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Fault Detection and Classification on a High voltage Transmission Line Using Wavelet Transforms

Kumar Raja Thokala [1], Baddu Naik B[2]
[1, 2] Department of Electrical and Electronics Engineering, Prasad V. Potluri Siddhartha Institute of Technology, Vijayawada, Andhra Pradesh, India

Abstract*: Electrical power system consists of many different complex dynamic and interacting elements, which are always prone to disturbance or an electrical fault. Transmission lines are exposed to atmosphere, the faults due to transmission lines are about 50% as compared to different types of faults that occur in the power system. The faults on electrical power system transmission lines are supposed to be first detected and then be classified correctly and should be cleared in least fast as possible time. This paper describes a fault-detection technique of faults in high voltage transmission lines using the wavelet transform. The wavelet transform (WT) has been successfully applied in many fields. The technique is based on using the absolute sum value of coefficients in multi resolution signal decomposition (MSD) based on the discrete wavelet transform (DWT). A fault indicator and fault criteria are then used to detect the faults in the transmission line. Wavelet transform is best suited for fault detection and classification. This paper describes a new fault detection technique which involves capturing the current signals generated in a system under faults. The detection process is based on calculating the absolute sum of the wavelet transform detail coefficients for one period. Wavelet transform is used for the decomposition of signals and feature extraction.
Keywords*: Wavelet transforms, Transmission lines, Electrical network parameters

I. INTRODUCTION

Transmission lines are important component in power system because electric energy is transferred through it to a long distance. So the study of fault analysis on transmission line is very important. Conventional relays are designed for transmission line protection is broadly over current, over voltage and distance relays etc. Conventional method of fault detection and classification are unreliable due to large power system.

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 [1] 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 [2-3]. 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 [4].

In the past two decades many techniques have been proposed to improve the detection of HIF in Power distribution systems. Some of these methods are mechanical methods [5], in these methods some devices are used to provide low impedance by catching the falling conductor. The installation and maintenance cost is very high. Electrical methods [6] such as proportional relay algorithm, arc detection methods, Kalman filtering method [7], low order current harmonic method [8,9], but each method has its own drawback. The early work examined arc frequency relaying and high frequency current detection but is not successful. The ratio ground relay was designed to trip for a fallen conductor, but the relay was more sensitive to earth faults than by simply measuring earth fault current. The Nordon HIF system monitored based on the third harmonic current calculations, but the system is installed on each breaker in the distribution system, but the cost increases. The reason for avoiding the power system frequency and its harmonics was that those signals vary substantially under normal as well as arcing conditions. Various techniques of fault detection encompass fractal techniques [10], expert systems, and dominant harmonic vectors. The availability of powerful microprocessors

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and signal processing algorithms has led to a wide range of new techniques to identify the waveforms associated with high impedance fallen conductor faults.

In the 1960s, the relays are electromechanical in nature. Such relays utilized flux generated due to fault voltages or currents to produce torque. Positive torque results in forces that tend to close the trip contacts to open the circuit breaker. In conventional methods phase current or voltage or instantaneous values of current or voltage are directly used as relay inputs. In this thesis Wavelet multi resolution analysis is found to be most suitable for extracting the information from transient fault signals. Second and third order harmonics are dominant in the fault signals and are hence chosen for the analysis (d6 coefficients) and Db4 as mother wavelet. Using wavelet MRA technique, the summation of detail coefficients for sixth level are extracted from the current signal. From the magnitude of detail coefficient summations, the presence of fault in a particular phase is detected. A generalised algorithm based on wavelets has been verified for the classification of transmission line faults. The most important of this algorithm is independent of fault location, impedance and inception angle.

II. WAVELET TRANSFORM

The fault current signals are non-stationary in nature. Therefore, conventional Fourier transform and short time Fourier transforms are inadequate to deal with such signals. The Wavelet theory and its applications are rapidly developing fields in applied mathematics and signal analysis. The wavelet transform is a tool that divides up data into different frequency components, and then evaluates each component with a resolution matched to its scale. The wavelet transform is useful in analysing the transient phenomena associated with transmission -line faults and/or switching operations. Wavelet analysis is the breaking up of a signal into shifted and scaled version of the original (or mother) wavelet. Scaling a wavelet means stretching (or compressing) it. Shifting a wavelet simply means delaying its onset [4]. Analogous to the relationship between continuous Fourier transform (FT) and Discrete Fourier Transform (DFT), the continuous wavelet transform (CWT)[11] has a digitally implement able counterpart known as the Discrete Wavelet Transform (DWT).

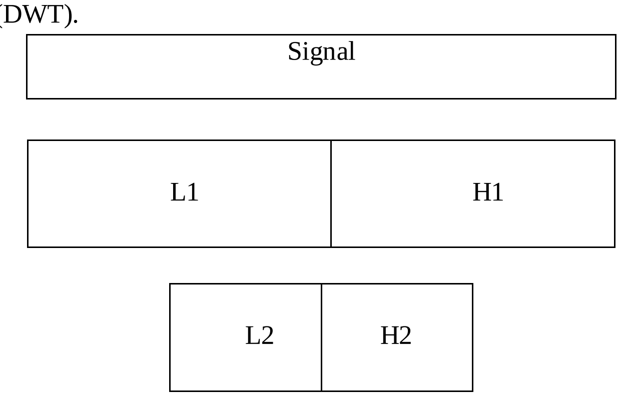
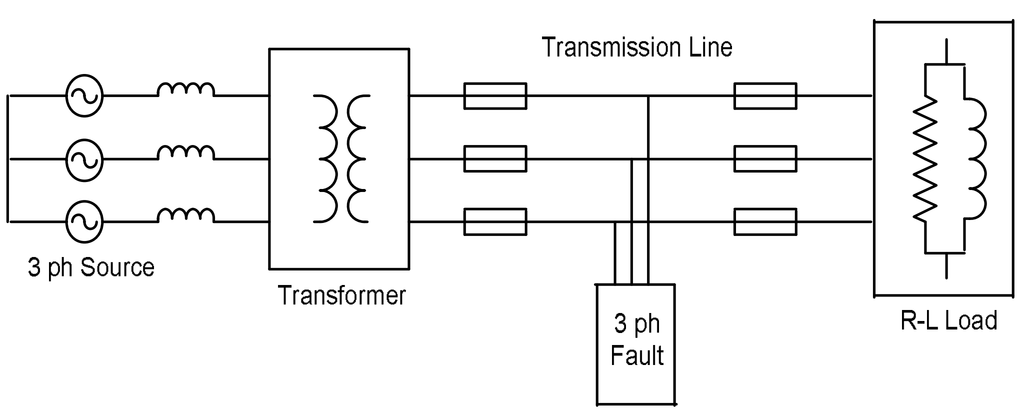


Fig.1. Channel analysis filter bank

III. FAULT CASES STUDY AND RESULTS

A 3 phase transmission line rated 400kV and length of line is 300km has been considered. The circuit diagram of the transmission line fault analysis is shown in figure.



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The fault analysis of transmission lines involves transient phenomena. Therefore, the positive, negative and zero sequence parameters of the source as well as transmission lines are necessary. The various line parameters pertaining to source as well as transmission line are shown in table. An active load of 500MW and a reactive load of 20MVAR (inductive) are used for the analysis. The fault may appear at any instant of time, and thus voltage or current ranging from 0 to 360 degrees. The angle at which fault occurs is called fault inception angle and it effects the amplitude of fault current. The fault distance changes then corresponding line impedance changes which is going change the fault current. Fault resistance also affects the fault current. Fault resistance increases fault current decreases [3]. Different types of power system faults are created using simulation model as shown, at different fault distances having different fault inception angles with different fault resistance. The wave forms are shown below.

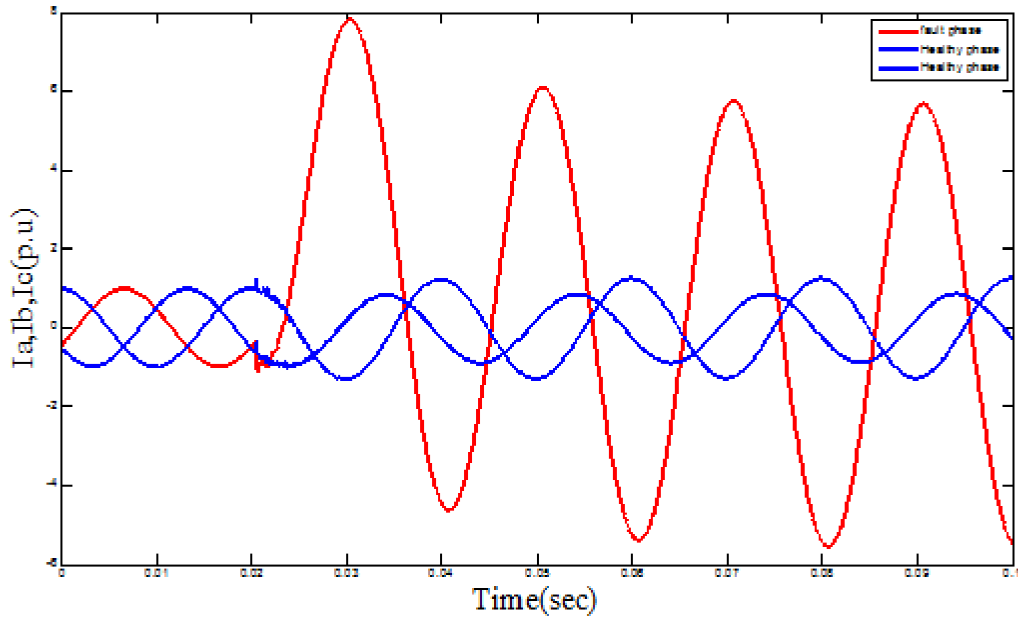

Fig.4 Ia, Ib, Ic for AG Fault at D==100Km, FIA=0, Rf=0.001Ω

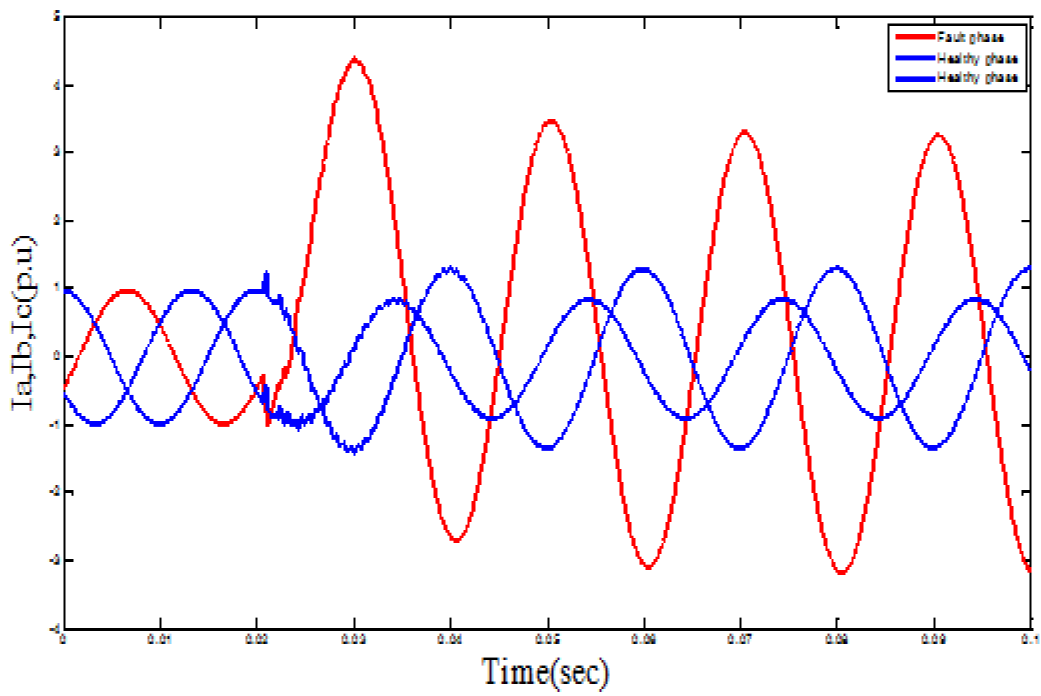

Fig.5 Ia, Ib, Ic for AG Fault at D==200Km, FIA=0, Rf=0.001Ω

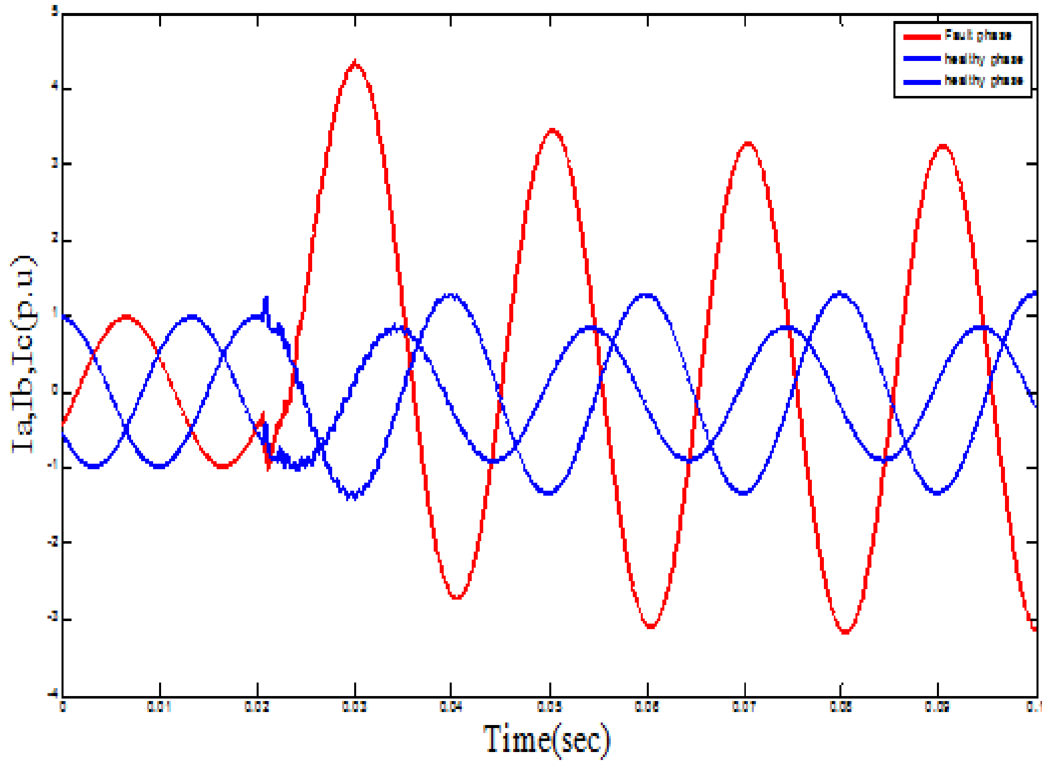

Fig.6 Ia, Ib, Ic for AG Fault at D==200Km, FIA=0, Rf=1Ω

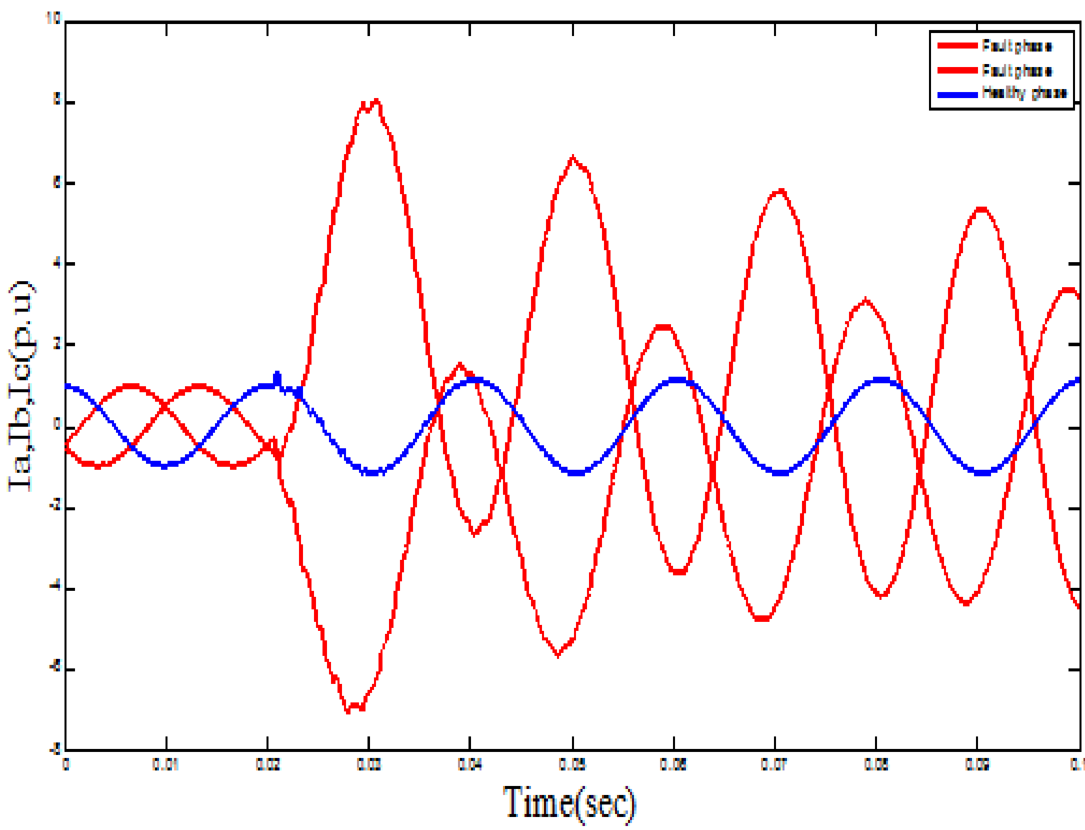

Fig.7 Ia, Ib, Ic for ABG Fault at D==200Km, FIA=0, Rf=1Ω

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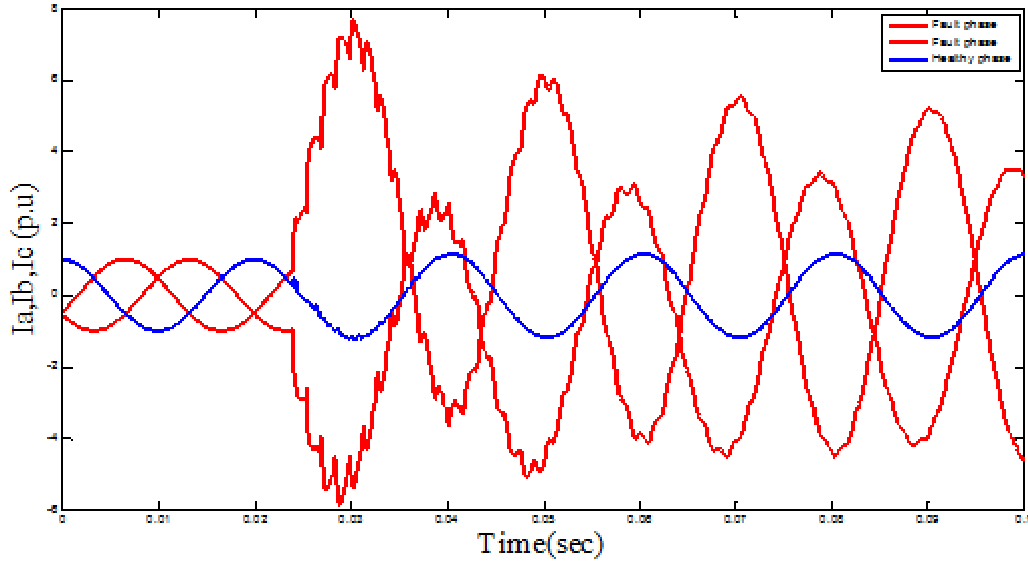
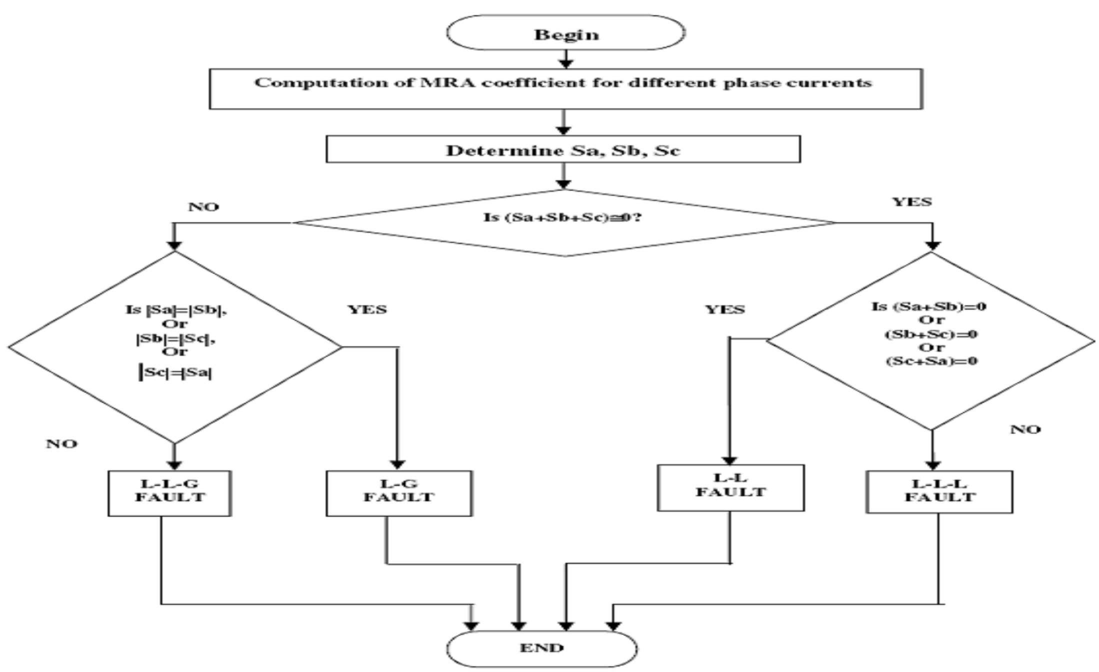


Fig.8 Ia, Ib, Ic for ABG Fault at D==200Km, FIA=60, Rf=1Ω

IV. FAULT DETECTION AND CLASSIFICATION ALGORITHM

Based on the sampling rate the signal is divided into 12 decomposition levels. Among different levels only 6th level is consider for analysis because the frequency corresponding to this level is covering 2^{nd} and 3^{rd} harmonics which are dominant in the fault conditions. Based on 6^{th} level detail coefficients, an efficient algorithm proposed [3]. The transmission line faults in a power system are usually classified as L-G, L-L-G, L-L and L-L-L. Let Sa, Sb, Sc be the coefficients obtained from the summation of 6th level wavelet detail coefficients for currents in phases A,B, and C. When the algebraic sum of Sa, Sb, Sc is zero, then it can be either L-L-L or L-L. To differentiate these two, the summation of any two phases is zero, and remaining healthy coefficient is very small value in L-L fault. Algebraic sum is not equal to zero, then it be either L-G or L-L-G. If the absolute values of any two coefficients are equal and much smaller than absolute value of remaining coefficients, then it is L-G fault. If the absolute value of any two coefficients is not equal to zero and is always much higher than the absolute value of remaining coefficients, then it is a L-L-G. The results tabulated show the efficiency of the fault classification of algorithm using db4 wavelet for different fault locations, fault resistances and FIA and the algorithm was verified.



L-L fault with different fault distances the values of S_a, S_b, S_c with FIA=0^0

	10(km)	30 (km)	50(km)	70(km)	90(km)	100(km)	150(km)	200(km)
S_a	5.5206	3.6877	2.8239	2.3508	2.0473	1.9327	1.5714	1.3852
S_b	-5.5007	-3.6679	-2.8041	-2.3310	-2.0275	-1.9129	-1.5514	-1.3652
S_c	-0.0199	-0.0197	-0.0197	-0.0198	-0.0198	-0.0198	-0.0199	-0.0199

TABLE II

L-G fault with different fault distances the values of S_a, S_b, S_c with FIA= 0^0

	10(km)	30 (km)	50(km)	70(km)	90(km)	100(km)	150(km)	200(km)
S_a	15.0673	7.3082	4.9285	3.7782	3.0993	2.8547	2.1021	1.7146
S_b	-0.0126	0.0073	0.0132	0.0156	0.0168	0.0171	0.0174	0.0193
S_c	-0.0978	-0.0776	-0.0717	-0.0694	-0.0682	-0.068	-0.0678	-0.0695

TABLE IIII

L-L-L fault with different fault distances the values of S_a, S_b, S_c with FIA=0

	10(km)	30 (km)	50(km)	70(km)	90(km)	100(km)	150(km)	200(km)
S_a	24.1143	14.0759	10.0703	7.9054	6.5395	6.0234	4.4194	3.5874
S_b	12.4673	6.7206	4.4424	3.2236	2.4647	2.1783	1.2965	0.8346
S_c	-36.581	-20.796	-14.512	-11.129	-9.0041	-8.2017	-5.7159	-4.4220

V. MATLAB/SIMULINK RESULTS

Case: 1 Transmission line Fault analysis

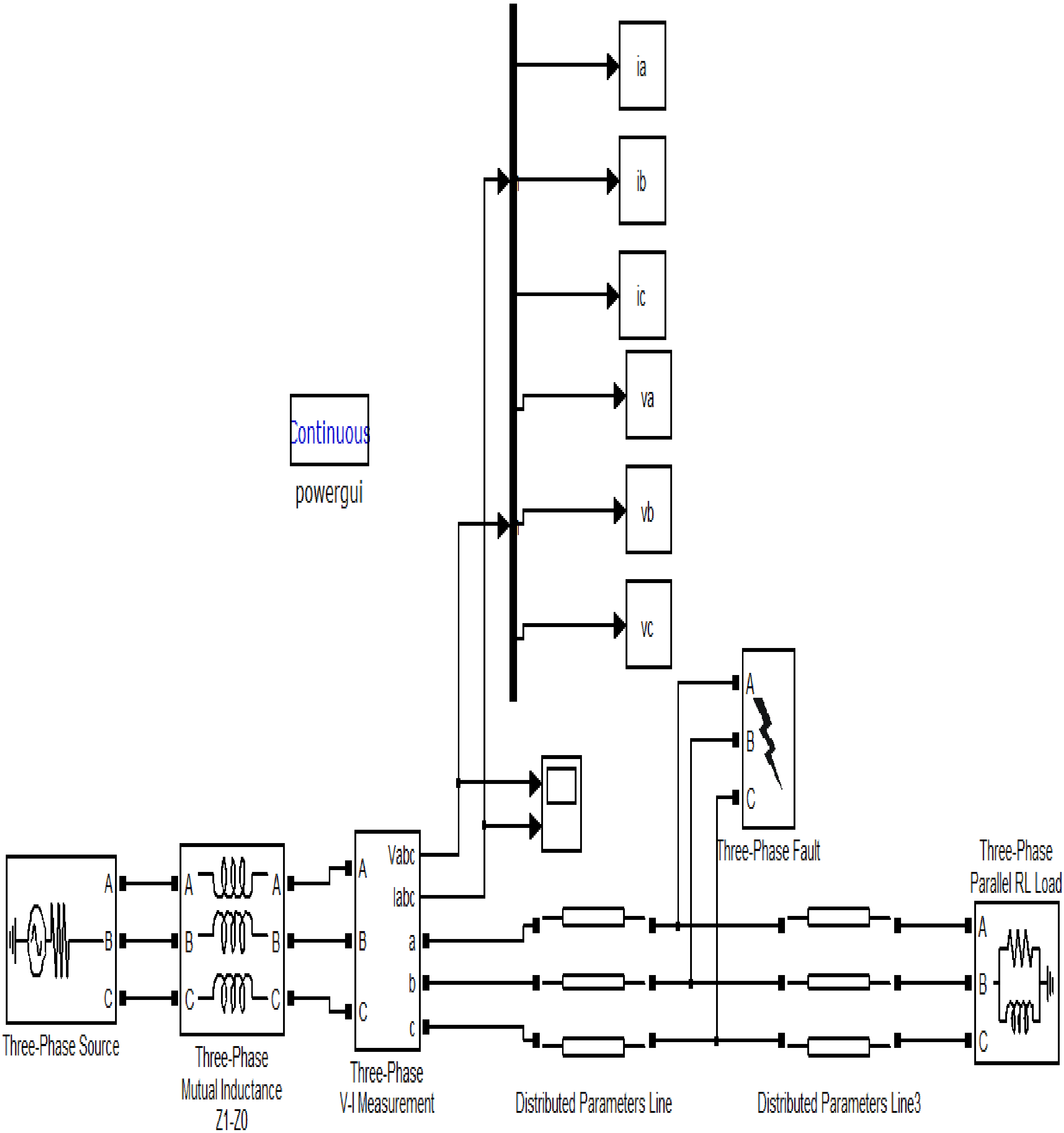


Fig.3 Simulink Model for Transmission line Fault analysis

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Case: 2 High Impedance Fault (HIF) Detection &Classification

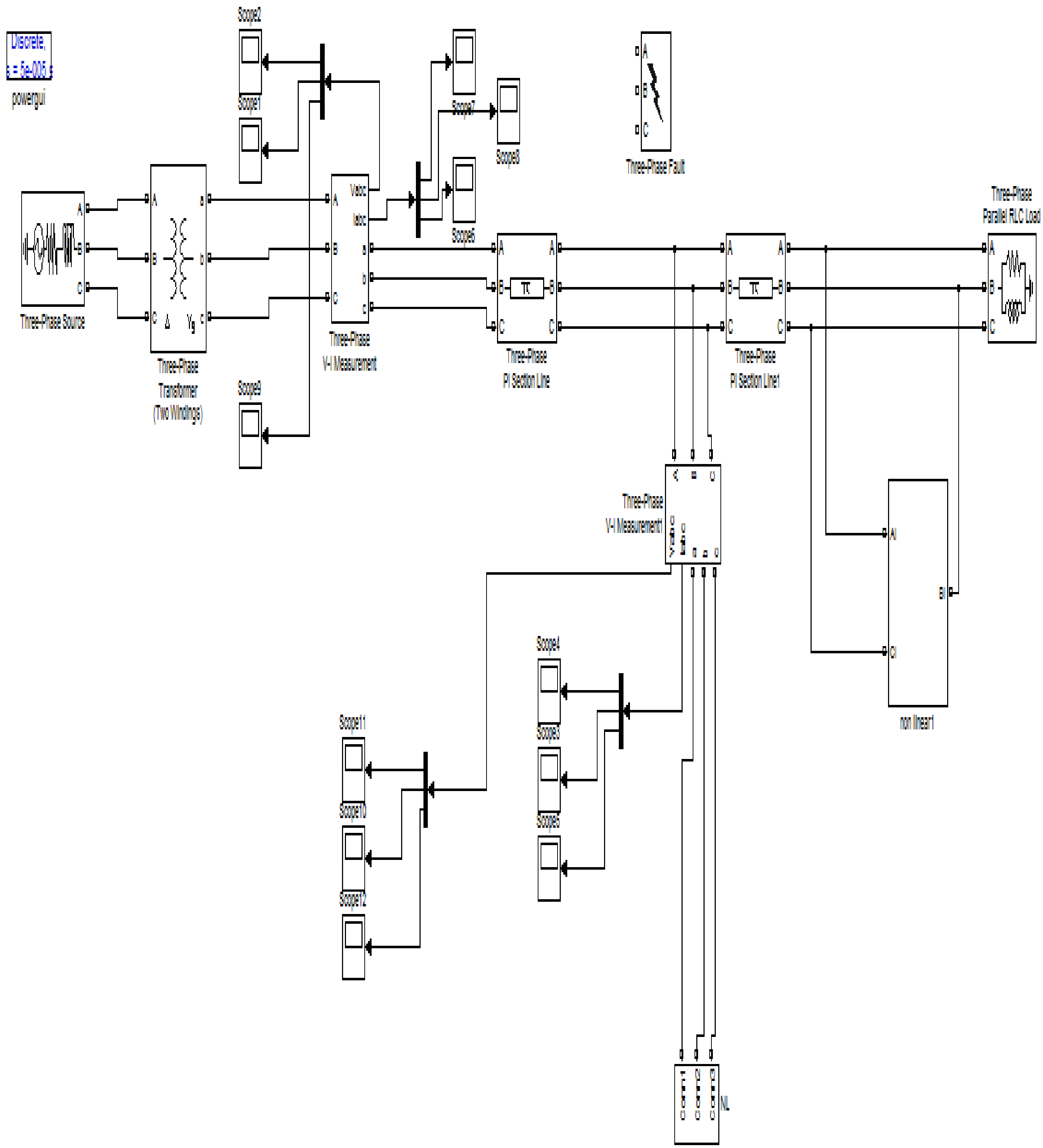

Fig.16 Simulation model of the Distribution system

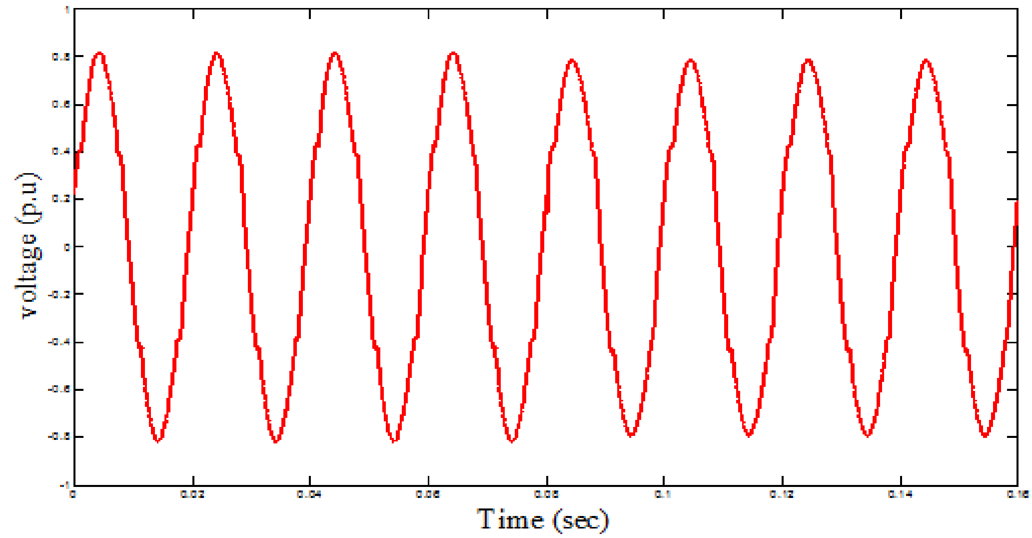

Fig.17 Source voltage under HIF

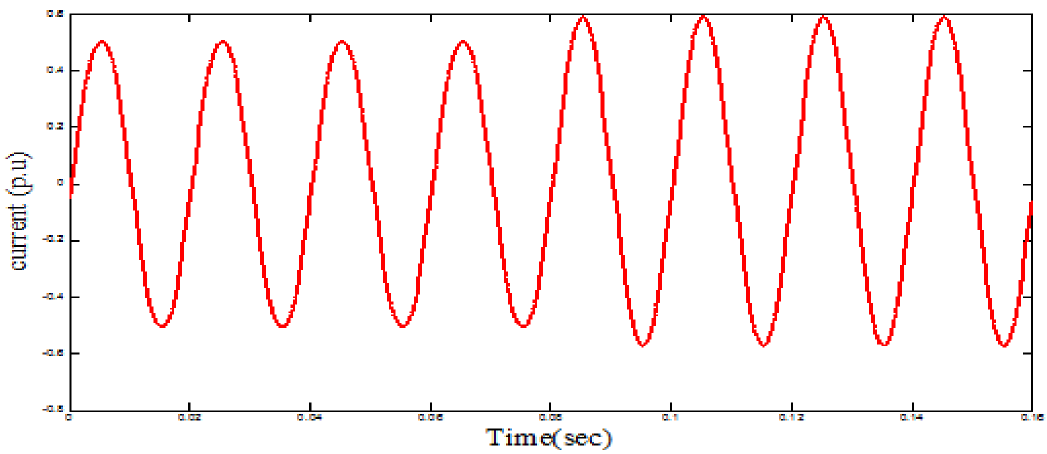

Fig.18 Source current under HIF

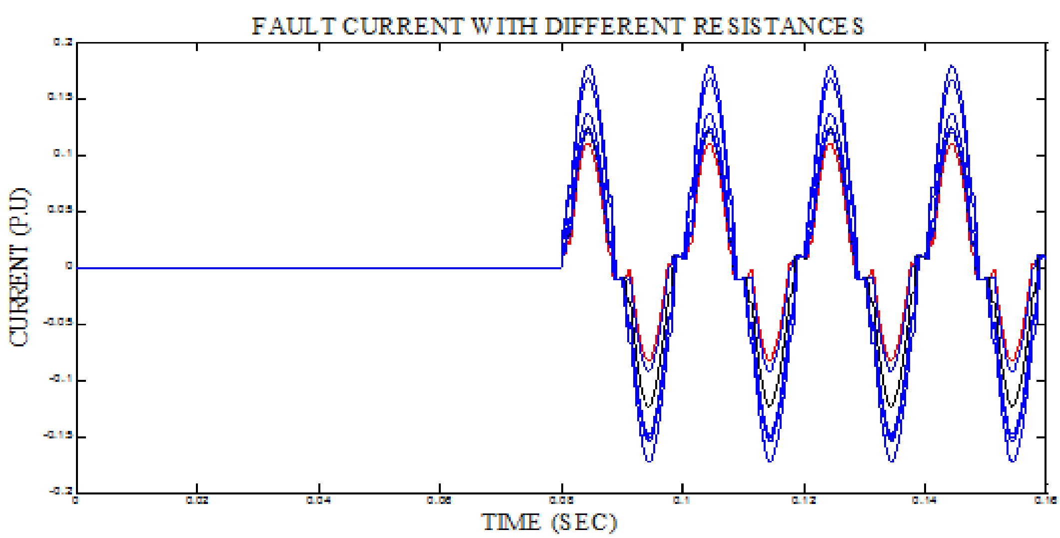

Fig.19 Typical Fault Current with different resistances

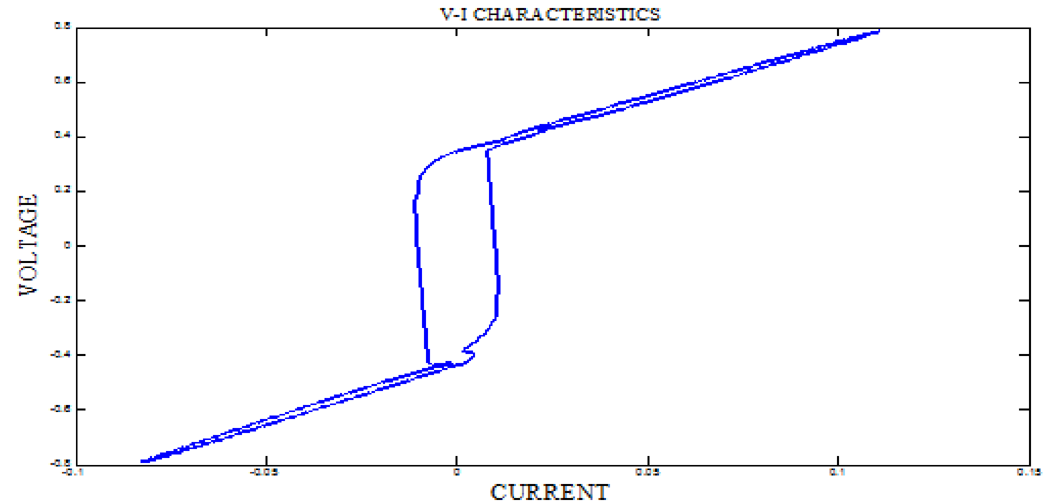

Fig.20 V-I Characteristics of HIF

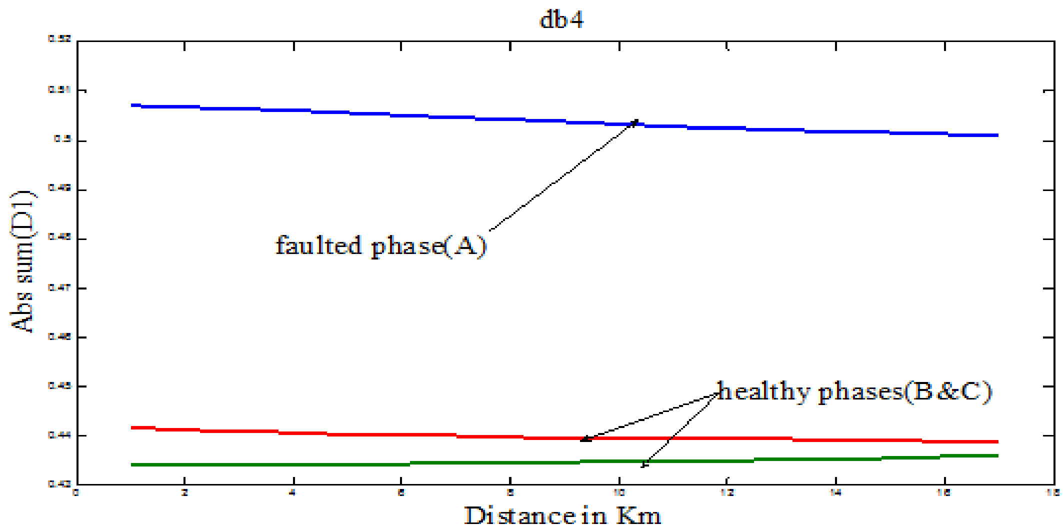

Fig.21 db4 as mother wavelet

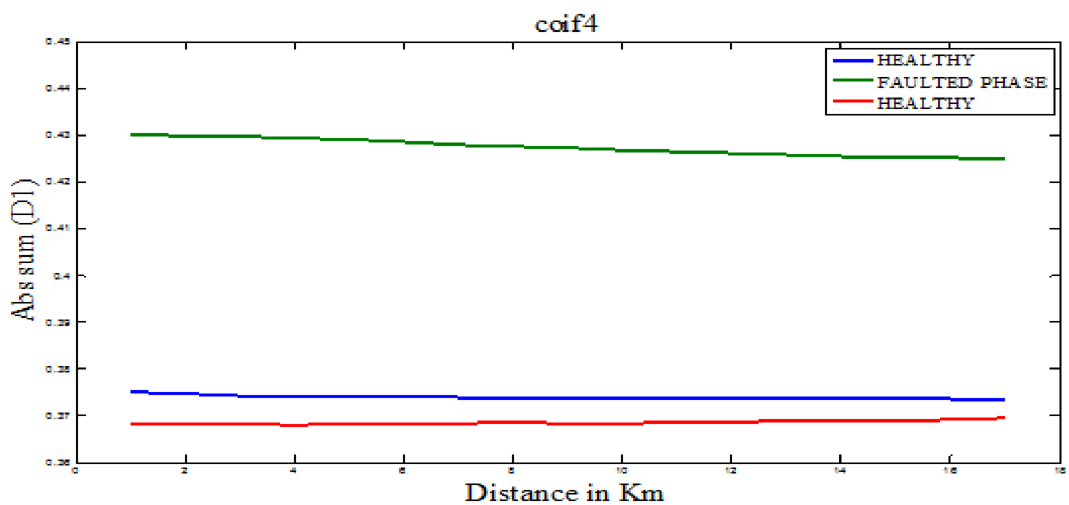

Fig.22 Coif4 as mother wavelet

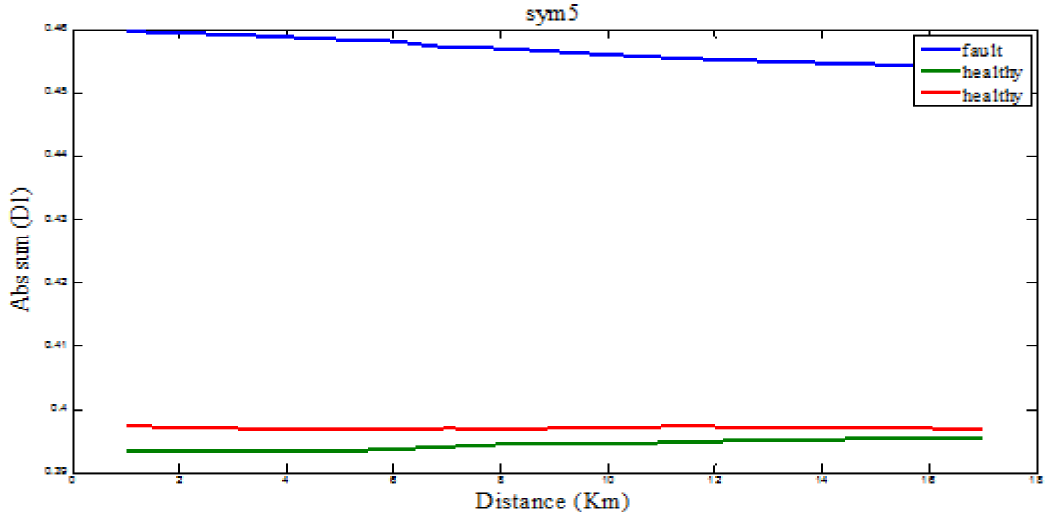

Fig.23 Sym5 as mother wavelet

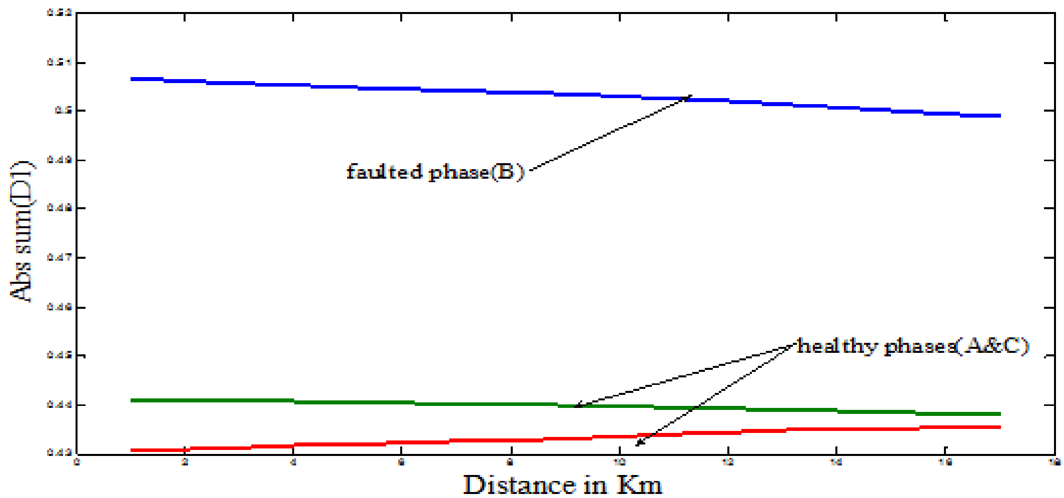

Fig.24 Fault on B phase

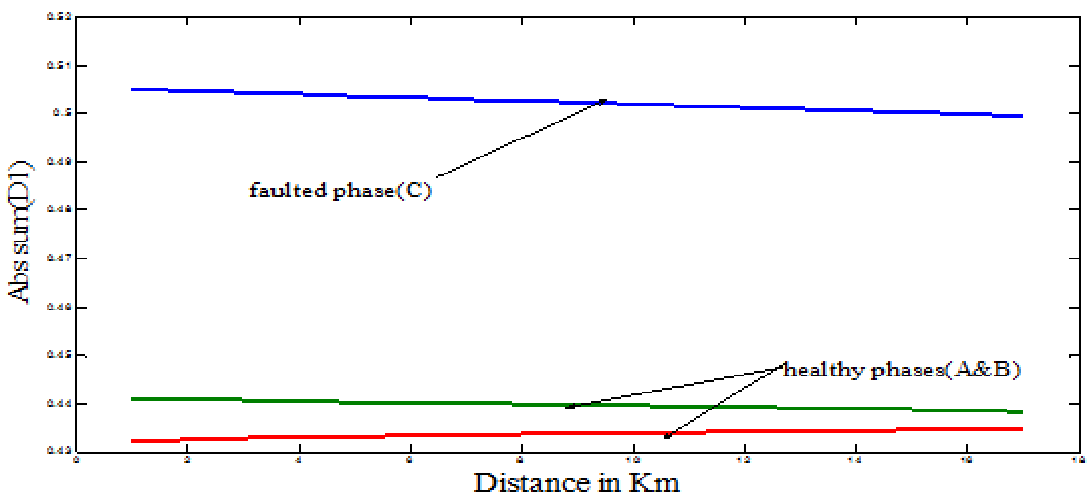

Fig.25 Fault on C phase

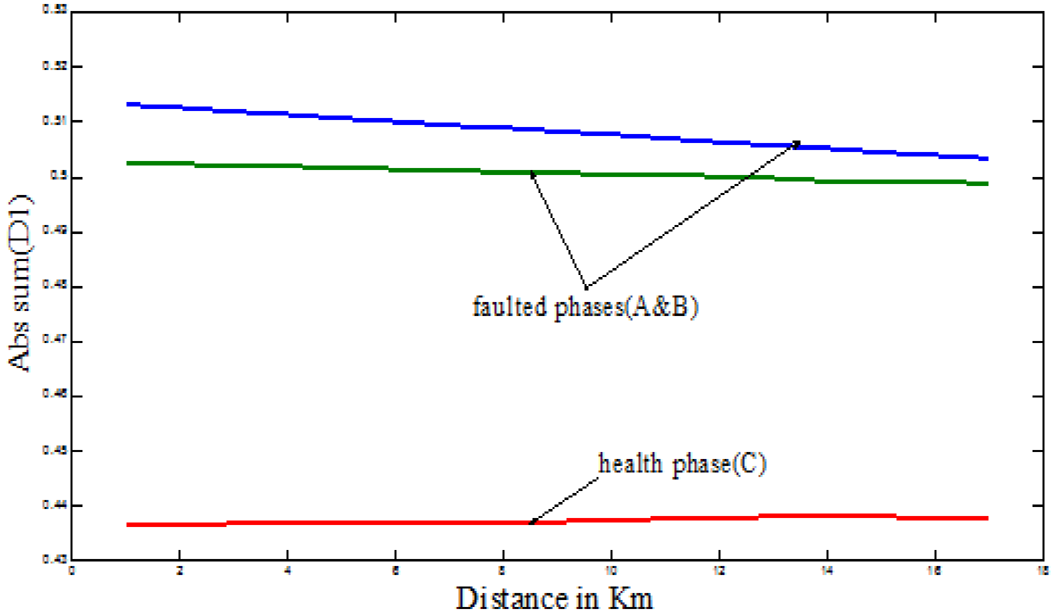

Fig.26 Fault on two phases

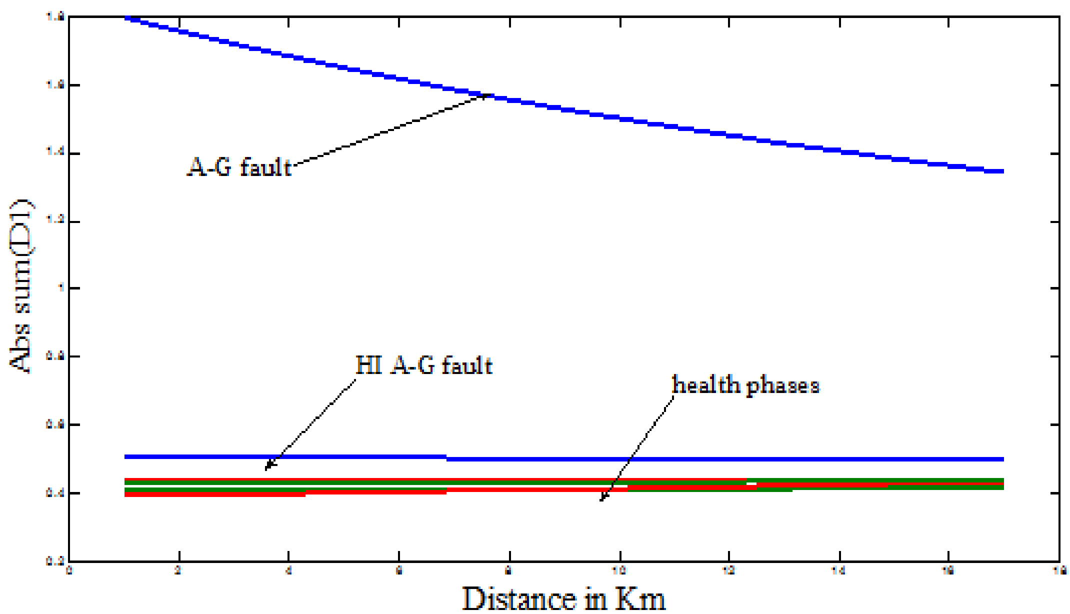

Fig.27 Comparison of HIF with A-G Fault

VI. CONCLUSION

Wavelet multi resolution analysis is found to be most suitable for extracting the information from transient fault signals. Second and third order harmonics are dominant in the fault signals and are hence chosen for the analysis (d6 coefficients) and Db4 as mother wavelet. Using wavelet MRA technique, the summation of detail coefficients for sixth level are extracted from the current signal. From the magnitude of detail coefficient summations, the presence of fault in a particular phase is detected. A generalized algorithm based on wavelets has been verified for the classification of transmission line faults. The most important of this algorithm is independent of fault location, impedance and inception angle. S-Transform is an extension to the idea of wavelet transform, and is based on a moving and scalable localizing Gaussian window. It can be used for the detection of power system fault analysis

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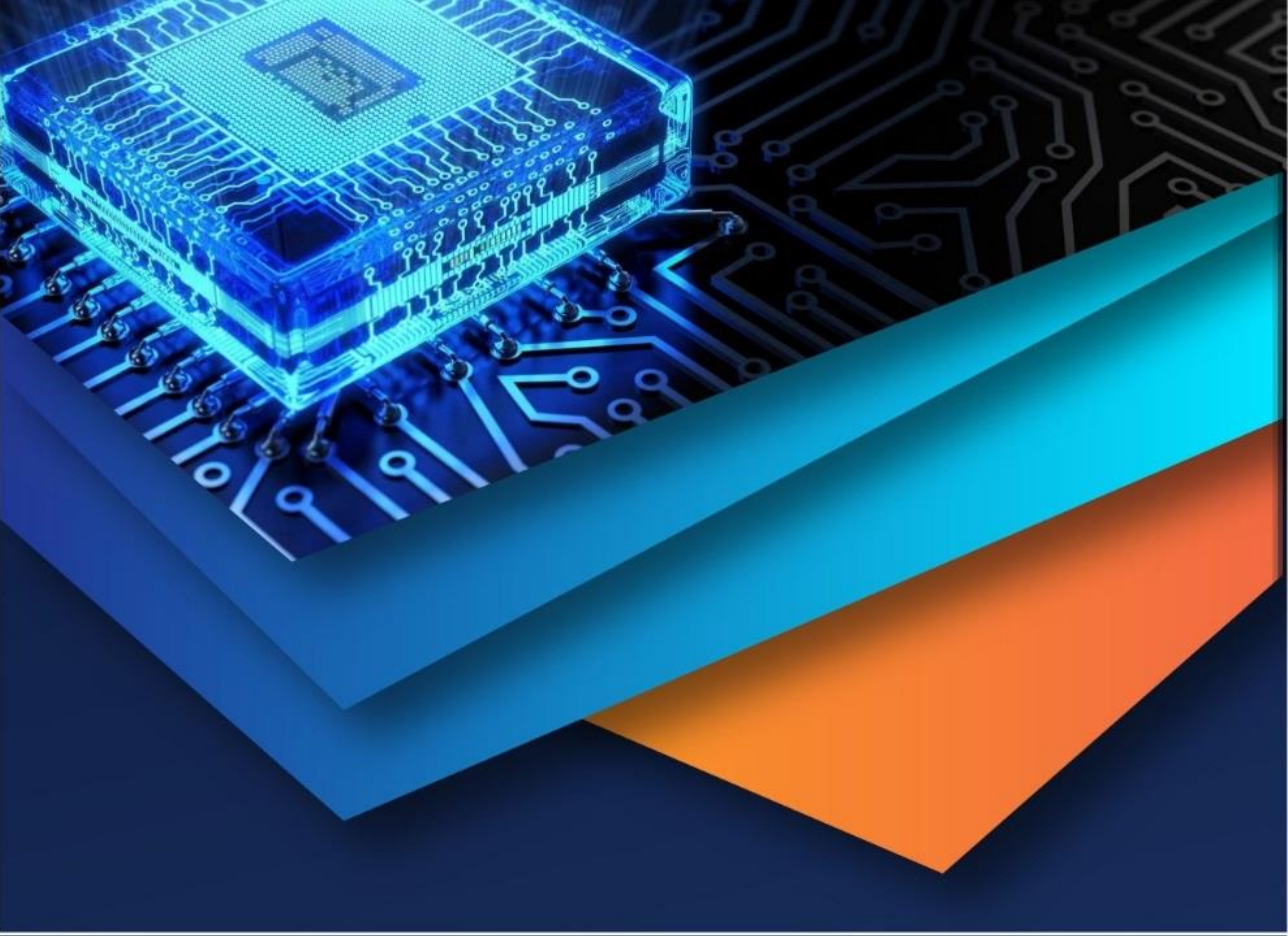

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