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Identification of Fault in a Transmission Line by using Wavelet and Location by Fuzzy

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Abstract: ***Fault Location estimation is very important issue in power system engineering in order to quickly clear faults and restore power supply as soon as possible with minimum interruptions. In case if any fault occurs in the system, then it may damage the whole system if it is not rectified quickly. So in order to rectify it we have several methods. We use real time wavelet-Fuzzy combined approach for digital relaying. Wavelet Transform is one the efficient tools for analysing non stationary signals such as transients and have been widely applied to solve numerous problems in power systems. This paper presents Fuzzy logic is employed to incorporate expert evaluation through FIS so as to extract important features through wavelet MRA coefficients for obtaining coherent conclusions regarding fault location. Computer simulation using MATLAB have been conducted.***
Keywords: Wavelet, Fuzzy,

I. INTRODUCTION

An electric power system is a network of electrical components used to supply, transmit and use electric power. It is a network that supplies a region's homes and industry with power for sizable regions. This power system is called as Grid and can be broadly divided into generating centres to the load centres and distribution system that feeds power to nearby homes and industries. Electrical power is the mathematical product of two quantities, current and voltage. These two quantities can vary with respect to time or can be kept at constant levels. Power transmission and distribution lines are vital links that achieve the essential continuity of service of electrical power to end users. As generating stations are far away from local centres, they may run over hundreds of kilometres. Hence chances of fault occurring in transmission lines are very high. Since faults can destabilize the power system they must be isolated immediately.

In a electric power system, a fault is any abnormal electric current. In three phase systems, a fault may involve one or more phases and ground, or may occur only between phases. In a polyphase, a fault may affect all phases equally. For restoration process, fault clearing should be done manually in case of permanent faults which require fault location. For quick patrol efficient and accurate methods are to be followed for fault location. Thus relaying of transmission line includes fault detection, classification and location. Conventional methods of fault detection and classification have become unreliable due to increasing size of network and insufficient algorithm. Wavelets are mathematical functions that divide the data into different frequency components and then study each component with a resolution matched to its scale. They have advantages over traditional Fourier methods in analysing physical situations where the signal contains discontinuities and sharp spikes. Wavelet analysis provides immediate access to information that can be obscured by other time frequency methods.

This paper presents a real time Wavelet-Fuzzy combined approach for digital relaying. By measuring the sharp variation values of MRA detail signals, faults in power system can be detected. The fault type is then identified by comparison of three phase MRA sharp variations. MRA provides an effective way to examine the features of a signal at different frequency bands. These features may be essential for pattern recognition. Hence it is well suited for fault detection and classification problem in power system.

II. FAULTS ON TRANSMISSION LINE

The fault occurs in power system due to insulation failure, failure of equipments, flash over of lines initiated by lightning strokes, due to permanent damage to conductors and towers or due to accidental faulty operation. In three phase systems, faults may occur between phases (or) one or more phases and ground in polyphase. These faults may either involve all three phases in a symmetrical manner (or) in asymmetrical.

A. Transient Fault

It is fault that is no longer present if power is disconnected for a short time. Many overhead power lines are transient in nature. At occurrence of a fault, power system protection operates to isolate area of fault. Typical examples of transient fault include bird (or) animal contact, momentary tree contact, lightening strikes, etc.

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B. Persistent Fault

A persistent fault does not disappear when power is disconnected. These are broadly classified into series and shunt faults. The shunt type fault involves short circuit between conductor and ground (or) short circuit between two (or) more conductors. They are

1) Line to ground fault
2) Line to Line fault
3) Double Line to ground fault
4) Three phase fault.

The series fault may occur within one (or) two broken conductors which create open circuits. It also happens to circuits controlled by fuses (or) breakers which do not open all the three phases.

III. MATHEMATICAL METHODS OF FAULT DETECTION

Mathematical transformations are applied to signals to obtain further information from those signals that is hidden and is not readily available in their raw format. Transforms widely used in signal analysis are:

1) Fourier transform
2) Fast Fourier transform
3) Short time Fourier transform
4) Wavelet transform

Of these, Fourier transform provides only frequency related information whereas other three transforms provide both frequency as well as time related information. First three transforms have their own drawbacks regarding time and frequency resolutions, which are overcome but wavelet analysis. In recent year, wavelet transform has emerged as powerful signal analysis tool and is being used successfully in many areas including image compression, biomedical applications, speech processing, acoustics and numerical analysis.

IV. WAVELET ANALYSIS AND FUZZY LOGIC CONTROLLERS

Wavelet Analysis represents the logical step: a windowing technique with variable sized regions. Wavelet analysis allows the use of long time intervals where we want more precise low frequency information and shorter regions where we want high frequency information.

A. Continuous Wavelet Transform

Mathematically the process of Fourier analysis is represented by Fourier transform: $F(\omega) = \int_{-\infty}^{\infty} f(t) e^{-j\omega t} dt$

Which is the sum of the signal f(t) multiplied by a complex exponential. This complex exponential can be broken down into real and imaginary sinusoidal components. The results of the transform are the Fourier coefficients, which when multiplied by a sinusoidal of frequency ω, yield the sinusoidal components of original signal. Graphically the process looks like as shown in figure below:
Similarly continuous wavelet transform is defined as the sum over all time of signal multiplied by scaled and shifter versions of wavelet function.

B. Multi-Resolution Analysis

In MRA, wavelet functions and scaling functions are used as building blocks to decompose and construct the signal at different resolution levels. The wavelet function will generate the detail version of decomposed signal and the scaling function will generate approximated version of decomposed signal.

Let $c_0(n)$ be a discrete time signal recorded from physical measuring device. This signal is decomposed into a detailed and smoothed representation. From MRA technique, the decomposed signals at scale 1 are $c_1(n)$ and $d_1(n)$ where $c_1(n)$ is smoothed version of original signal and $d_1(n)$ is the detailed representation of original signal $c_0(n)$ in the form of wavelet transform coefficients. They are defined as:

$$c_1(n) = \sum h(k-2n) c_0(k)$$

$$d_1(n) = \sum g(k-2n) c_0(k)$$

That means in first stage decomposition, the original signal is divided into two halves of frequency bandwidth. The next higher scale decomposition is now based on $c_1(n)$. Thus the procedure is repeated until the signal is decomposed to a pre-defined certain level.

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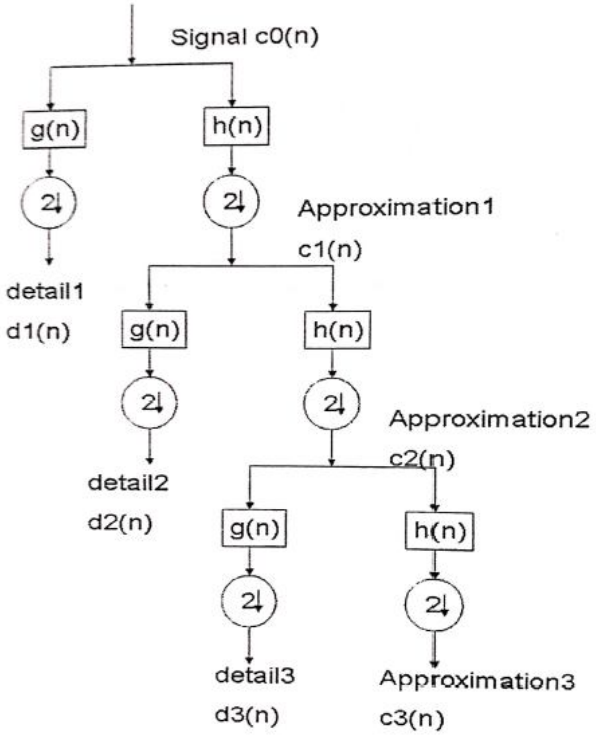


Fig.1 Multi Resolution Analysis

C. Fuzzy Logic Controllers

Fuzzy logic controllers are already used in appliances like washing machine, refrigerators, vacuum cleaners etc.

Fuzzification is related to vagueness and imprecision in natural language. It is a subjective valuation, which transforms a measurement into a valuation of an objective input space to fuzzy sets. In fuzzy control applications, the observed data are usually crisp. Since the data manipulation in fuzzy logic controller is based on fuzzy set theory, Fuzzification is necessary in an earlier stage. Generally in fuzzy system, four different shapes of Membership functions are used. They are Triangular, Trapezoidal, Gaussian, Sigmoid etc.

Fuzzy interface process includes:

1) Fuzzification of input variables.
2) Application of Fuzzy operator.
3) Implication from antecedent to consequent.
4) Aggregation of consequents across rules
5) Defuzzification.

Implication process is for evaluation of individual rules. The methods used are Mamdani and Suguno.

V. PROPOSED METHOD

The single diagram of power system model considered for simulation study is shown. The line parameters and other relevant data for power system model are as follows.

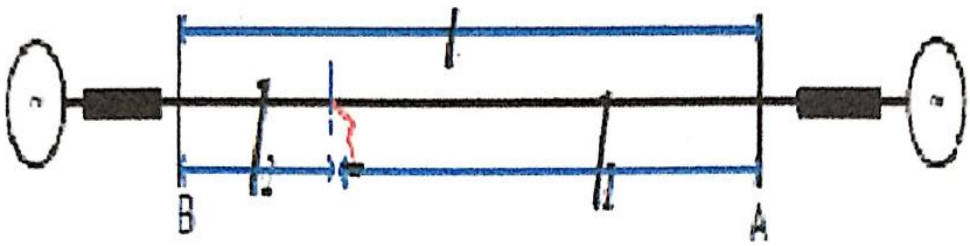


Fig.2 Single line diagram of power system

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Line length = 100 km
Source voltage = 400kV
Positive, Negative sequence line parameters: R=2.34Ω, L= 95.10mH, C=1.24μF
Zero sequence line parameters: R=38.85Ω, L= 325.08mH, C=0.845μF
MATLAB Simulink Diagram and Fuzzy Simulink Diagram for power system is shown below in Fig.

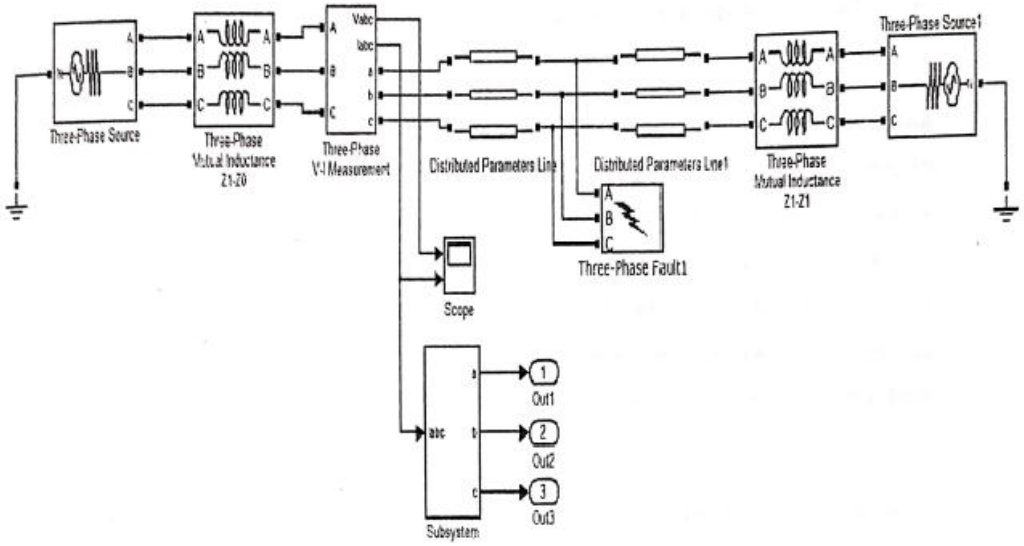


Fig.3 MATLAB SIMULINK Diagram of Power System

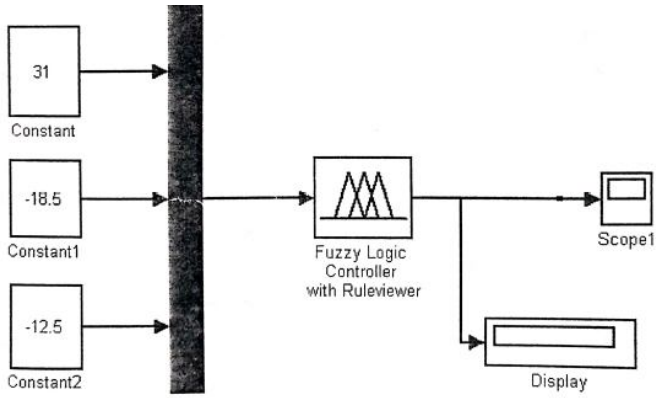


Fig.4 Fuzzy SIMULINK Diagram of Power System

Using Simulink program, MRA coefficients Sa, Sb and Sc are obtained. These coefficients contain all information regarding frequency components associated with any faults in transmission line but they are in raw data form. In order to represent such uncertainity in expert system, analysis begins from fundamental model based on fuzzy logic. Such an analysis leads to rule based expert system development to effitively extract information from available data for obtaining coherent conclusion.
The summation of wavelet MRA coefficients for three phases Sa, Sb and Sc are the basis for fault location and therefore these values are used as inputs to fuzzy interference system. Fault distance from source end (D) is considered as output. Fuzzy interference system as well as membership functions are shown. Usually Sa, Sb and Sc decreases as the fault distance increases from source end, through triangular memebership function with a decreasing trend. Each input varaiable is quantized into three linguistic variables such as LOW(L), MEDIUM(M) and HIGH(H) . Fuzzy interference system as well as membership functions are shown.

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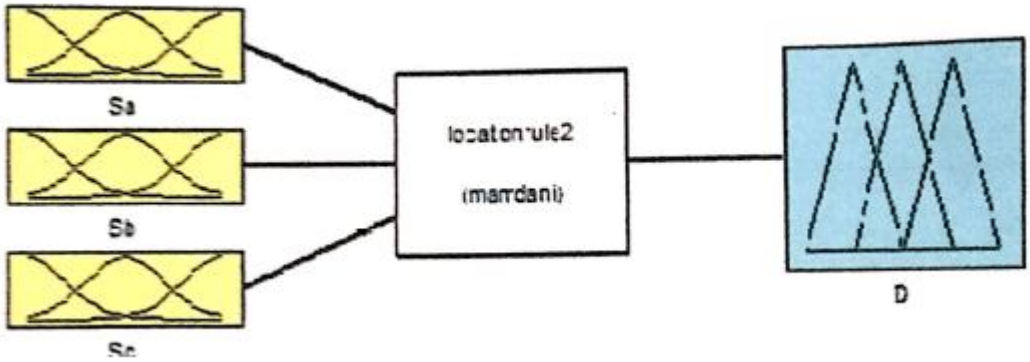


Fig.5 Fuzzy Interference system

Fuzzy Rules for fault locations and various Membership functions are shown.

1	If (S_a is L) and (S_b is L) and (S_c is L) then (D is z10)
2	If (S_a is L) and (S_b is L) and (S_c is M) then (D is z10)
3	If (S_a is L) and (S_b is L) and (S_c is H) then (D is z9)
4	If (S_a is L) and (S_b is M) and (S_c is L) then (D is z9)
5	If (S_a is L) and (S_b is M) and (S_c is M) then (D is z8)
6	If (S_a is L) and (S_b is M) and (S_c is H) then (D is z8)
7	If (S_a is L) and (S_b is H) and (S_c is L) then (D is z9)
8	If (S_a is L) and (S_b is H) and (S_c is M) then (D is z7)
9	If (S_a is L) and (S_b is H) and (S_c is H) then (D is z7)
10	If (S_a is M) and (S_b is L) and (S_c is L) then (D is z9)
11	If (S_a is M) and (S_b is L) and (S_c is M) then (D is z6)
12	If (S_a is M) and (S_b is L) and (S_c is H) then (D is z6)
13	If (S_a is M) and (S_b is M) and (S_c is L) then (D is z5)
14	If (S_a is M) and (S_b is M) and (S_c is M) then (D is z5)
15	If (S_a is M) and (S_b is M) and (S_c is H) then (D is z4)
16	If (S_a is M) and (S_b is H) and (S_c is L) then (D is z6)
17	If (S_a is M) and (S_b is H) and (S_c is L) then (D is z6)
18	If (S_a is M) and (S_b is H) and (S_c is H) then (D is z3)
19	If (S_a is H) and (S_b is L) and (S_c is L) then (D is z8)
20	If (S_a is H) and (S_b is L) and (S_c is M) then (D is z5)
21	If (S_a is H) and (S_b is L) and (S_c is H) then (D is z3)
22	If (S_a is H) and (S_b is M) and (S_c is L) then (D is z3)
23	If (S_a is H) and (S_b is M) and (S_c is M) then (D is z2)
24	If (S_a is H) and (S_b is M) and (S_c is H) then (D is z2)
25	If (S_a is H) and (S_b is H) and (S_c is L) then (D is z1)
26	If (S_a is H) and (S_b is H) and (S_c is M) then (D is z1)
27	If (S_a is H) and (S_b is H) and (S_c is H) then (D is z1)

Fig.6 Fuzzy Rules

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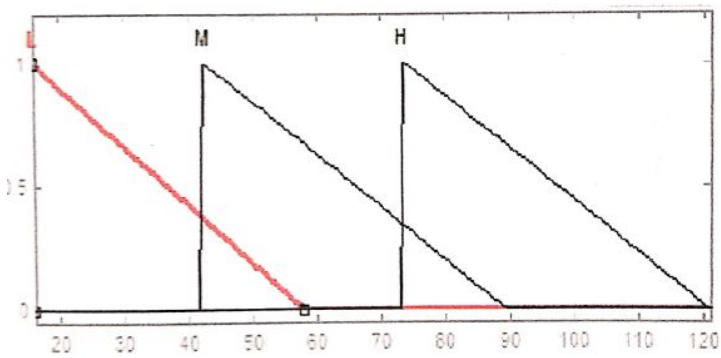


Fig.7 Membership Function for input variable Sa

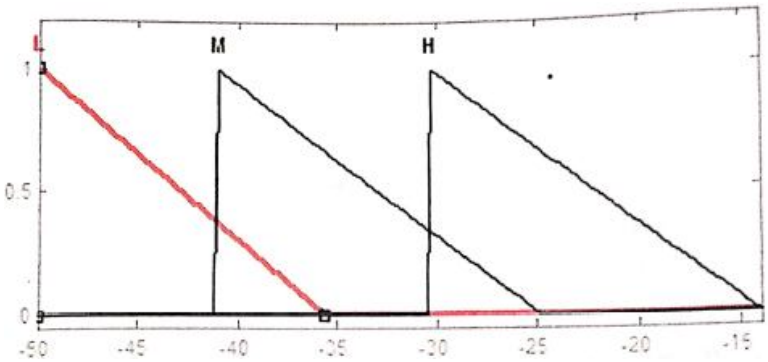


Fig.8 Membership Function for input variable Sb

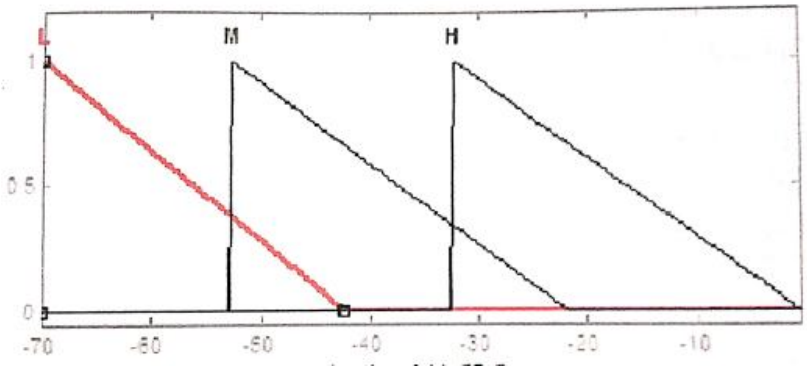


Fig.9 Membership Function for input variable Sc

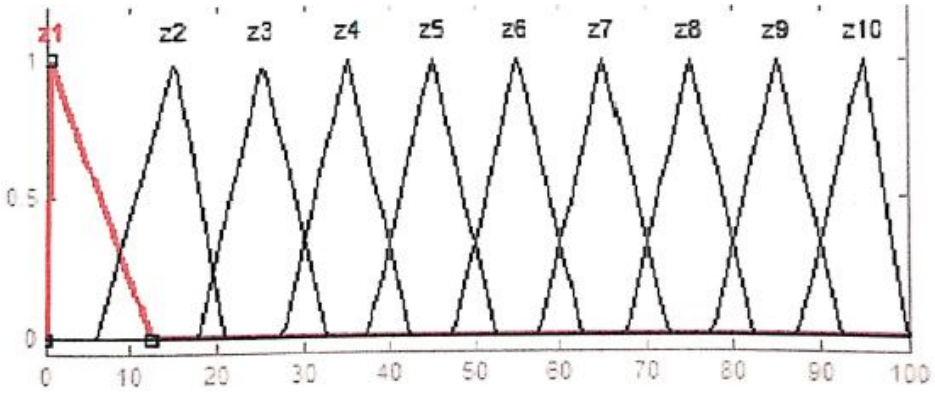


Fig.10 Membership Function for output variable D

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VI. RESULTS

The current waveforms for various types of faults are shown below.

A. LLL Fault in the Distance Range of 40-49 km

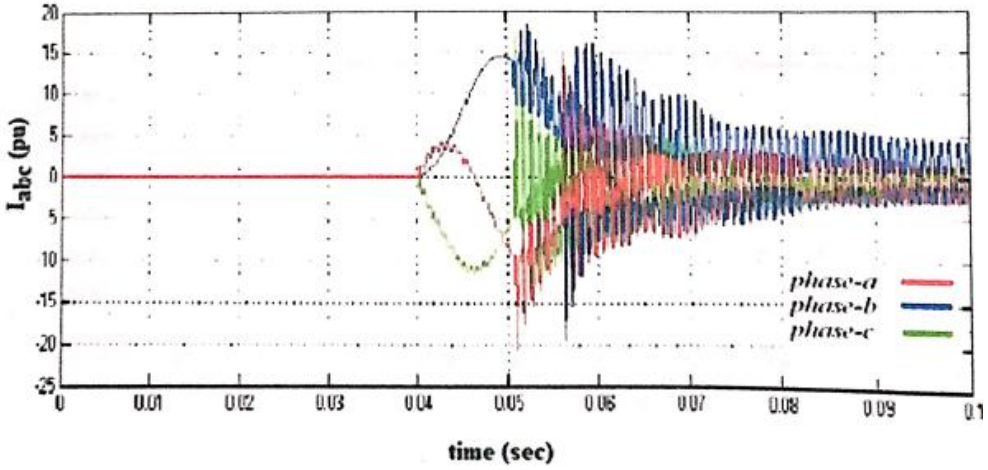


Fig.11 Iabc waveform for LLL fault

B. LG Fault in the Distance Range of 40-49 km

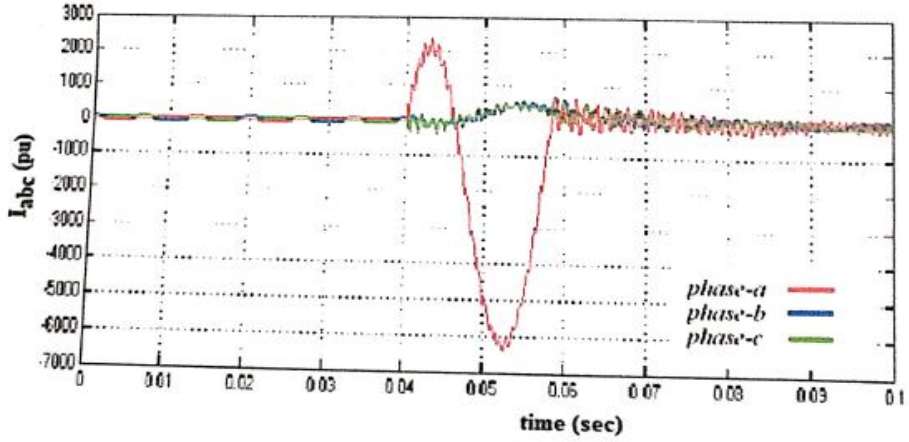


Fig.12 Iabc waveform for LG fault

C. LL Fault in the Distance Range of 40-49 km

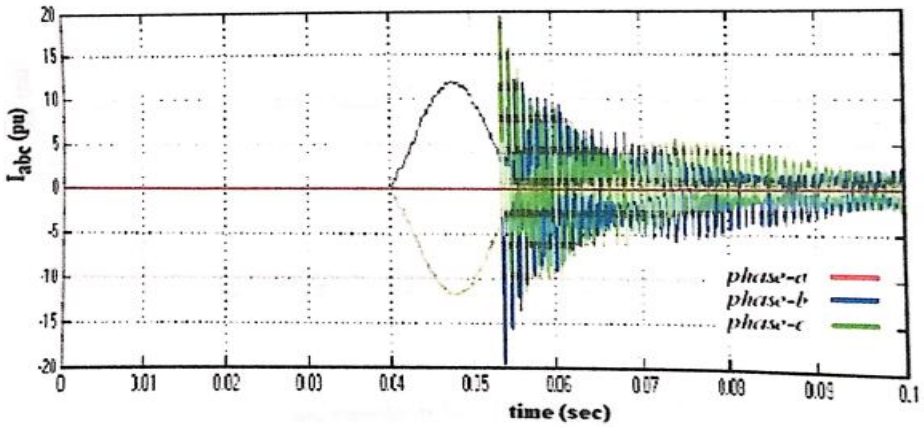


Fig.12 Iabc waveform for LL fault

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D. LLG Fault in the Distance Range of 40-49 km

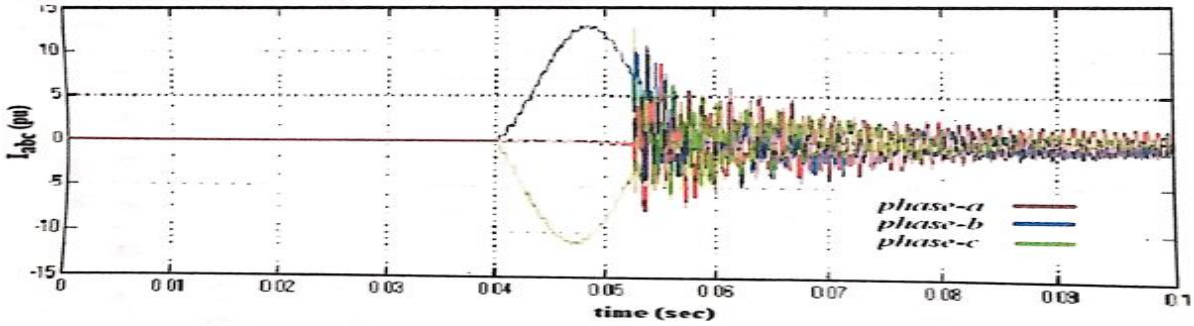


Fig.13 Iabc waveform for LLG fault

In the same way, the current waveforms for various types of faults in different ranges of fault location have been obtained and are tabulated below:

RANGE OF THE FAULT LOCATION	ELEMENTS	TYPES OF FAULTS			
		LLL	LG	LL	LLG
(40-49km)	t_1(ms)	49	36	50	50
	t_2(ms)	53	40	54	54
	Distance (km)	44.17	44.17	44.17	44.17
(60-69km)	t_1(ms)	61.5	61	71	64
	t_2(ms)	70	70	80	73
	Distance (km)	62.5	63.1	63.1	63.1
(70-73km)	t_1(ms)	70	70	70	70
	t_2(ms)	84	84	84.7	84
	Distance (km)	70.38	70.38	71	70.38

Fig.14 Simulation Result Analysis

The Fuzzy Output in the range of 60-69 km is shown. Hence the fault location is 65 km.

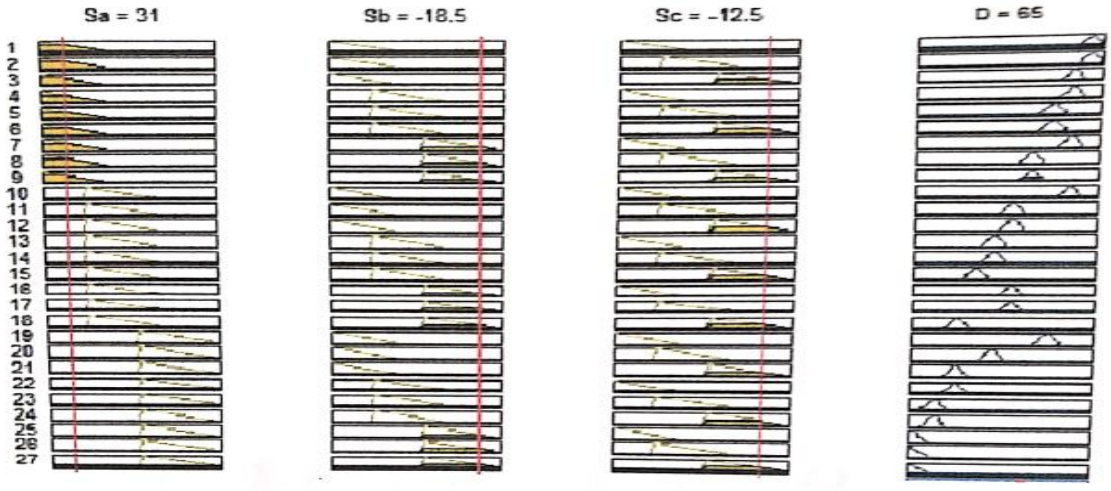


Fig.15 Fuzzy Output

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VII. CONCLUSIONS

An efficient methodology has been described in this paper to solve the problem of detection and location of faults in transmission line in a power system. In this paper, the fuzzy combined wavelet MRA theory is employed to detect and classify the fault on a transmission line. Accurate location of the fault is useful for improving the protection of power system equipment. It presents a simple analytical approach for quick location of faults.

An advantage of this proposed method is the capability of locating faults over the wide range of lengths. The results show that the solution method is practical and valid for real time operation. The property of multi resolution in time and frequency using wavelets is found very effective for this problem. This is simple, robust and can be used for identification of high impedance faults as well. It is seen that expert evaluation is extremely useful when used in fuzzy interference system to extract important features embedded in fault current signal as theses signals are having uncertainties, being in raw data form. The efficiency of proposed approach has been validated through case studies and seems to be promising for real time digital relay applications, owing to its accuracy for fault location, which would lead to faster maintenance and restoration of power supply.

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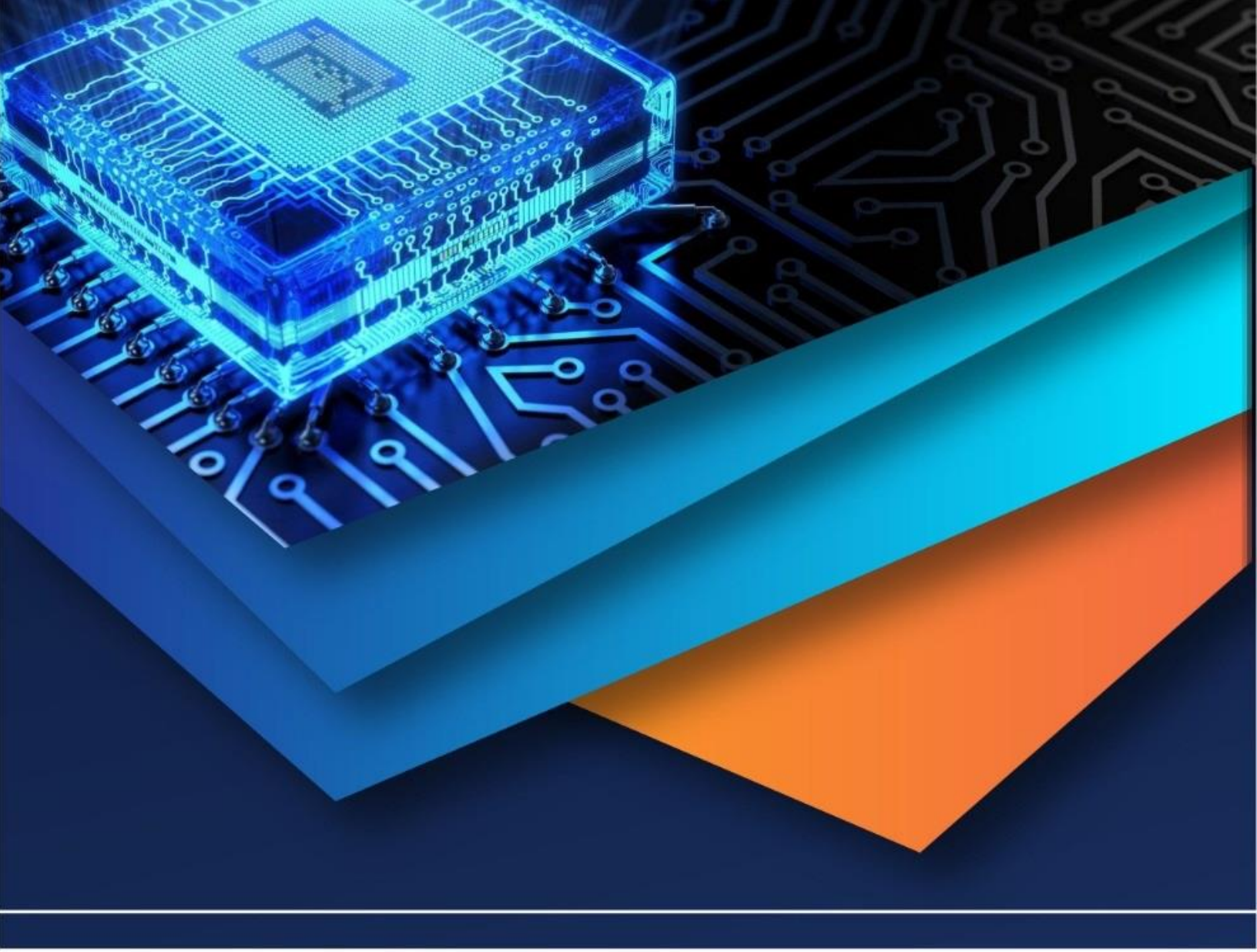
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