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Wavelet Approach for the Transient Current Based Multi Terminal Transmission Protection Scheme in Presence of Statcom

P.Mamatha
Department of Electrical and Electronics Engineering, Baba Institute of Technology and Sciences, P.M. Palem, Visakhapatnam, Andhra Pradesh 530041, India.

M.V.S.Prem Sagar
Department of Electrical and Electronics Engineering, Baba Institute of Technology and Sciences, P.M. Palem, Visakhapatnam, Andhra Pradesh 530041, India.

ABSTRACT

This research paper represents a new approach to develop protection technique for EHV overhead transmission lines. The outage time is greatly reduced by faults occurring on a transmission line with multiple line taps being isolated at effective section of the transmission line. This is a significant challenge for operators of power transmission grids. The complication of calculating fault index is very much reduced by developing and using wavelet based multi resolution analysis which not finds the detailed coefficients of the signals. Fault indexes are matched with the threshold value to identify, detect and classify faults on entire transmission system. The proposed algorithm in this research project is prepared for the early detection, classification of fault on transmission lines that is almost independent of the fault impedance, fault distance and fault inception angle of a transmission line. The proposed research is proved in the presence of the STATCOM which has either over reach or under reaches the relay.

INRODUCTION

Wavelet Transforms are the most efficient means of analyzing transient currents and voltages. Unlike DFT, WT [1-3] uses short window at high frequencies and long window at low frequencies. This helps to analyze the signal in both frequency and time domains effectively. A 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.

There are many types of wavelets such as Haar, Daubechies, and Symlets etc. The selection of mother wavelet is based on the type of application. Hence, Wavelet Transform based digital protection schemes provide better speed, accuracy in location, selectivity, and sensitivity. In this work the multi resolution analysis of Wavelet Transforms has been exploited for the protection of multi terminal Transmission line with FACTs Controllers [5].

INTRODUCTION TO WAVELET TRANSFORMS:

Mathematical transformations are applied to signals to obtain further information from that signal that is not readily available in the raw signal. Most of the signals in practice are TIME-DOMAIN signals [7]. If the FT of a signal in time domain is taken, the frequency-amplitude representation of that signal is obtained. The information that cannot be readily seen in the time-domain can be seen in the frequency domain. FT is probably the most popular transform being used (especially in electrical engineering); it is not the only one. There are many other transforms that are used quite often by engineers and mathematicians. Hilbert transform, short-time Fourier transform, Wigner distributions, the Radon Transform, and of course our featured transformation, the wavelet transform, constitute only a small portion of a huge list of transforms that are available at engineer's and mathematician's disposal [9].

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Every transformation technique has its own area of application, with advantages and disadvantages, and the wavelet transform (WT) is no exception. FT gives the spectral content of the signal, but it gives no information regarding where in time those spectral components appear. Therefore, FT is not a suitable technique for non-stationary signal, with one exception: FT can be used for non-stationary signals, if we are only interested in what spectral components exist in the signal, but not interested where these occur.

However, if this information is needed, i.e., if we want to know, what spectral component occur at what time (interval), then Fourier transform is not the right transform to use. 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 [11].

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 analyzing 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 [2].

WAVELETS OVERVIEW:

The fundamental idea behind wavelets is to analyze according to scale. Indeed, some researchers in the wavelet field feel that, by using wavelets, one is adopting a whole new mindset or perspective in processing data.

Wavelets are functions that satisfy certain mathematical requirements and are used in representing data or other functions. This idea is not new. Approximation using superposition of functions has existed since the early 1800's; Joseph Fourier discovered that he could superpose sines and cosines to represent other functions. However, in wavelet analysis, the scale that we use to look at data plays a special role. Wavelet algorithms [4] process data at different scales or resolutions. If we look at a signal with a large window," we would notice gross features. Similarly, if we look at a signal with a small window," we would notice small features. The result in wavelet analysis is to see both the forest and the trees, so to speak. This makes wavelets interesting and useful.

For many decades, scientists have wanted more appropriate functions than the sine's and cosines which comprise the bases of Fourier analysis, to approximate choppy signals. By their definition, these functions are non-local. They therefore do a very poor job in approximating sharp spikes. But with wavelet analysis, we can use approximating functions that are contained neatly in finite domains [6].

Wavelets are well-suited for approximating data with sharp discontinuities. The wavelet analysis procedure is to adopt a wavelet prototype function, called an analyzing wavelet or mother wavelet. Temporal analysis is performed with a contracted, high-frequency version of the prototype wavelet, while frequency analysis is performed with a dilated, low-frequency version of the same wavelet. Because the original signal or function can be represented in terms of a wavelet expansion (using coefficients in a linear combination of the wavelet functions), data operations can be performed using just the corresponding wavelet coefficients. And if you further choose the best wavelets adapted to your data, or truncate the coefficients below a threshold, your data is sparsely represented. Other applied fields that are making use of wavelets include astronomy, acoustics, nuclear engineering, sub-band coding, signal and image processing, neurophysiology, music, magnetic resonance imaging, speech discrimination, optics, fractals, turbulence, earthquake prediction, radar, human vision, and pure mathematics applications such as solving partial differential equations [8].

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STANDARD WAVELETS:

Haar:

Any discussion of wavelets begins with Haar wavelet which is the first and simplest. Haar wavelet is discontinuous and resembles a step function.

It represents the same wavelet as Daubechies Db1.

Daubechies:

Daubechies, one of the brightest stars in the world of wavelet research, invented what are called compactly supported orthogonal wavelets, thus making discrete wavelet analysis practicable. The names of the Daubechies family wavelets are written DbN, where N is the order, and Db is the surname of the wavelet.

Biorthogonal:

This family of wavelets exhibits the property of linear phase, which is needed for signal and image reconstruction. By using two wavelets one for decomposition and the other for reconstruction instead of same single one interesting properties are derived.

Symlets:

The symlets are nearly symmetrical wavelets proposed by Daubechies as modifications to the Db family. The properties of two wavelet families are similar. Coif lets is also one of the wavelet families.

Wavelet transforms converts amplitude versus time signal to scale versus time signal. Wavelet is a waveform of effectively limited duration that has an average value of zero. The actual implementation of discrete wavelet transform is done by multi resolution analysis. By MRA, a signal can be analyzed is decomposed into a smooth approximation and a detail. The approximation is further decomposed into an approximation and a detail and the process is repeated. The decomposition of signal is obtained by successive high pass and low pass filtering of the time domain signal. The successive stages of decomposition are known as levels and the above procedure is known as sub band coding. The sub band information is useful for fault classification.

In order to reduce the computational burden the sampling frequency should not be too high but it should be high enough to capture the information of fault. By randomly shifting the point of fault on transmission line, more number of simulations was being carried out using MATLAB/ SIMULINK. The generated current signal for each case is analyzed using wavelet transform. A sampling frequency of 12.5 kHz is selected. Biorthogonal wavelet Bior1.5 is used as mother wavelet since it has good performance results for power system fault analysis. Detail coefficients of fault current signal in first level, gives the frequency components corresponding to second and third harmonics. On this basis, summation of 1^{st} level detail coefficients of the three phase currents I_a, I_b and I_c are being used for the purpose of detection and classification of faults in the transmission line [10].

Filter bank theory [1] is the basis for the formulation of the discrete wavelet transform (DWT). At level (k), the above technique can be implemented by using a high pass and a low pass filters efficiently. Down sampling of the results is performed by a factor two and the two filters are applied to the output of the low pass filter from the earlier stage. The high pass filter is obtained from the mother wavelet function and further measures the details in a certain input. Similarly, the low pass filter delivers a smoothed version of the input signal and is derived from a scaling function, which is associated to the mother wavelet function [2] & [3]. For a function f (t), its continuous wavelet transform (WT) can be calculated from the following equation:

$$W,m(t) = \frac{1}{\sqrt{m}}\int_{-\infty}^{\infty} s(t)\, \psi\left(\frac{t-\tau}{m}\right) dt$$

$$C(m,t) = \int_{0}^{-\infty} s(t) W'_{\tau,m}(t)\, dt$$

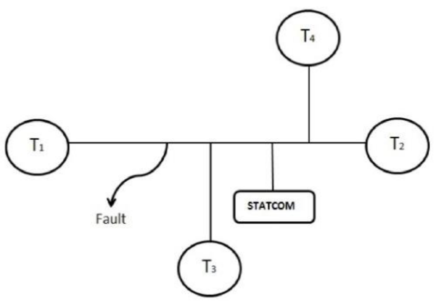

Fig: single line diagram for proposed four terminal transmission system

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The single line diagram of the multi terminal transmission system considered for the proposed scheme. Four 110-km 400 kv transmission lines compensated with 100mva static synchronous compensator (statcom) at the middle of the second terminal are interconnected. The scheme is evaluated using 400kv, 50hz four terminal transmission system whose line parameters are r0=0.1888ω/km, r1=0.02ω/km, l0=3.5mh/km, l1=0.94mh/km, c0=0.0083μf/km., c1=0.012μf/km.a sampling frequency of 16khz is chosen to capture the high frequency content of current signals.the system is modeled in matlab simulink environment. The network is simulated for various fault situations. exhaustive simulations were carried out for l-g, l-l-g, l-l-l faults occurring at different locations along the paths of terminal 1 to terminal 2, terminal 2 to terminal 3, terminal 3 to terminal 1, and terminal 4 to terminal 1. For each type of fault at a particular location, the fault inception angle was varied to evaluate the performance of the proposed scheme. Influence of fault resistance also being considered with value of 5 ohms. Synchronized sampling of three phase currents at all terminals was carried out and the detail d1 coefficients were used for detection and classification of the type of fault. The three phase currents of the local terminal are analyzed with bior1.5 mother wavelet to obtain the detailed coefficients (d11) at terminal 1 over a moving window of half cycle length.

Result analysis of Transmission line with STATCOM:

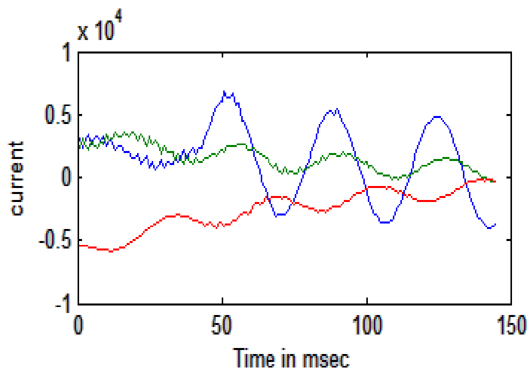

Figure : Three Phase currents at Terminal-1 of AG fault at 40% of the Transmission line with STATCOM

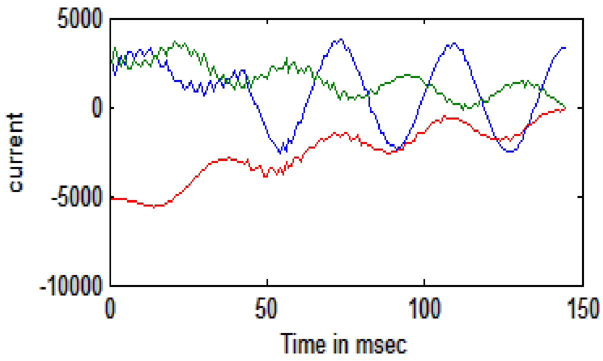

Figure : Three Phase currents at Terminal-2 of AG fault at 40% of the Transmission line with STATCOM

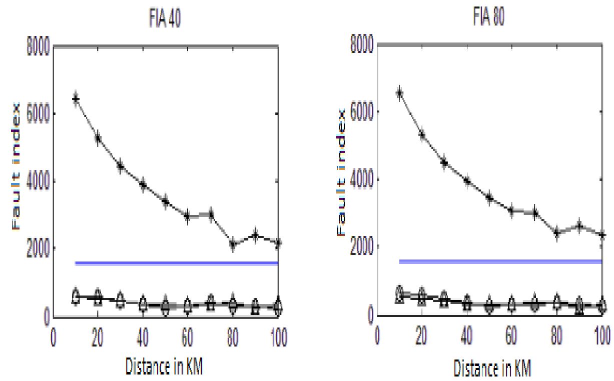

Figure 5.9 :Variations in Fault Indexes of three phase currents for AG Fault at terminal 1 for Incidence Angle of 40^o and 80^0 of Transmission line with STATCOM at terminal 2

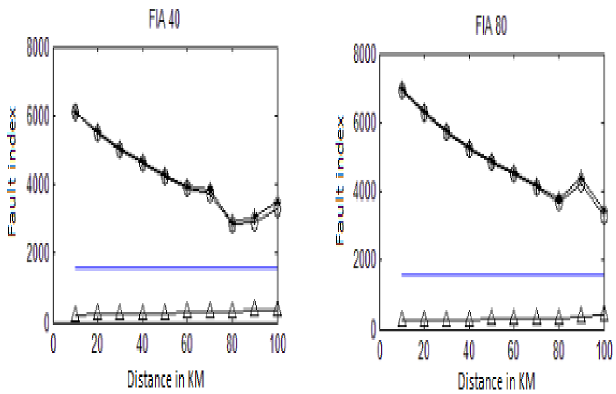

Figure 5.10: Variations in Fault Indexes of three phase currents for AB Fault at terminal 1 for Incidence Angle of 40^o and 80^0 of Transmission line with STATCOM at terminal 2

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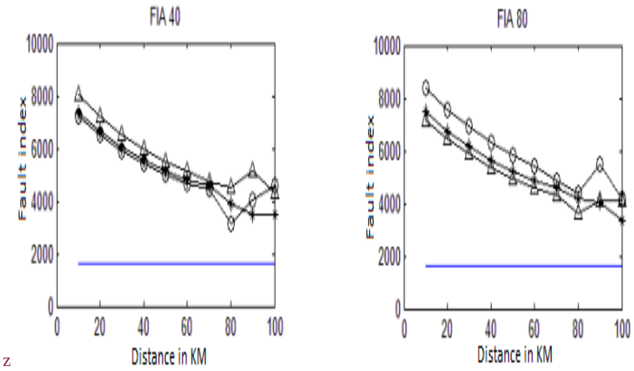

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Figure 5.11: Variations in Fault Indexes of three phase currents for ABCG Fault at terminal 1 for Incidence Angle of 40° and 80⁰ of Transmission line with STATCOM at terminal 2

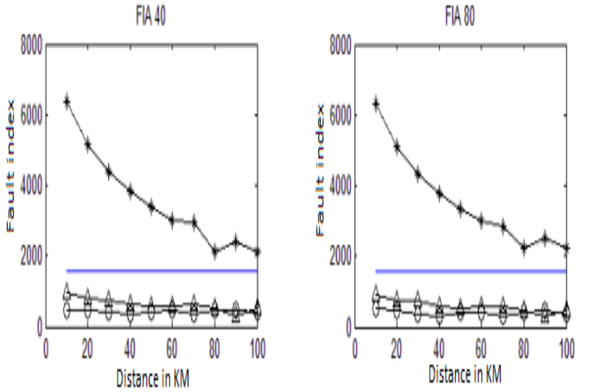


Figure 5.12: Variations in Fault Indexes of three phase currents for AG Fault at terminal 2 for Incidence Angle of 40° and 80⁰ of Transmission line with STATCOM at terminal 3

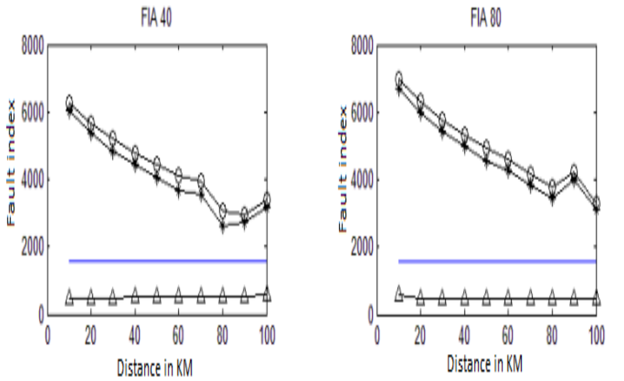


Figure 5.13: Variations in Fault Indexes of three phase currents for AB Fault at terminal 2 for Incidence Angle of 40° and 80⁰ of Transmission line with STATCOM at terminal 3

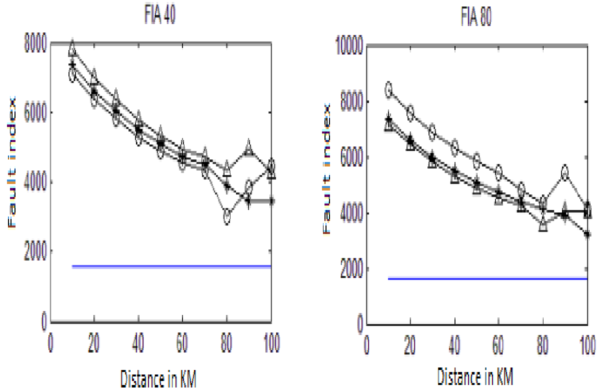


Figure5.14:Variations in Fault Indexes of three phase currents for ABCG Fault at terminal 2 for Incidence Angle of 40° and 80⁰ of Transmission line with STATCOM at terminal 3

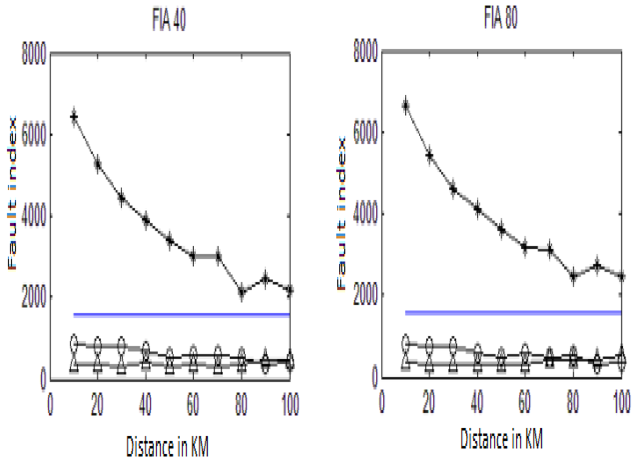
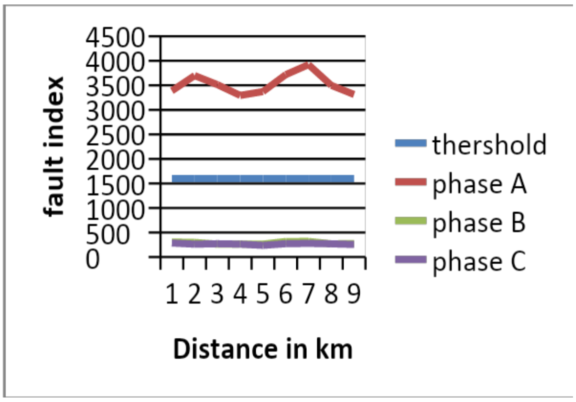


Figure 5.15 :Variations in Fault Indexes of three phase currents for AG Fault at terminal 3 for Incidence Angle of 40° and 80⁰ of Transmission line with STATCOM at terminal 1



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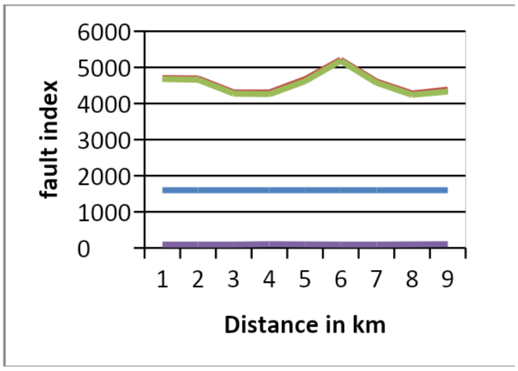


Fig 5.18: variation of fault indices with distance at a fault inception angle for A-G, AB fault from terminal-1 with statcom

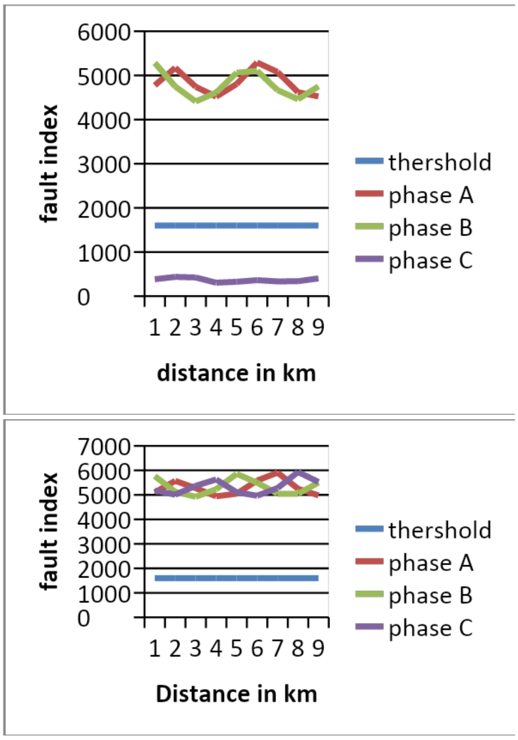
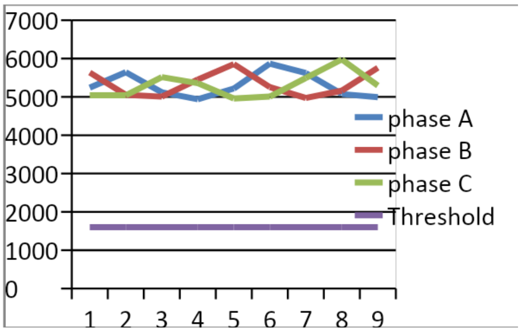


Fig 5.19 : Variation of fault indices with distance at a fault inception angle for ABG,ABCG fault from terminal-1 with statcom



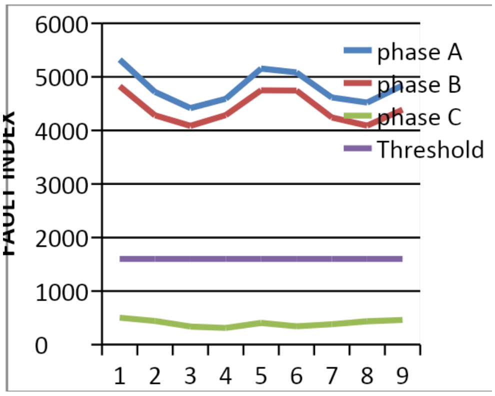


Fig 5.20:variation of fault indices with fault inception angle for AB-G,ABC-G fault from terminal-2 with statcom

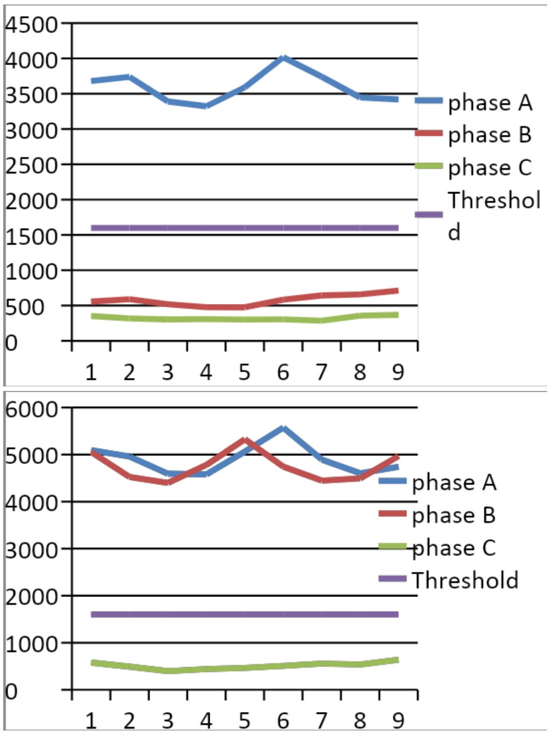
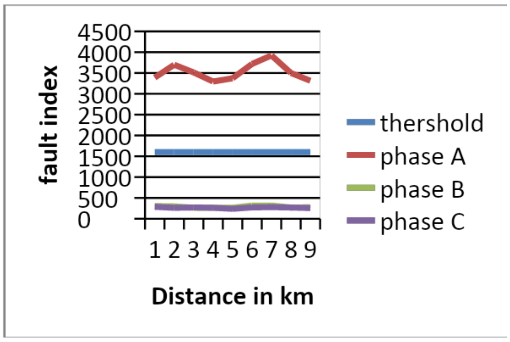


Fig 5.21: variation of fault indices with fault inception angle for A-G, AB fault from statcom



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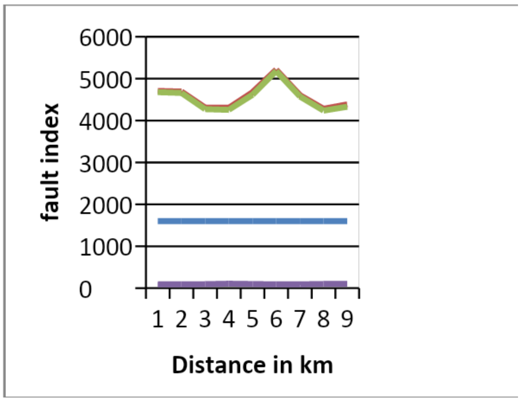

Fig 5.22 : variation of fault indices with fault inception angle for A-G,AB fault from terminal 3 with statcom

CONCLUSION

The conventional distance relay is likely to over reach or under reach depending upon the mode, type of facts devices incorporated in the transmission system and can be rectified by wavelet based multi-resolution analysis approach that is applied for effective fault detection, classification and faulty terminal identification in multi-terminal transmission lines. the above algorithm has been implemented for all types of faults with variations in fault inception angle and fault distance and location of statcom at all terminals. the results indicate the accuracy in fault detection, classification and faulty terminal identification, and fault location estimation this scheme is proved to be unaffected by the presence of statcom by testing the protection scheme on same transmission system without statcom. the proposed protection scheme is found to be fast, reliable and accurate for various types of faults on transmission lines with and without flexible ac transmission control device such As Statcom At Different Locations And With Various Inception Angles.

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