Wavelet Approach for Transient Current based Multi Terminal Transmission System Protection Scheme in the Presence of Shunt Compensating Devices

M. Vaidehi
E.E.E Department
Raghu Engineering College
Visakhapatnam, Andhra Pradesh

G. Ravikumar
E.E.E Department
Bapatla Engineering College
Bapalta, Andhra Pradesh

R. Kameswara Rao
E.E.E Department
Raghu Engineering College
Visakhapatnam, Andhra Pradesh

***Abstract*—This paper presents a wavelet based protection scheme for a multi terminal transmission system in presence of SVC and STATCOM. Increase in the power transfer capability and the efficient utilization of available transmission lines, improving power system stability and controllability have made strides and created Flexible AC Transmission (FACTS). These FACTS devices have adverse effects on distance protection. Severe under reaching is the most important problem of relay which is caused by current injection at the point of connection to the system. This work presents an efficient method based on wavelet transform. 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 of faults on Transmission lines which is almost independent of fault impedance, fault inception angle, fault distance of transmission line and location of FACTS devices.**

Keywords— Wavelet transforms, transmission line, fault, power system protection and FACTS deices.

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].

The performance of the power system is affected by faults on the transmission lines, which result in the interruption of power flow. From the transient phenomena, fault on transmission lines need to be detected, classified, locateaccurately, 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. Flexible AC Transmission is a technology that provides the requisite corrections of transmission functionality in order to fully utilize existing transmission systems thus in turn minimizes the gap between the stability and thermal limits [3] and poses challenge in conventional distance protection scheme. The conventional distance relay is likely to over reach or under reach depending upon the mode, type of FACTS devices incorporates in the transmission system [4]. The investigations of the existing transmission line distance protection scheme with the installation of shunt FACTS controllers can affect the distance relays with regards to impedance measurement, phase selection and operating times.

This paper presents a Wavelet approach for multi terminal transmission system protection scheme**.** 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 mentions about the location of fault on multi terminal. Wavelet transform analyzes transient voltage and current signals associated with faults both in frequency and time domain.

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 which is almost independent of fault impedance, fault location, SVC and STATCOM location and fault inception angle of multi terminal transmission line fault currents.

II. WAVELET ANALYSIS

Wavelet Transform is a linear transformation much like the Fourier transform, however with one important difference: it allows time localization of different frequency components of a given signal. So, it is a mathematical technique used in signal analysis. Wavelet analysis is particularly efficient where the signal being analyzed has transients or discontinuities, e.g., the post fault voltage/current waveform. In wavelet transform, the analyzing functions, which are called Wavelets, will adjust their time width to their frequency in such a way that, higher frequency wavelets will be very narrow and lower frequency ones will be boarder. 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 utilitiesset 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.

Given, a function f(t), its continuous wavelet transform(WT) be calculated as follows

$$WT(a,b) = \frac{1}{\sqrt{a}} \int x(t) g\left(\frac{t-b}{a}\right) dt$$

Where a and b are the scaling (dilation) and translation (time shift) constants respectively, and ψ is the wavelet function which may not be real as assumed in the above equation for simplicity.

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

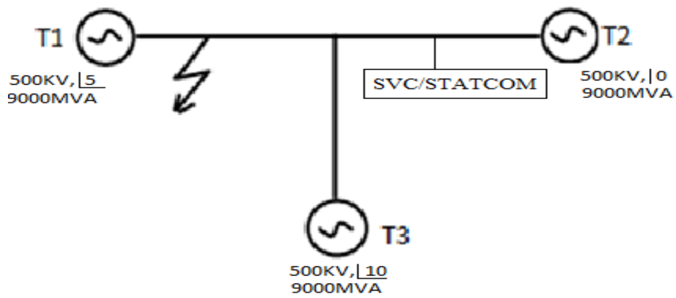


Fig. 1 The proposed system model

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

Three 110km length transmission line from each terminal to center point of three terminal transmission system, 9000MVA short circuit levels (SCLs) sources and the angle difference 20° with Static VAR compensator is installed anywhere in the transmission system. A 300-Mvar Static Var Compensator (SVC) regulates voltage on 500-KV system. The SVC consists of a 500-KV/16KV 333-MVA coupling transformer, one 109-Mvar Thyristor Controlled Reactor bank (TCR) and Three 94-Mvar Thyristor Switched Capacitors banks (TSC1 TSC2 TSC3) or connected on to the secondary side of the transformer. 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 CLASIFICATION 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.

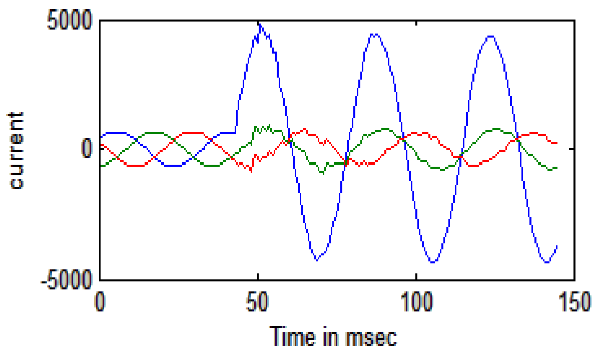


Fig. 2 Three Phase currents at AG fault at 40% from the terminal

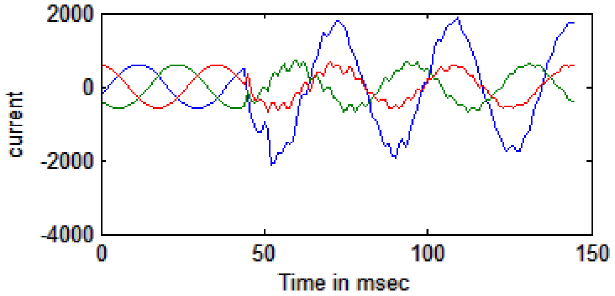


Fig. 3 Three Phase currents at AG fault at 40% from the terminal 2

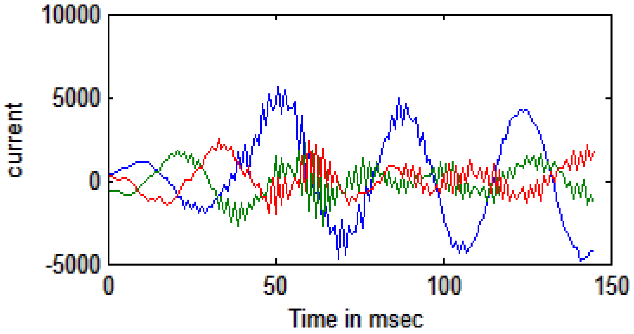


Fig 4 Three Phase currents at AG fault at 40% from the terminal 3

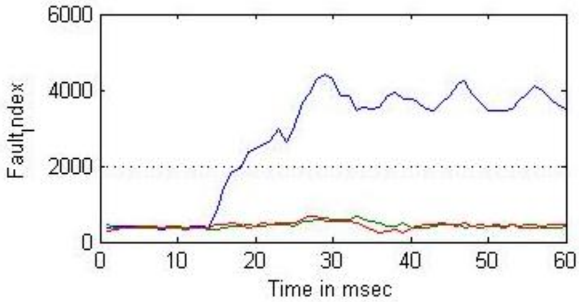


Fig 5. Variation of Fault Index for Phase-A fault from the terminal1 at 40% of the line

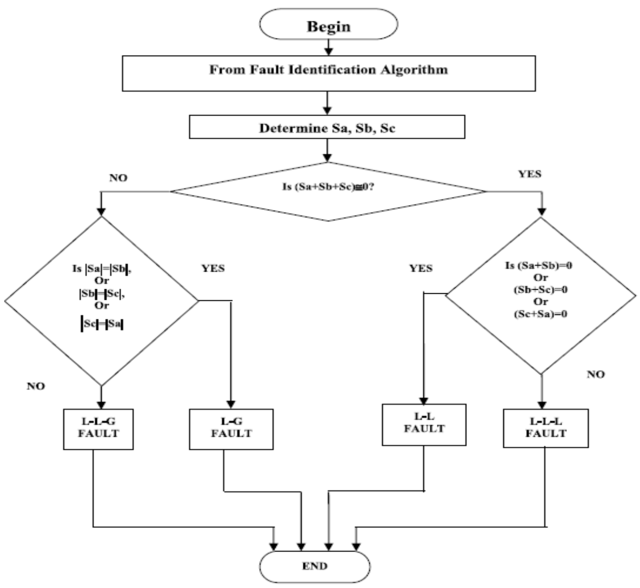


Fig 6. Flow chart for the detection of the fault

Figures 2,3&4 show the variation of three phase currents for AG fault and Fig. 5 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. The complete flow chart for fault classification is as shown in Fig. 6. When the algebraic sum of S_a ,S_b andS_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 andS_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 an L-L-G fault.

V. RESULT ANALYSIS

The results are by using the algorithm for different faults are given below. Figures 7-9 illustrates the Variation of fault index for transmission system with and without SVC and STATCOM at fault inception angle 80^0 with LG, LL, LLG and LLLG Faults on Phase ABCG on terminal1, terminal2 and Terminal3.

Figures 10-12 illustrates the Variation of fault index for transmission system with and without SVC and STATCOM at distance 50km with LG, LL, LLG and LLLG Faults on Phase ABCG on terminal1, terminal2.

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 (□) in the range 0-180°.

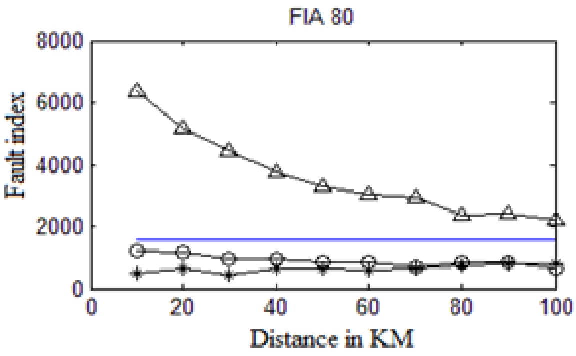


Fig. a

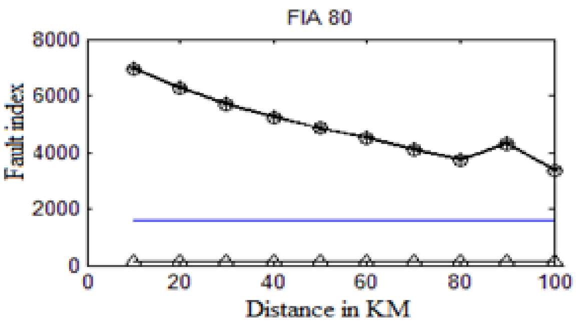


Fig b

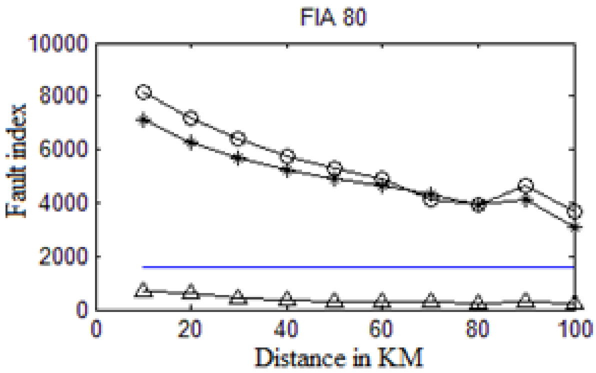


Fig c

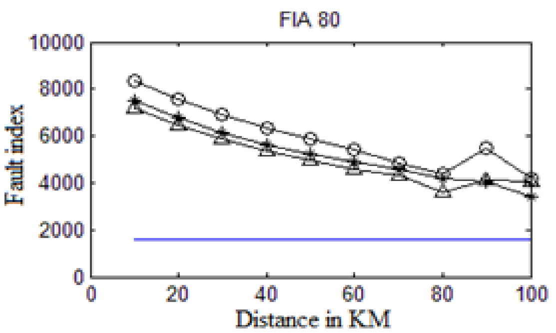


Fig d

Fig 7. 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.

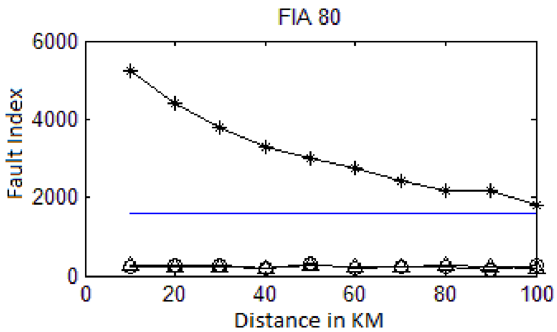


Fig a

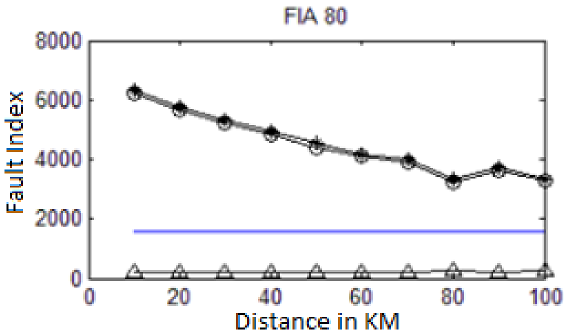


Fig b

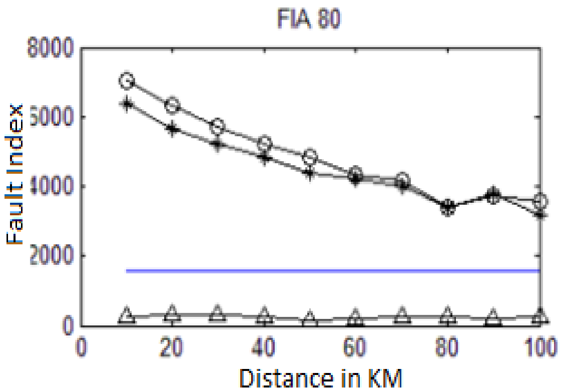


Fig c

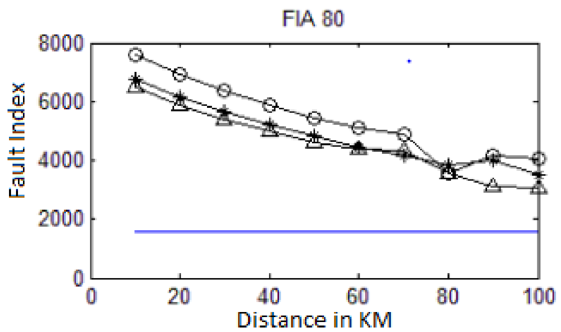


Fig d

Fig.8 Variation of fault index for transmission line in the presence of SVC at terminal 1 at 80° 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

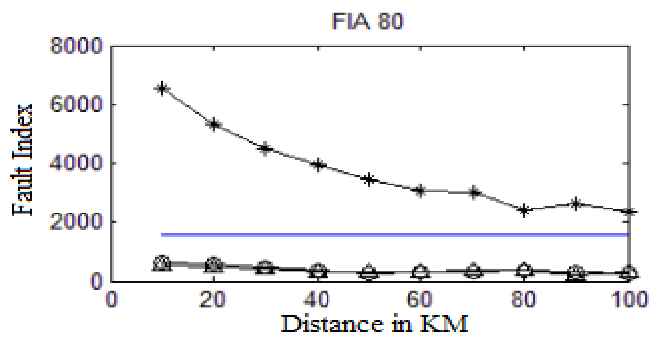


Fig. a

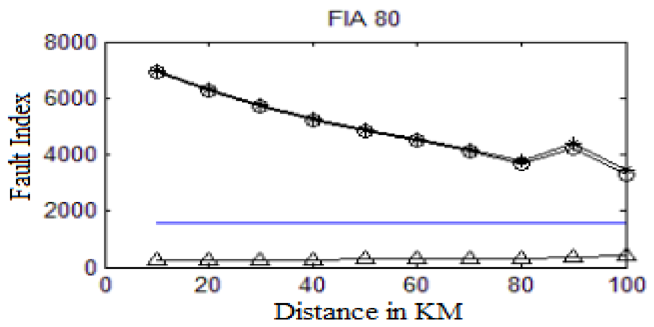


Fig. b

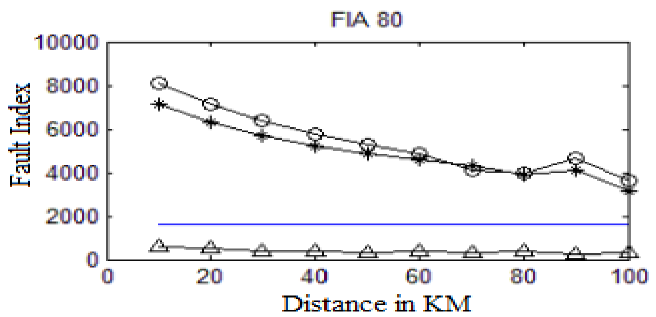


Fig. c

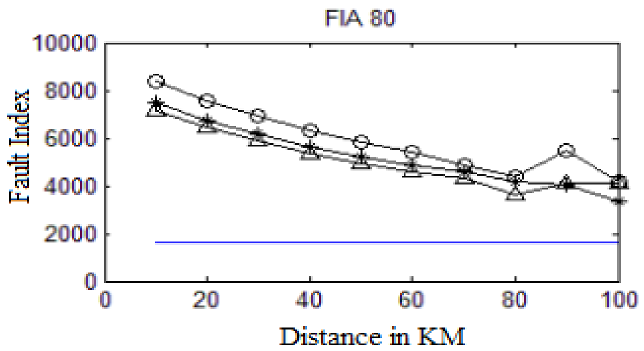


Fig. d

Fig.9 Variation of fault index for transmission line in the presence of STATCOM at terminal 2 at 80° 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

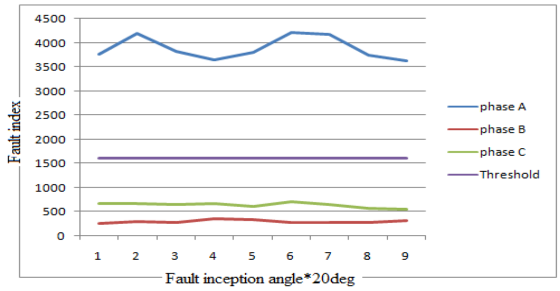
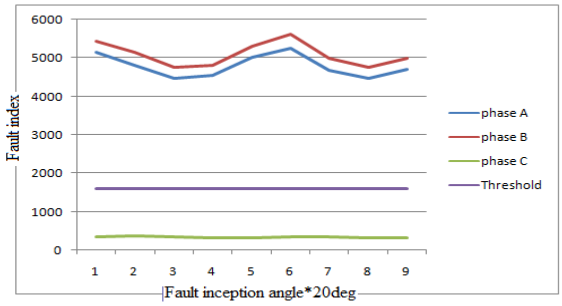


Fig. a



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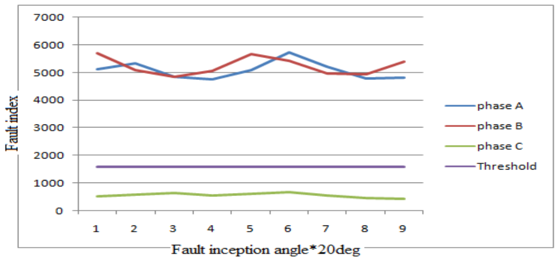

Fig. c

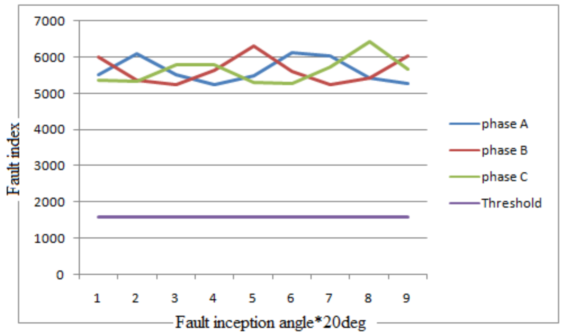

Fig. d

Fig.10. Variation of fault index at 50km from terminal 1 without SVC (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

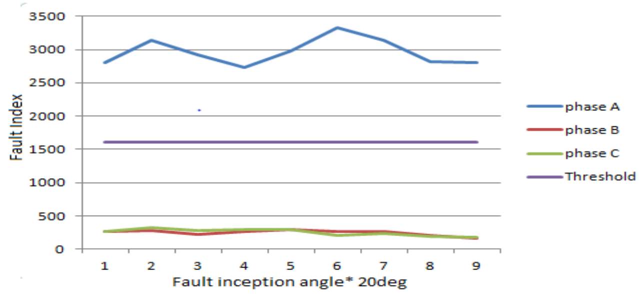

Fig. a

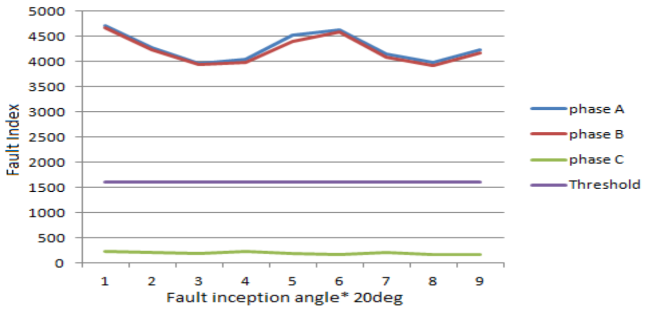

Fig. b

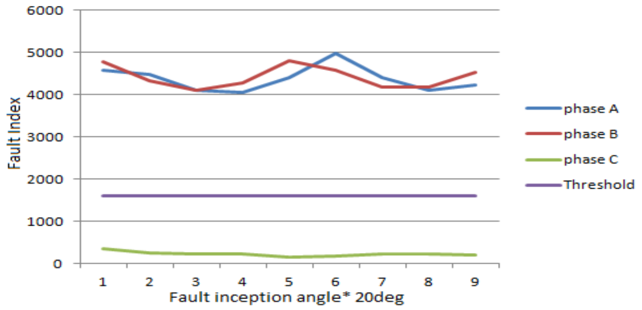

Fig. c

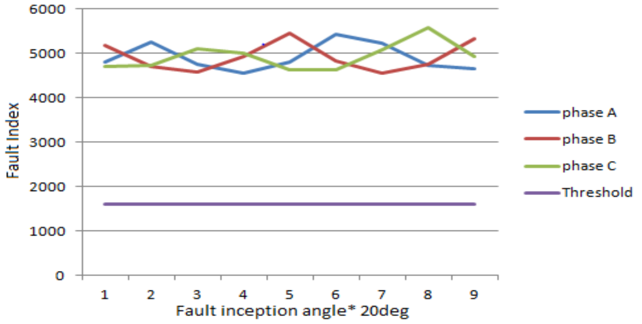

Fig. d

Fig.11. Variation of fault index at 50km from terminal 1in the presence of SVC located at 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

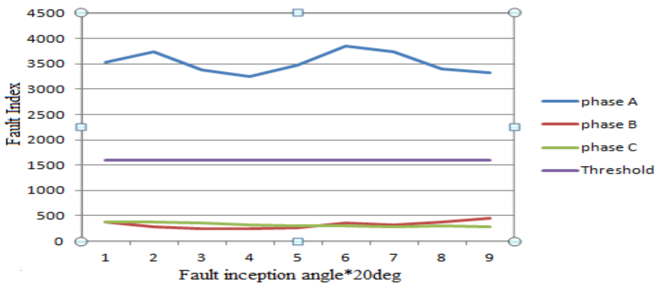

Fig. a

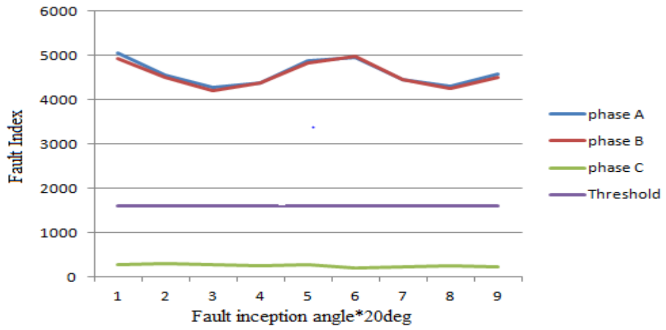

Fig. b

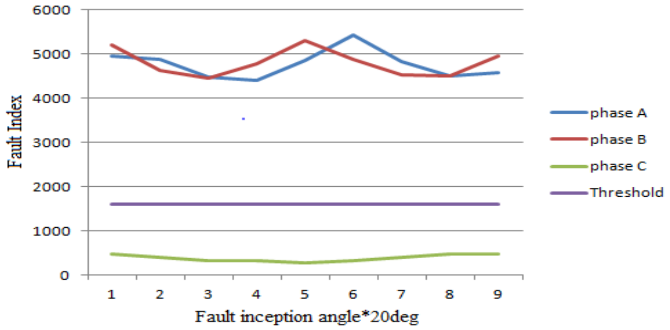

Fig. c

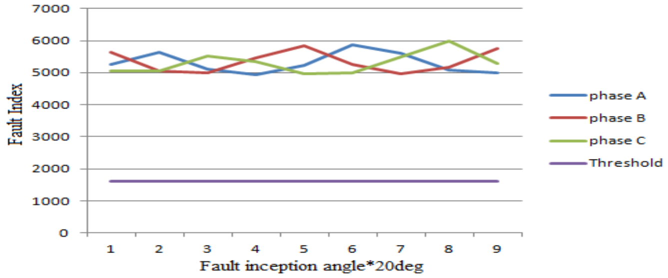

Fig. d

Fig.12. Variation of fault index at 50km from terminal 1in the presence of STATCOM located at terminal 2 (a) for LG fault on Phase AG (b) for LLG fault on Phase ABG

VI. CONCLUSION

The conventional distance relay is likely to over reach or under reach depending upon the mode, type of FACTS devices incorporate in the transmission system can be rectified by wavelet based multi-resolution analysis approach that is applied for effective detection and classification. This scheme is proved to be unaffected by the presence of SVC and STATCOM by testing the protection scheme on same transmission system without SVC and STATCOM. 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 with and without SVC & STATCOM, at different locations and with variations in incidence angles.

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