supply as soon as possible with minimum interruption.

Natural events can cause short circuits i.e. faults which can either be single phase to ground or phase to phase or phase

to phase to ground or a three phase fault. Most faults in an electrical system occur with a network of overhead lines are single-phase to ground faults caused due to lightning induced transient high voltage and from falling trees. In the overhead lines, tree contact caused by wind is a major cause for faults. The appropriate percentages of occurrences various faults are listed below:

Single line to ground fault – 70-80%

Line-Line to ground fault - 10-17%

Line-Line fault – 8-10%

Three phase – 2-3%

Recently, several fault location methods for transmission and distribution system have been proposed. They are categorized in three main categories;

1) Impedance based methods; these methods usually calculate the apparent impedance sequences using measurement point data and estimate the possible fault locations based on iterative algorithms. Considering the multiple fault locations estimation in these method and existence of many laterals in distribution system is the drawback of impedance base methods.

2) Intelligent methods consist of artificial neural networks (ANN), expert systems and etc. ANN based method need to be trained after any change in system and update network weights, the other drawback with ANN based methods is that in case of complicated networks they became slow and may fall in local optimum. Expert system methods have a slow response time since they involve knowledge based maintenance and conventional interference mechanism.

3) Wavelet transform; The wavelet transform (WT) is a recently developed mathematical tool which can be used for signal processing with a wide variety of applications, e.g. acoustics, communications, transient analysis, medicine, etc. The main reason for this growing activity is the ability of the wavelet not only to decompose a signal into its frequency components, but also to provide a non-uniform division of the frequency domain, whereby it allows the decomposition of a signal into different levels of resolution.

In general, the first step in the power system relaying algorithms is the detection of fault and the next step is classification. This work uses a combination of Wavelet Transforms and multi-resolution detecting and classifying power system faults. The Objective of this work is to classify the faults according to the following parameters:

1. Fault type

2. Fault location

The fault cases are classified as single phase to ground faults, phase to phase to ground faults and a three phase faults. The fault location is an important parameter especially in high voltage power systems. The knowledge of fault location leads to high speed fault clearance as well as improved transient stability.

II. HISTORICAL REVIEW: FROM FOURIER ANALYSIS TO WAVELET ANALYSIS

The history of wavelets begins with the development of the traditional Fourier Transform (FT), which is widely applied in signal analysis and image processing. Fourier Transform breaks down a signal into the sum of infinite series of sines and cosines of different frequencies. Fourier transform is very effective in problems dealing with frequency location. However, time information is lost during the process of transforming to frequency domain.

To improve the performance of the FT, the Short Time Fourier Transform (STFT) has been developed in signal analysis. STFT compromises between the time and frequency based views of a signal by examining a signal under a fixed time window. The drawback of STFT is that , for all the frequencies the time window is fixed. Many signals require a more flexible approach; the window size is required to vary according to the frequency.

Wavelet analysis or wavelet transform is close to the Fourier transform, but has a significant advance. It applies a windowing technique with variable-sized regions, a shorter time interval is used to analyze the high frequency components of a signal and a longer one is used to analyze the low frequency components of the signal. Wavelet analysis is very effective for dealing with local aspects of a signal, like trends, breakdown points, and self similarity. Furthermore, wavelet analysis is capable of removing noise from signal and compress signal.

III. DISCRETE WAVELET TRANSFORM (DWT) AND MULTI-RESOLUTION ANALYSIS (MRA)

The wavelet transform is a mathematical tool that divides up data, functions or operators into different frequency components and then studies each component with a resolution matched to its scale. Basically, wavelet transforms are divided into two, namely: Continuous Wavelet Transform (CWT) and Discrete Wavelet Transform (DWT). Since most operations are now performed using computers, which uses digital forms of data, the latter is preferred by most researchers and is used in this study.

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The DWT analyses the original signal at different frequency bands with different resolutions by decomposing the signal into a coarse approximation and detail information. In doing this, the DWT employs two sets of functions called Scaling functions and Wavelet functions. These are respectively associated with high and low pass filters.

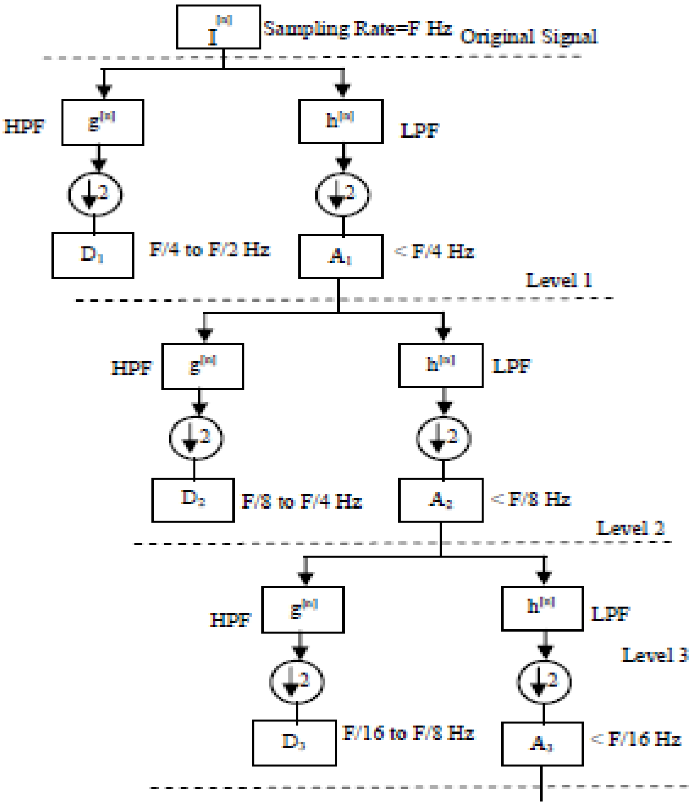

Fig.1 Schematic Diagram of Multi-Resolution Analysis of DWT Decomposition

KEY


=Down Sampling by 2
LPF= Low Pass Filter
HPF= High Pass Filter
A=Approximation Co-efficient
D =Detail Co-efficient

A very useful implementation of DWT, called multi-resolution analysis, is demonstrated in Fig. 1. It is designed to produce good time resolution and poor frequency resolution at high frequencies and good frequency resolution and poor time resolution at low frequencies. The original sampled signal I(n) is passed through a high pass filter g(n) and a low pass filter h(n). Then the outputs from both filters are decimated by 2to obtain the detail coefficients and the approximation coefficients at level 1 (D1 andA1). The approximation coefficients are then sent to the second level to repeat the procedure. Finally, the signal is decomposed at the expected level.

In the case shown in Fig.1, if the original sampling frequency is F, D1 captures the signal information between F/4 and F/2 of the frequency band. D2 captures the signal between F/8 and F/4. D3 captures the information between F/16 and F/8, and A3retains the rest of the information of original signal between 0 and F/16. By such means, we can easily extract useful information from the original signal into different frequency bands and at the same time the information is matched to the related time period. In this work db5 wavelet is used to make a 3 level decomposition. The wavelet tool box in MATLAB provides a lot of useful techniques for wavelet analysis.

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IV. MATLAB SIMULATION

A simulation model is developed for the system shown in figure 2 using simulink.

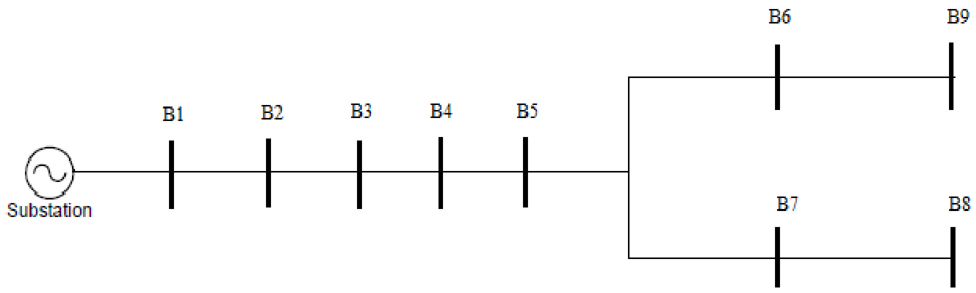

Fig.2 Single line diagram of the 9-bus distribution system

Table I: Generator rating

Generators	Ratings
Generating station	11KV, 50Hz

Table II: Distribution line data set

Sending End bus	Receiving End Bus	R (ohm)	X (henry)
0	1	0.1233	0.4127
1	2	0.0140	0.6050
2	3	0.7463	1.2050
3	4	0.6984	0.6084
4	5	1.9831	1.7276
5	6	0.9053	0.7886
6	7	2.0552	1.1640
7	8	4.7953	2.7160
8	9	5.3434	3.0264

Table III: 9BUS data set

Bus No.	Active Power (P) in KW	Reactive Power (Q) in KVAR
1	1840	460
2	980	340
3	1790	446
4	1598	1840
5	1610	600
6	780	110
7	1150	60
8	980	130
9	1640	200

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A. The Phase Currents of the Simulation Model without Faul:

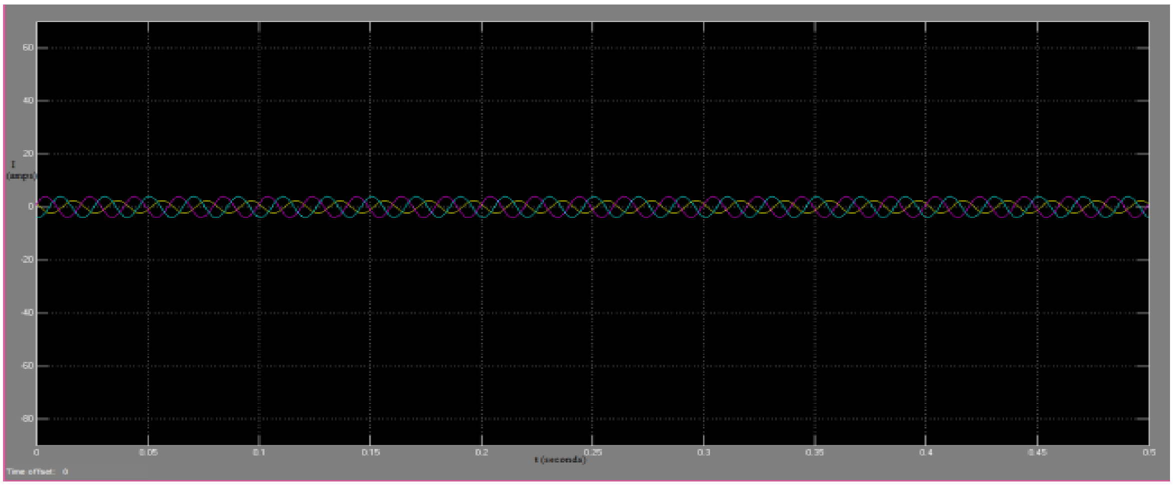

Fig.3 Healthy 3phase current signal

B. The Phase Currents of the Simulation Model with L-G Fault:

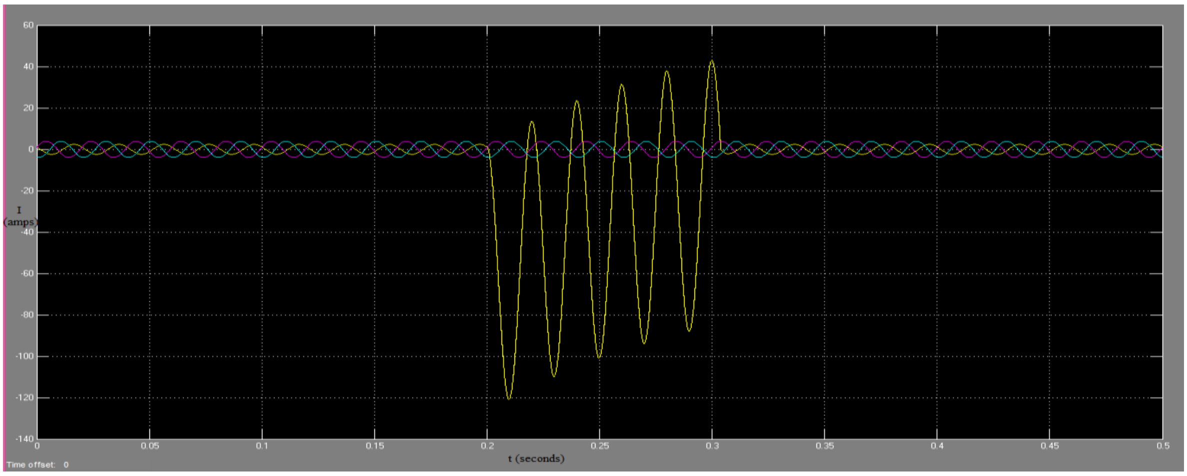

Fig.4 Current waveforms for an L-G fault

V. RESULTS AND DISCUSSION

A. Wavelet Distance Protection Algorithm:

In order to investigate the applicability of the proposed wavelet transform distance protection algorithm, a simulation of distribution line model is developed. Fault simulations were carried out using MATLAB. The three phase current signals are then filtered using the pre-band-pass filters to attenuate the dc component. The output filtered signals are the input to the proposed wavelet distance protection algorithm.

B. Analysis of L-G Fault:

The simulated fault signals are being analyzed through the wavelet transform using MATLAB wavelet toolbox. Three phase current signals are loaded to wavelet 1-D in the wavelet toolbox main menu. The proposed technique is divided into two sections.

1) Fault Detection:

The first section is detection of the fault by observing the output of the high pass filter details of the first decomposition level. This decomposition level has the ability to detect any disturbances in the original current waveform. The loaded current signals are decomposed at one level with the db1 wavelet.

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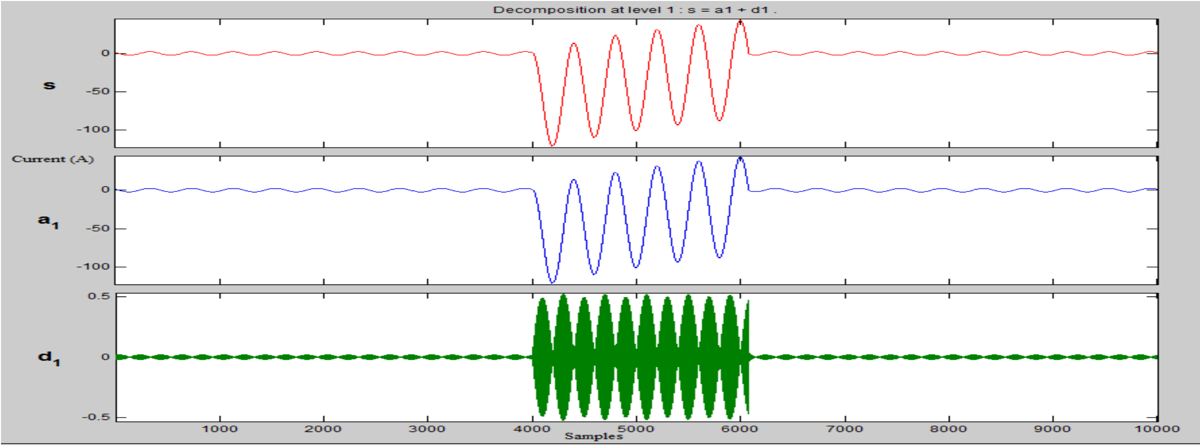

Fig.5 First level decomposition of phase 'a'

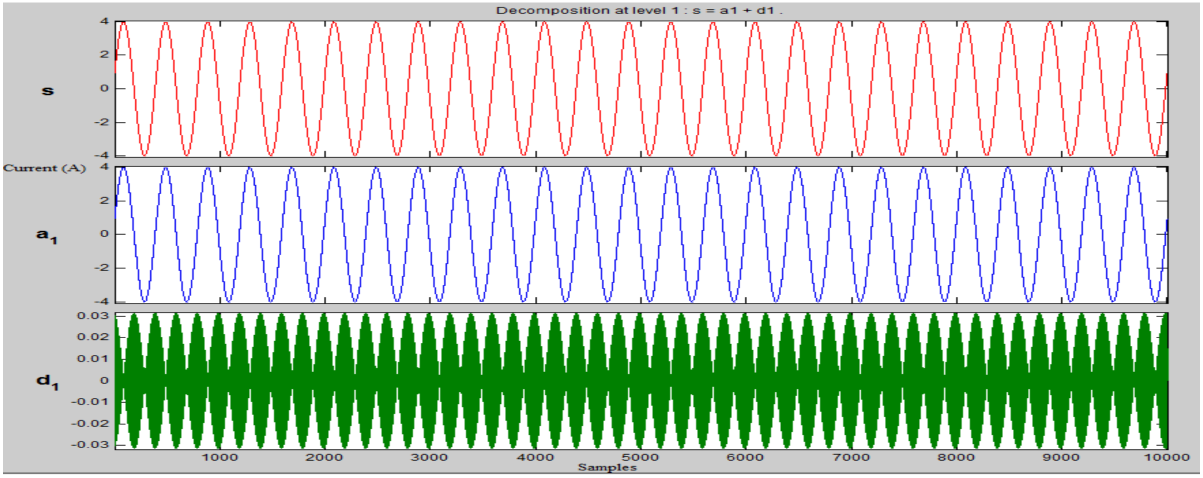

Fig.6 First level decomposition of phase 'b'

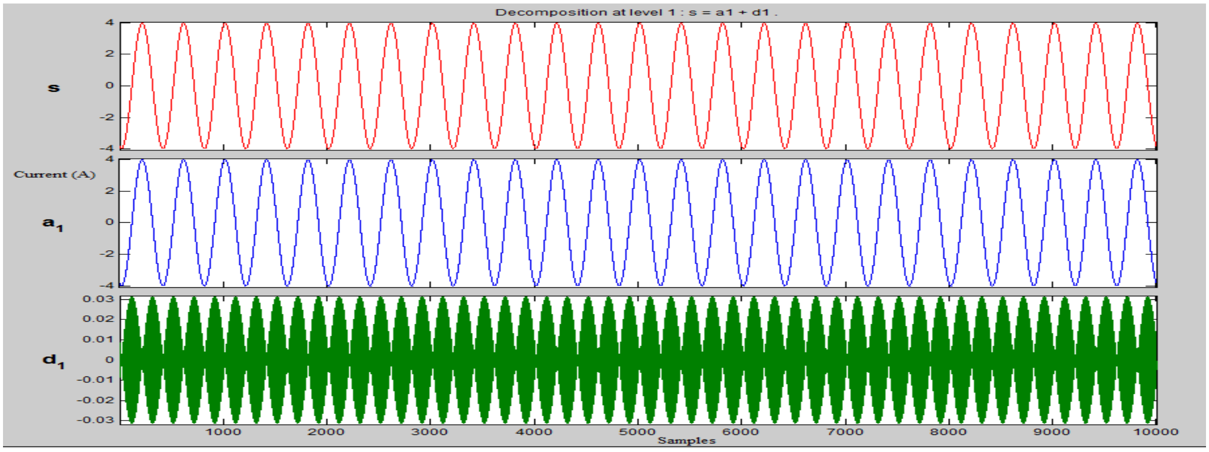

Fig.7 First level decomposition of phase 'c'

2) Estimation of Current:

The second section of the algorithm is the estimation of the fundamental frequency currents. It can be done by observing the output of the low-pass filter at the third decomposition level (A3). The third level of decomposition gives good approximation of the phasors. At this level the high frequencies in the signal are eliminated by the high-pass filters of the first and second decomposition levels and DC component has already been eliminated by pre-band-pass filtering the signal. The estimation of phasors is based on capturing the peak value of each signal (magnitude).The three phase current signals are decomposed by the db5 wavelet.

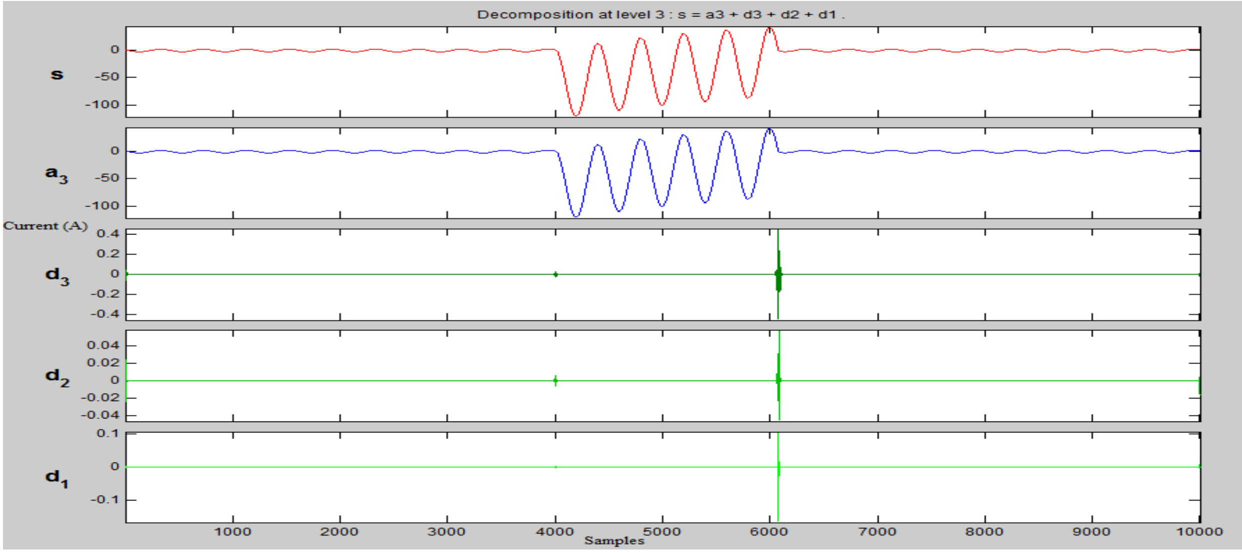

Fig.8 3-levels of decomposition of phase 'a'

VI. CONCLUSION

In this paper, the wavelet Multi-Resolution Analysis (MRA) has been applied to identify and locate the fault in the radial distribution system and is tested on 9-bus distribution system. This wavelet based technique allows decompose the signal into frequency bands (multi-resolution) in both time and frequency allows accurate fault detection as well as estimation of fault current signal at the fundamental frequency. The MRA approach is found to be very effective in identifying various types of fault (LG, LL, LLG, and LLLG) and also in locating the faulty section. Hence, the method is quite simple to adopt and extremely fast for the fault identification and location.

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