Wavelet Approach for Transient Current based Multi Terminal Transmission System Protection Scheme

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***Abstract*— This paper presents a wavelet based protection scheme for a multi terminal transmission system. A wavelet based multi resolution analysis is used to find the detailed coefficients of the signals which are utilized to calculate fault index. These fault indexes are compared with the threshold value to detect and classify faults on transmission system. The proposed algorithm is proved for the detection, classification and location of faults on Transmission lines which is almost independent of fault impedance, fault inception angle and fault distance of transmission line.**

Keywords: Wavelet transforms transmission line, fault, and power system protection.

I. INTRODUCTION

Modern power system networks have grown in complexity and the increased deregulation of utility markets have helped dedicated fault locator systems garner much attention. Traditional electro-mechanical distance relays can be considered the first in a series of attempts to realize the aim of fault distance location. However, these were designed to provide rapid and reliable indication of the general faulted area rather than furnish fault distance estimates with pin-point accuracy.

Distance relay based protection is a non-unit system of protection that provides economic and technical advantages when installed on critical high-voltage power transmission lines. Unlike over-current relays, the fault convergence of distance relays is independent of source impedance variations [1]. The basic principle that all distance relays work on is the linear relationship between transmission line impedance and its length [2].

In the past decades, the development of fault diagnosis for the power system has progressed with the applications of wavelet transform. However, the work rarely mention about the location of fault on multi terminal. Thus, nowadays several decision algorithms for locate of fault on multi-terminal have been proposed [3-5].but several algorithms have different solutions and technique.

Power transmission line protection is one of the most important concerns for the power utilities. Different types of fault occur on transmission line. From the transient phenomena, fault on transmission lines need to be detected, classified, locate accurately, and should be cleared as fast as possible. In transmission line protection, fault phase identification and location of fault are the two most important items which need to be addressed in a reliable and accurate manner. Identification and classification of faults on transmission line are essential for relaying decision and auto-reclosing requirements. This paper presents a Wavelet approach for multi terminal transmission system protection scheme.

The Global Position System (GPS) based algorithms with better performance and accuracy have been proposed. There is always a need to develop innovative methods for transmission line protection. In this paper, Wavelet Multi Resolution Analysis is used for detection, classification and location of faults on transmission lines. Detail D1 coefficients of current signals using Bior1.5 wavelets are used to detect, classify and location of fault.

This paper presents an efficient method based on wavelet transforms both fault detection, classification and location which is almost independent of fault impedance, fault location and fault inception angle of multi terminal transmission line fault currents.

II. WAVELET ANALYSIS

Wavelet transform is a mathematical technique used in signal analysis. Wavelet transform is a tool that cuts up data or functions or operators into different frequency components, and then studies each component with a resolution matched to its scale. The advantage of the transform is that the band of analysis can be fine adjusted so that high frequency components and low frequency components are detected precisely. Results from the wavelet transform are shown on both the time domain and the frequency domain. The wavelet transform can expand signals in term of using shift in time as well as compression in time or dilation of a fixed wavelet function named as the mother wavelet. Power transmission line protection is one of the most important concerns for the power utilities set of basic functions called Wavelets, are used to decompose the signal in various frequency bands, which are obtained from a mother wavelet by dilation and translation. Hence the amplitude and incidence of each frequency can be found precisely. Wavelet Transform is defined as a sequence of a function {h (n)}(low pass filter) and {g(n)}(high pass filter).

The selection of mother wavelet is based on the type of application. In the following section a novel method of detection and classification of faults using Multi Resolution Analysis of the transient currents associated with the fault is discussed.

III. TEST SYSTEM

Using the power system block set (PSB) and the SIMULINK software, the test system is simulated. The test system is shown in Fig.1 and simulated model is described in Fig.2.

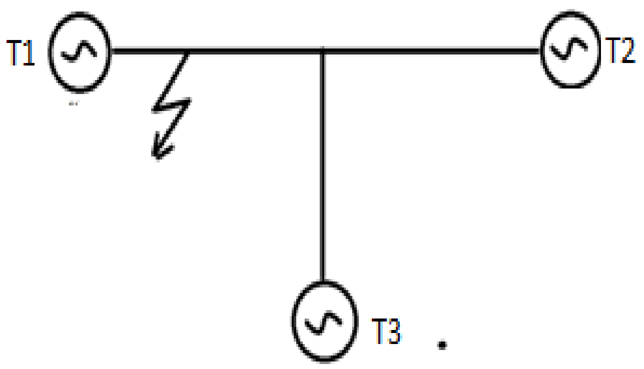


Fig 1. The proposed system model

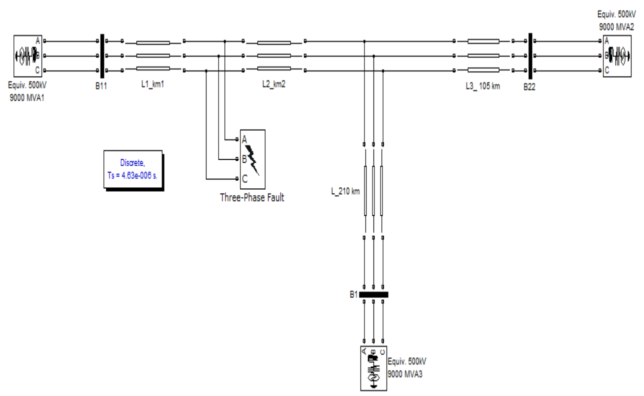


Fig 2. Simulation model for test system

The power system is a 500KV, 9000MVA, 60HZ and 110KM length from each terminal to centre point of three terminal transmission systems. The parameters such as positive sequence parameters, negative sequence parameters and zero sequence parameters of transmission line and positive sequence impedance, negative sequence impedance and zero sequence impedance are assumed here. The threshold value for fault index considered to be 1600.

IV. DETECTION AND CLASSIFICATION OF FAULTS

The three phase currents of the local terminal are analyzed with Bior.1.5 mother wavelet to obtain the detail coefficients ($D1_L$) over a moving window of half cycle length. These $D1_L$ coefficients are then transmitted to the remote end. The detail coefficients received from the remote bus ($D1_R$) are subtracted to the local detail coefficients ($D1_L$) to obtain effective D1 coefficients ($D1_E$). The Fault Index (I_{f1}) of each phase is then calculated..

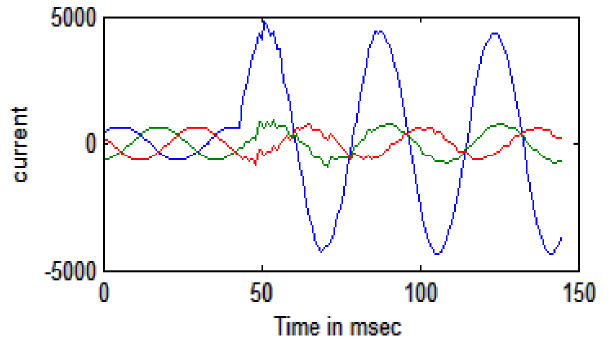


Fig 3. Three Phase currents at AG fault at 40% from the terminal 1

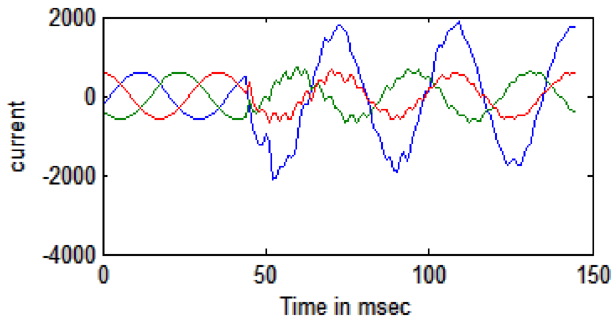


Fig 4. Three Phase currents at AG fault at 40% from the terminal 2

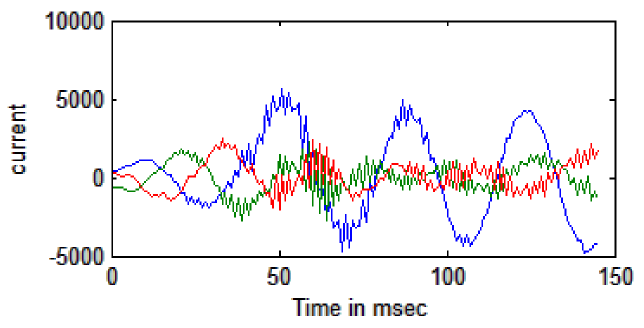


Fig 5. Three Phase currents at AG fault at 40% from the terminal 3

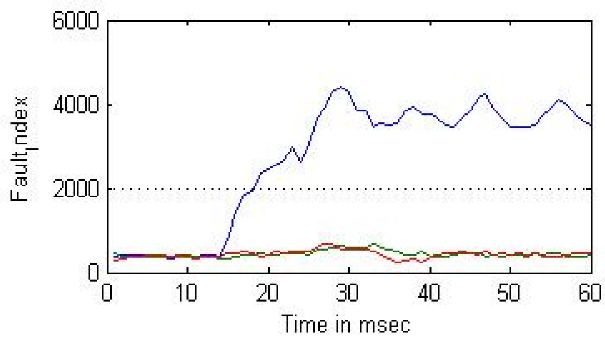


Fig 6. Variation of Fault Index for Phase-A fault from the terminal1 at 40% of the line

Figures 3, 4&5 show the variation of three phase currents for AG fault and Fig. 6 illustrate the variation of Fault Index for phase-A for the same fault.
The types of faults considered in the analysis are L-G, L-L-G, L-L, L-L-L, faults. The simulations show that fault inception angle has a considerable effect on the phase current samples and therefore also on Wavelet transform output of post-fault signals. As the waves are periodic, it is sufficient to study the effect of inception angle in the range of 0^0 to 160^0 in step of 20^0.

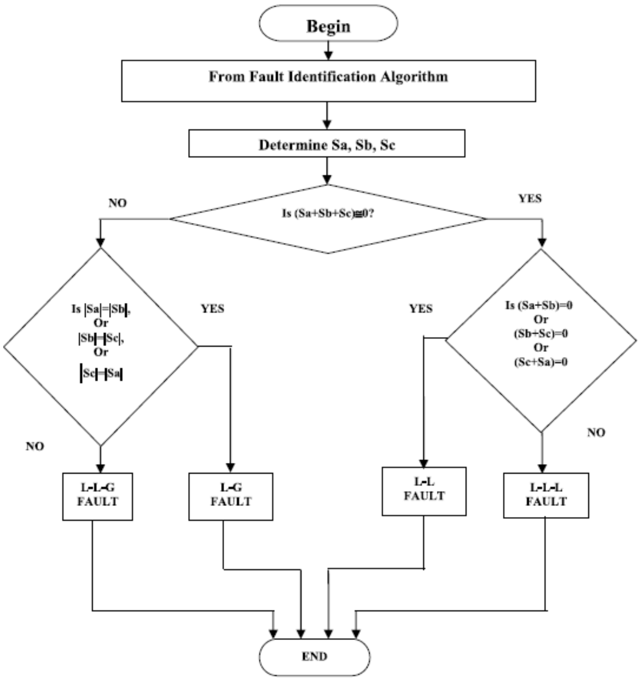


Fig 7. Flow chart for the detection of the fault

The complete flow chart for fault classification is as shown in Fig. 7. When the algebraic sum of S_a ,S_b and S_c is zero, then the fault can either L-L-L or L-L fault. The discrimination between these two types of faults is based on the fact that the magnitudes of S_a, S_b and S_c are comparable to each other in case of L-L-L fault. But in the case of L-L fault, the addition of coefficients of any two faulty phases tends to nearly equal to zero. The remaining healthy phase coefficient is very small and almost negligible compared to coefficients of other two faulty phases having equal values with opposite signs. When the summations of S_a ,S_b and S_c is not equal to zero, then it can be either L-G or L-L-L-G fault. If the absolute values of any two coefficients are equal and always much smaller than the absolute value of the remaining coefficients, then it is an 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 fault.

V. RESULT ANALYSIS

The results are by using the algorithm for different faults are given below. Figures 8-10 illustrates the Variation of fault index for transmission system at fault inception angle 80^0 with LG, LL, LLG and LLLG Faults on Phase ABCG on terminal1, terminal2 and Terminal3.

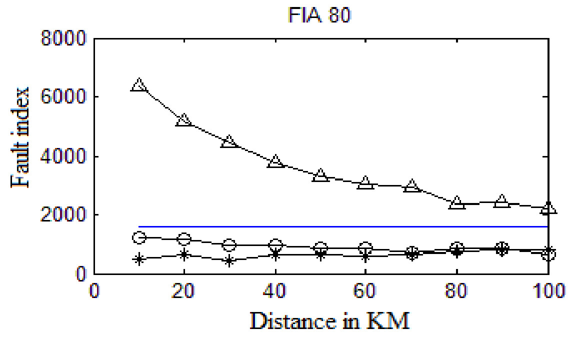


Fig. a

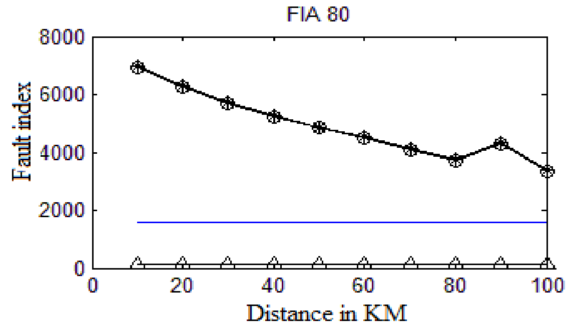


Fig b

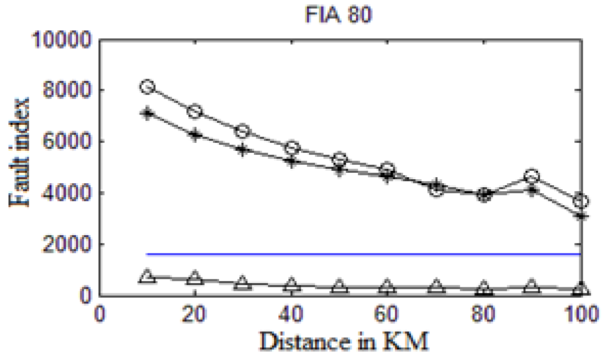


Fig. c

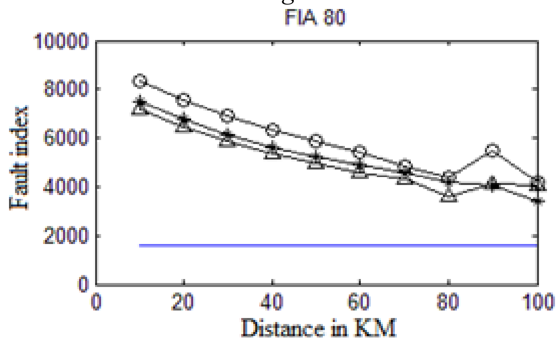


Fig. d

Fig 8. Variation of fault index for transmission line at 80^0 from terminal 1 (a) LG Fault on Phase A (b) LL Fault on AB (c) LLG Fault on Phase ABG (d) LLLG Fault on Phase ABCG.

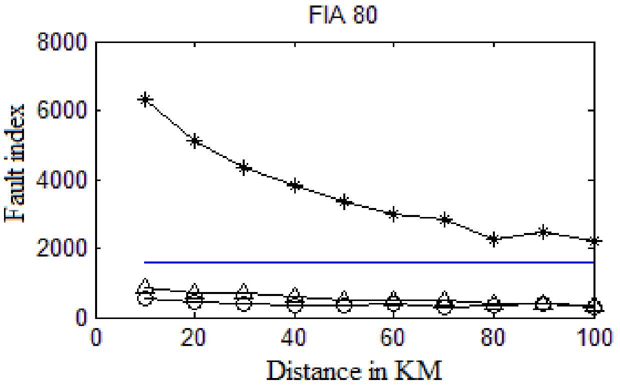
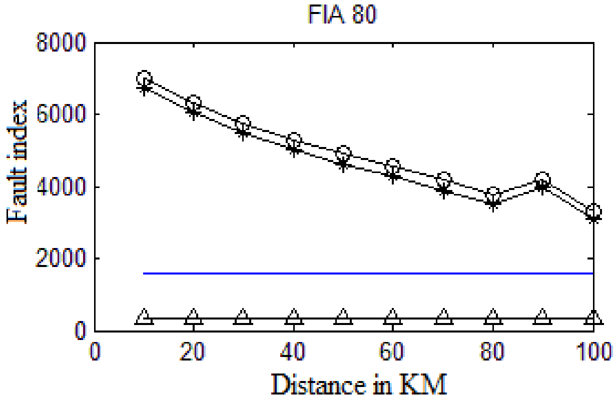


Fig. a



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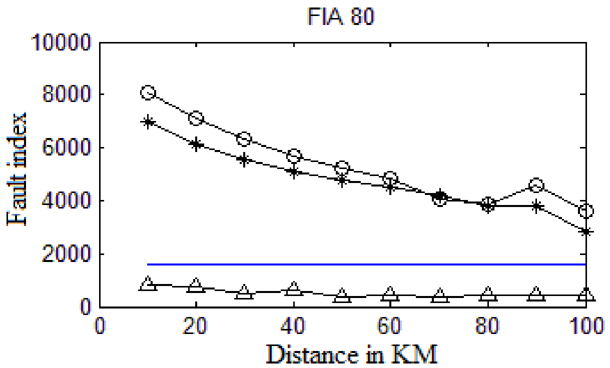


Fig. c

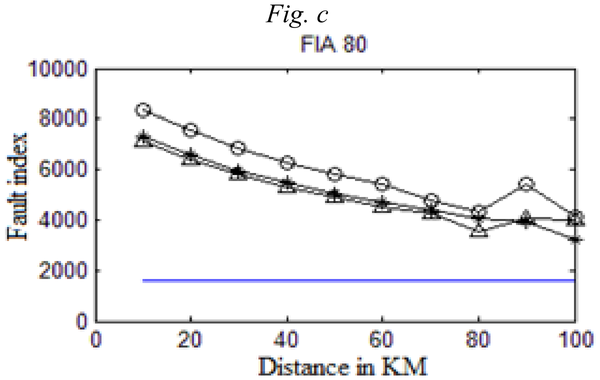


Fig. d

Fig. 9. Variation of fault index for transmission line at 80^0 from terminal 2 (a) LG Fault on Phase A (b) LL Fault on AB (c) LLG Fault on Phase ABG (d) LLLG Fault on Phase ABCG.

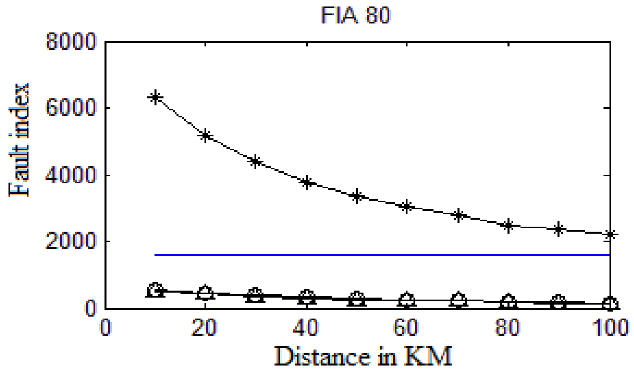
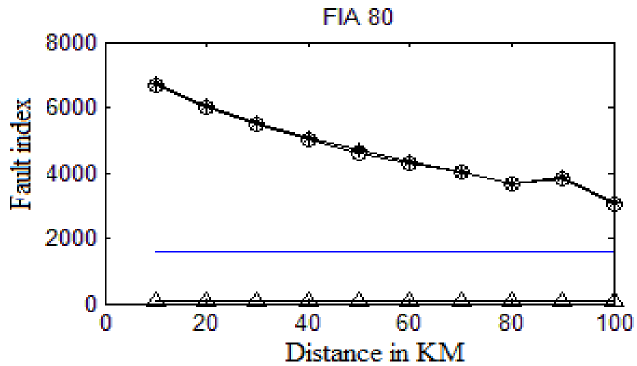


Fig. a



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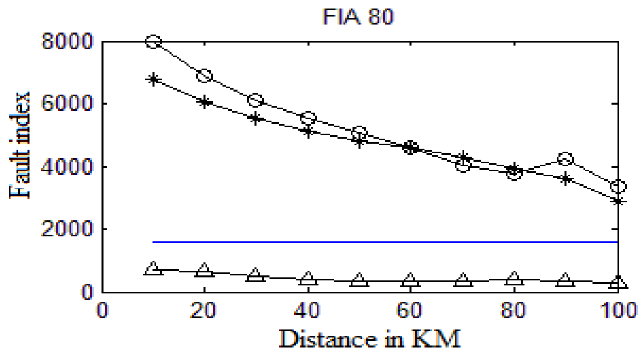

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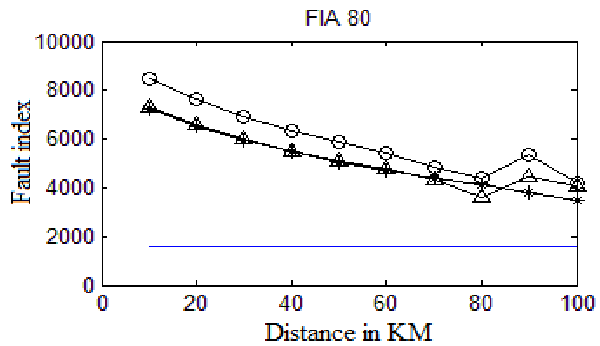


Fig. d

Fig. 10. Variation of fault index for transmission line at 80^0 from terminal 3 (a) LG Fault on Phase A (b) LL Fault on AB (c) LLG Fault on Phase ABG (d) LLLG Fault on Phase ABCG

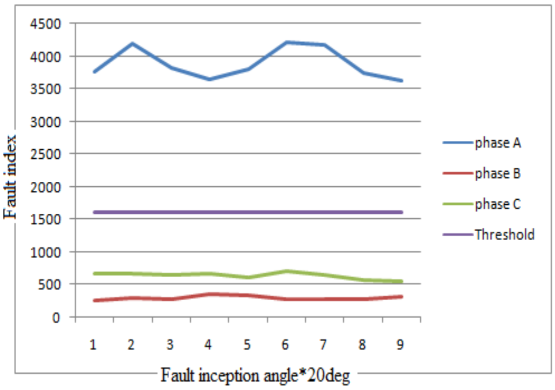


Fig. a

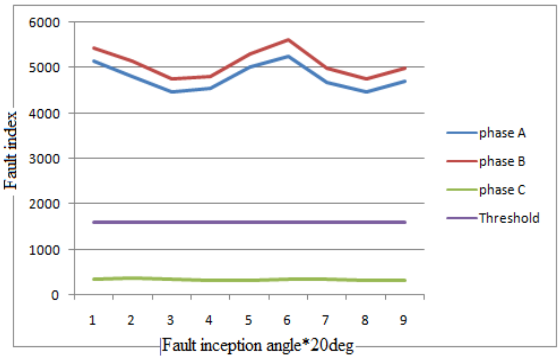
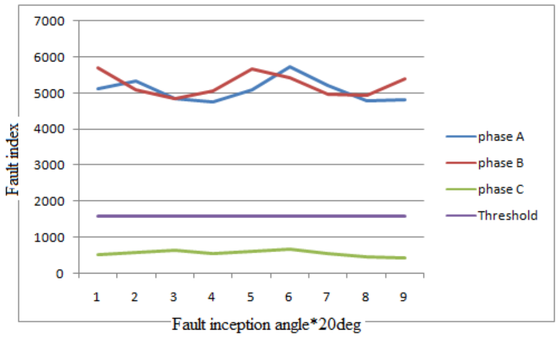


Fig b



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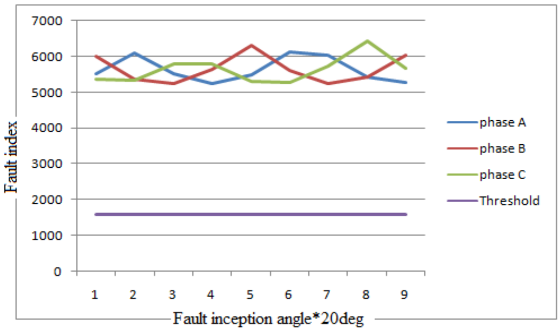


Fig d

Fig.11. Variation of fault index at 50km from terminal 1 (a) for LG fault on Phase AG (b) for LL fault on Phase AB (c) for LLG fault on Phase ABG (d) for LLLG faults on ABCG

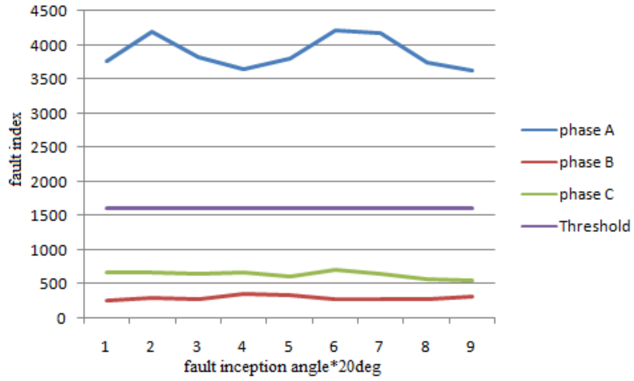
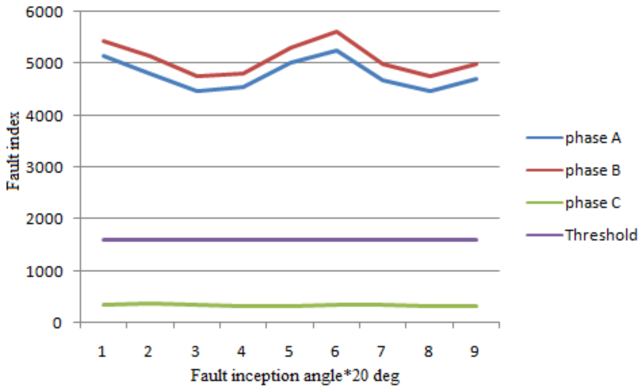


Fig. a



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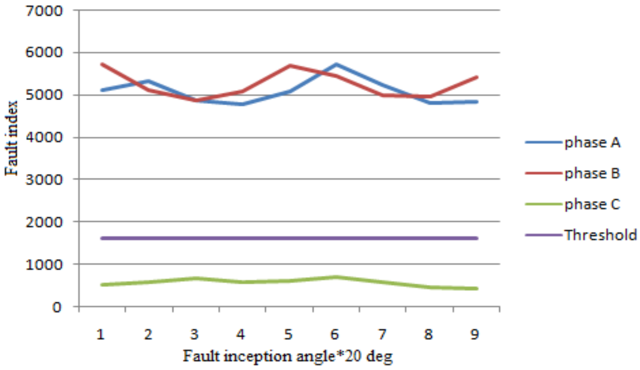


Fig.c

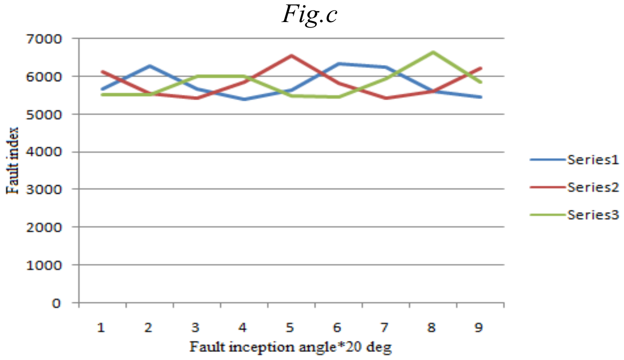


Fig. d

Fig.12. Variation of fault index at 50km from terminal 2 (a) for LG fault on Phase AG (b) for LL fault on Phase AB (c) for LLG fault on Phase ABG (d) for LLLG faults on ABCG.

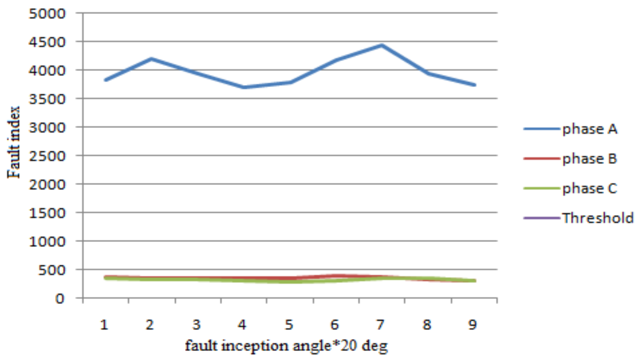
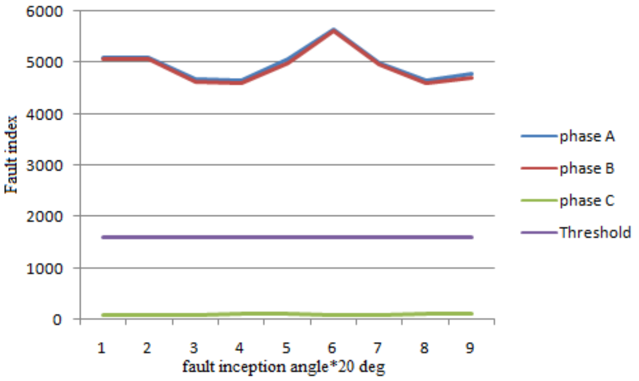


Fig. a



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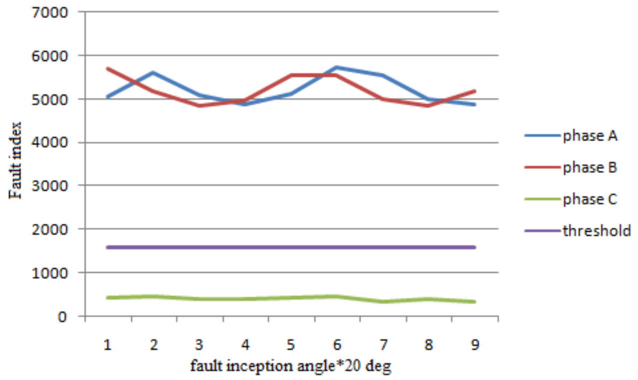

Fig. c

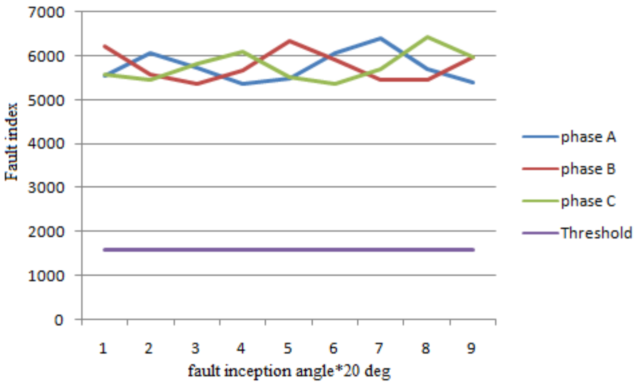

Fig. d

Fig.13. Variation of fault index at 50km from terminal 3 (a) for LG fault on Phase AG (b) for LL fault on Phase AB (c) for LLG fault on Phase ABG (d) for LLLG faults on ABCG.

Figures 11-13 illustrates the Variation of fault index for transmission system at distance 50km with LG, LL, LLG and LLLG Faults on Phase ABCG on terminal1, terminal2 and Terminal3.

It is observed that the fault index of faulty phase is large compared to those of healthy phases. Thus the number of faulty phases is determined by comparing the Fault Index (I_{f1}) with a Fault Threshold (I_{th}).The proposed algorithm has been tested for all types of faults, considering variations in fault locations and fault incidence angles (θ) in the range 0-180^o. This scheme is proved to be effective in detecting and classifying various types of faults. Fig6-a, b, c, d shows the variation of three phase currents D1 Coefficients of Phase A, Phase B &Phase C for LG, LL, LLG, LLL &LLLG fault on transmission line Controller.

VI. CONCLUSIONS

This paper presents an efficient method based on wavelet transforms both fault detection and classification which is almost independent of fault impedance, fault location and fault inception angle of transmission line fault currents. Fault detection and classification can be accomplished within a half a cycle using detail coefficients of currents at both the ends. The proposed protection scheme is found to be fast, reliable and accurate for various types of faults on transmission lines, at different locations and with variations in incidence angles.

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