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Integration of PV and Wind Energy System with SVC for Protection of a Five Terminal Transmission Line using Wavelet Approach

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Abstract— **Locating faults on a transmission line with multiple line taps and then isolating the effected section of the transmission line, to reduce outage time, is a significant challenge for operators of power transmission grids. In our current environment, reliability and continuity of service have become extremely important to customers. It is quite common for utility networks to have transmission lines with one or more taps on them between substations. In an ideal world, there would be a substation with protection and isolating devices at each tap. As a result, most transmission lines have been built with multiple taps that may or may not have a disconnect switch for isolation. Current solutions being applied for the detecting and isolation of a faulted transmission lines. This paper adopts a new approach for detection, discrimination of faults for five terminal transmission line protection in presence of PV and Wind Energy system. It deals about transient current based protection scheme for SVC compensated multi terminal transmission system with discrete wavelet transform. Fault indices of all phase currents at all terminals are obtained by analyzing the detail coefficients of current signals using bior 1.5 mother wavelet. This scheme is tested for various types of faults in multi terminal transmission system in presence of hybrid generation and it is found effective for detection of faults with various fault inception angle, fault impedance at different distances.**

Keywords—*Multiterminal Transmission lines, Wavelets, Wind source, PV source, SVC.*

1. Introduction

With the invariably increasing demand for electric power, there is a need for improving the efficiency and operation in the transmission of energy. There are several areas where transmission of electric energy is still not possible for utilities. Transmission is the bulk movement of energy from power stations to load centers and from one load center to another. With increase in power-line voltages there has of necessity been an increase in the size of pylons or towers which support the lines. The overhead power lines use high voltages for efficient transmission of electrical energy. In the face of rigorous environmental governing, the need for forms of generation has never been more obvious. Another aspect of modern power systems which has a considerable impact on the environment is the presence of the overhead power transmission system[9].Renewable energy production from wind, solar ,ocean etc. are considered as feasible technologies available to harness the power from renewable sources[1] however, the problem lies in making this energy available for use. Domestic consumers nearly all take their electricity in the form of single phase power, all power systems use three phases. It is the essential part of the design of a power supply network is the calculation of the currents which flow in the components when the three phase faults of various types occur. In the fault survey, faults are applied at various points in the network and the resulting currents are obtained by digital computation. If a component develops a fault, it should be isolated from rest of the system as rapidly as possible to preserve the stability of rest of the system[2]. If the faulty component is an overhead line or a transformer feeding an overhead line, then other lines will carry extra current. 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[5]. Hence the amplitude and incidence of each frequency can be found precisely. The Discrete Wavelet Transform (DWT) is easier to implement than Continuous Wavelet Transform is computed by changing the scale of the analysis window and shifting the window in time or multiplying the signal and the information of interest is often a combination of features that are most speedy[8]. The main advantage of WT over Fourier Transform is that the size of analysis window varies in proportion to the frequency analysis at which WT can offer a better compromise in terms of localization. and classifying practical for analyzing power system transients and disturbances[6]. The system must be designed so that this extra current does not result in the other lines exceeding their maximum capacity. The proposed algorithm describes a new approach for detection, discrimination of faults for five terminal transmission line protection in presence of PV and Wind Energy system. It deals about transient current based protection scheme for SVC compensated multi terminal transmission system with discrete wavelet transform[4]. The scheme is tested for various types of faults in multi terminal transmission system in presence of hybrid generation.

2. Hybrid energy sources

Due to availability of hybrid sources worldwide, PV and wind energy generation is increasing day by day which helps to develop rural electrification[3], job opportunities in science and technology . But there are some limitations to the penetrating of wind energy and solar energy into the grid. The success of a wind powered generator depends on balancing factors of the useful life, capital cost, the maintenance costs and the output power. To achieve a long useful life it must be able to withstand the largest gust of wind which may occur only once in 100 years. This increases the capital cost. High quality materials can reduce maintenance costs and extend useful life but an important factor is good design. The huge amount of solar energy is available on the earth. Customers are interested in solar power due to low cost, environment friendly, flexible installation and no reactive power consumption by solar panel. Most of the PV system is designed with unity power factor and the characteristics of output power are dependent on the inverter. There is no LVRT (Low voltage-ride through) capability and it does not contribute at the time of fault or any transient condition of the system. Since photovoltaic system has no inertia, some extra devices are required to maintain the system profile. The effect of wind and solar penetration is analyzed for distribution system in most of the literatures[7].

3. Static var compensator

The objective of applying a static compensator in a power system is to increase the power transmission capability ,with a given transmission network,from generators to the loads.In order to meet the general compensation requirements of the power system,the output of the static var generator is to be controlled to maintain or vary the voltage at the point of connection to the transmission system[10].The proper compenstionof the ac power system requires some specific variation in the amplitude and time[11].TheCompensator must stay in synchronous operation with the ac system at the compensated bus under all the operating conditions including major disturbances. If the bus voltage be lost temporarily due to near by faults, the compensator will be able to recapture synchronism immediately after fault clearing. The output of the VAR generator has to be varied to increase power flow and to stabilize specific parameters of the power system in face of network contingencies and dynamic disturbances.

4. System model

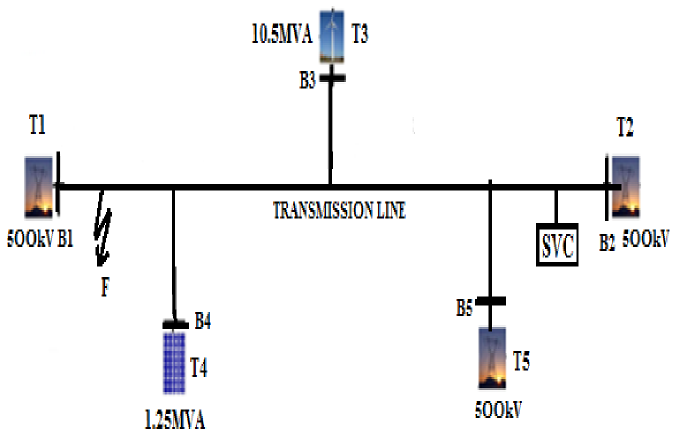


Fig. 1. Five terminal transmission line model with hybrid source

5. Flow chart of proposed scheme

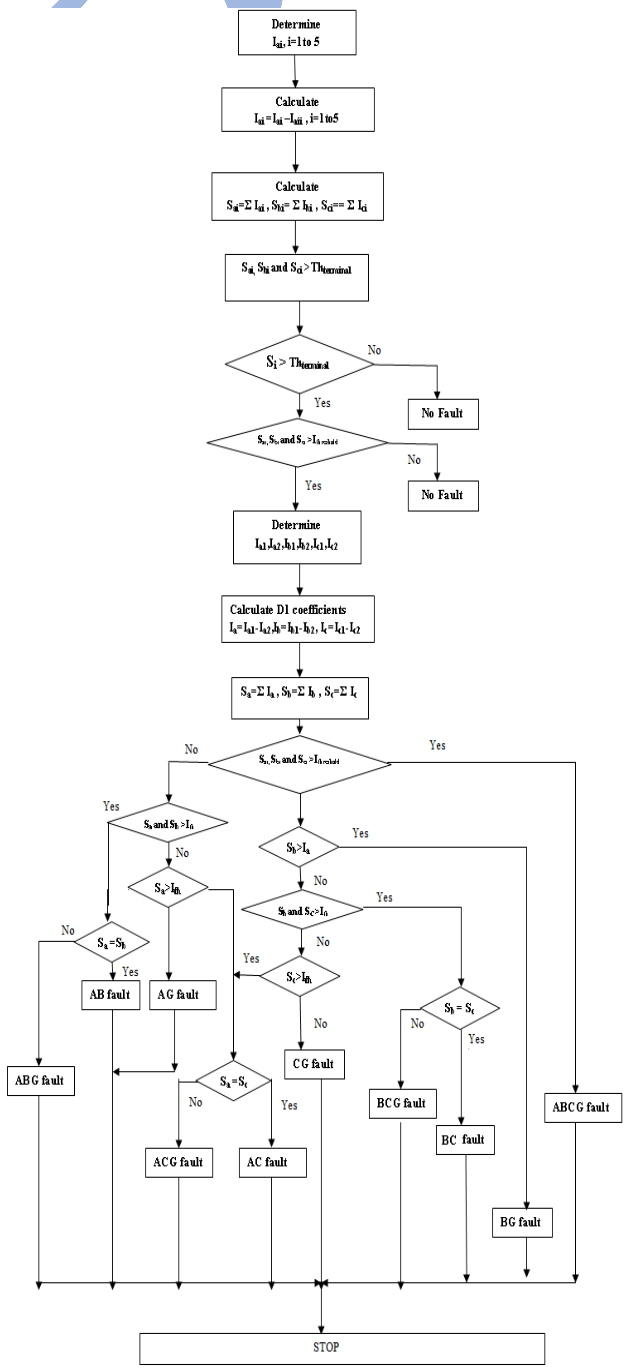


Fig. 2 Flowchart of Proposed scheme.

6. Parameters Of The Model

Terminal 1	G1	500KV ,9000MVA Y-g, Phase angle=0^0
Terminal 2	G 2	500 KV, 9000MVA Y-g, Phase angle at A=20^0
Terminal 3	Wind	10.5MVA
Terminal4	PV	1.25MVA
Terminal 5	G3	500KV ,9000MVA Y-g, Phase angle=0^0
Transmission line (Distributed)		R=0.01273 Ω/Km R_0 = 0.3864Ω/Km L= 0.9337e-3H/Km L0=4.1264e-3H/Km C=12.74e-9 F/km, C0 = 7.751e-9 F/km
SVC		Rating: 300-Mvar Coupling transformer: 500kV/16-kV 333-MVA TCR:One 109-Mvar TSC:Three 94-Mvar
Mother Wavelet		Bior 1.5
Sampling frequency		216Khz
Frequency band		108Khz-54Khz
Samples/cycle		21600

Table.I Parameters of Proposed scheme.

7. Results And Discussions

The wavelet based Fault classifier modules are tested using data sets consisting of fault index, fault inception angle, distance and fault resistance and were changed to investigate the effects on the performance of the proposed algorithm.

A .Test results of single phase to ground faults (LG)

The network was tested by presenting different single phase to ground fault cases with varying fault inception angles from 0^0 to 180^0 with steps of 20. Fig. 3 shows the detection of LG fault at Phase A of the module at terminal. Fig. 4 illustrates the analysis of detailed coefficients of Single Phase to ground fault at Phase A and is observed that the faulty phase detailed coefficient values are greater than the threshold value. The variation of Fault distance from 0 to 100 km in steps of 10 with constant Fault Inception angle (FIA) at 120^0 and Fault inception angle with constant distance at 60km and fault resistance R_f = 5Ω of Single Line to Ground (SLG) fault at terminal1is shown in fig. 4.

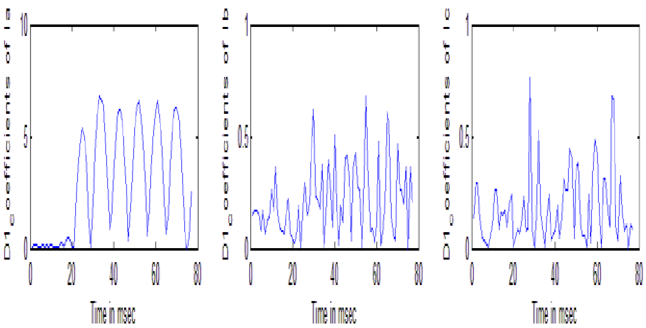


Fig. 3. Detection of LG fault at Phase A

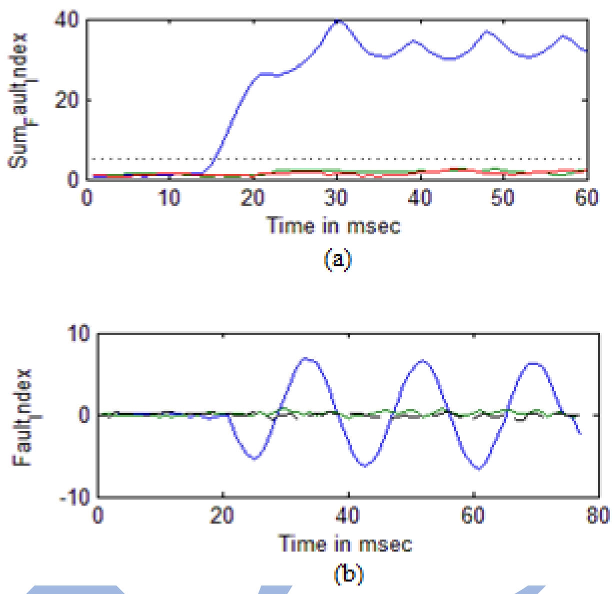
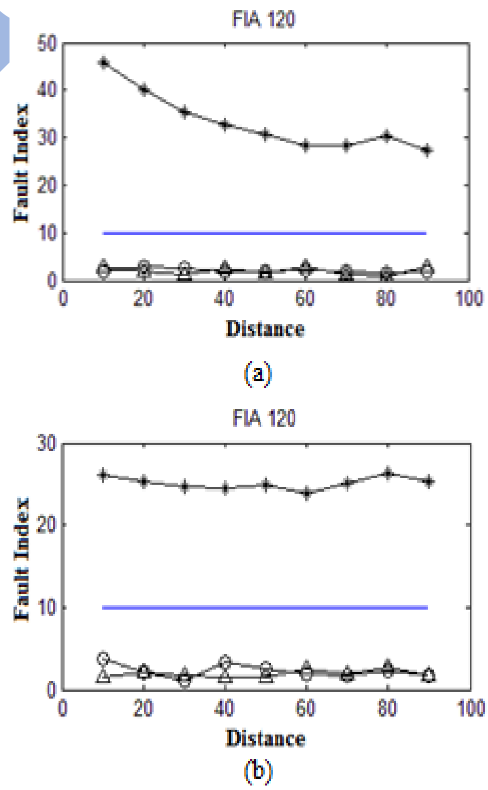


Fig. 4 (a) & (b) Analysis of detailed coefficients of Single Phase to ground fault at Phase A.

The Fault Index I_{f1} is calculated with various locations from 10km to 100km with step size of the transmission line. The Fault index and variation of distance of Three Phase Currents for incidence angle of 120^0 transmission line with SVC at terminals 1,3,4,5 and between terminal3 &4 and terminal4&5 of all combinations of Phase A, Phase B and Phase C . It is observed that fault index I_{f1} of all faulty phases is greater than Threshold T_{h1} value. The fault Index of healthy phases remains less than the threshold value and is illustrated in Fig.5.



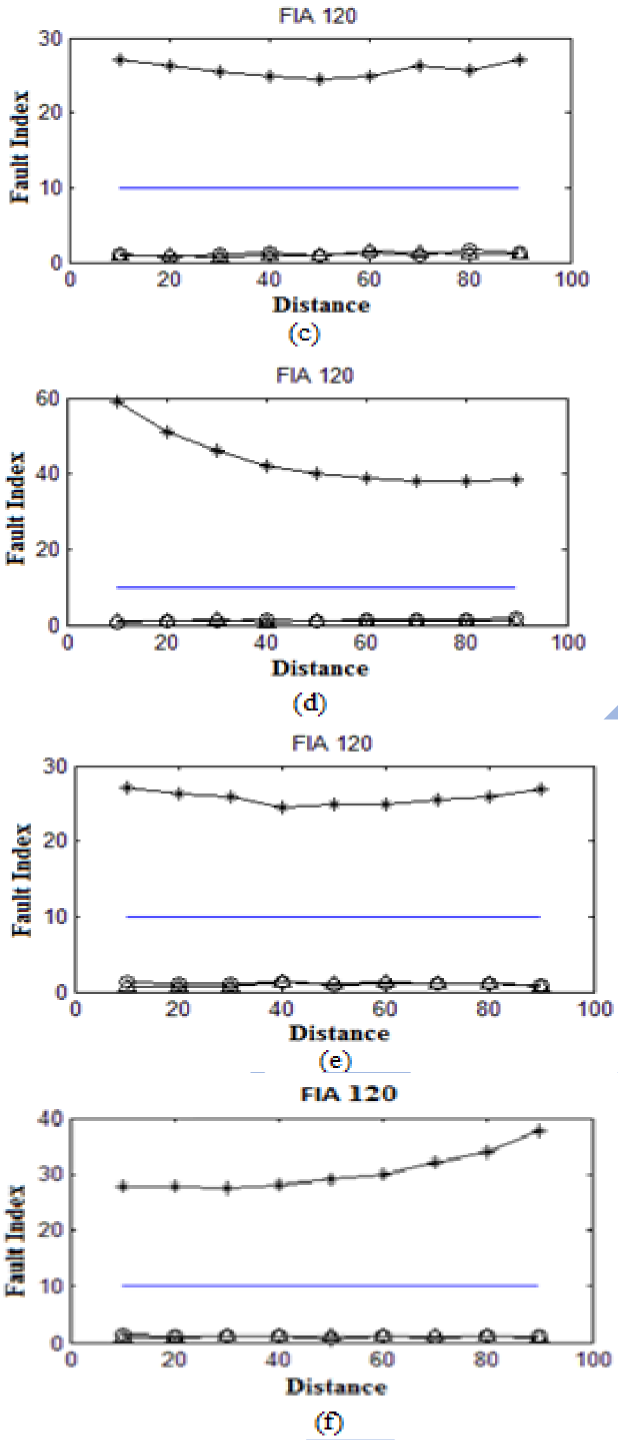


Fig. 5 Fault index and variation of distance of 3ph Currents for Fault inception angle of 120^0 of Multiterminal transmission system with SVC for LG fault at (a)Terminal1 (b)Terminal3 (c)Terminal4 (d)Terminal5 (e) Between Terminal3&4 (f) Between Terminal 4&5.

The effect of variation in fault index is studied by varying the incidence angle ranging from 0^o to 180 ^{o} in steps of 20^o at various locations. In all the cases I_{f1} is always less than T_{h1}. Fig.6. illustrates Variation in fault index and incidence angle of Three Phase Currents at Terminals 1,3,4,5 and between Terminal 3 & 4 and Terminal 4 & 5 for 60% of the transmission line with SVC at Line to ground fault. It is observed that the proposed algorithm detects the fault less than half cycle using wavelet analysis.

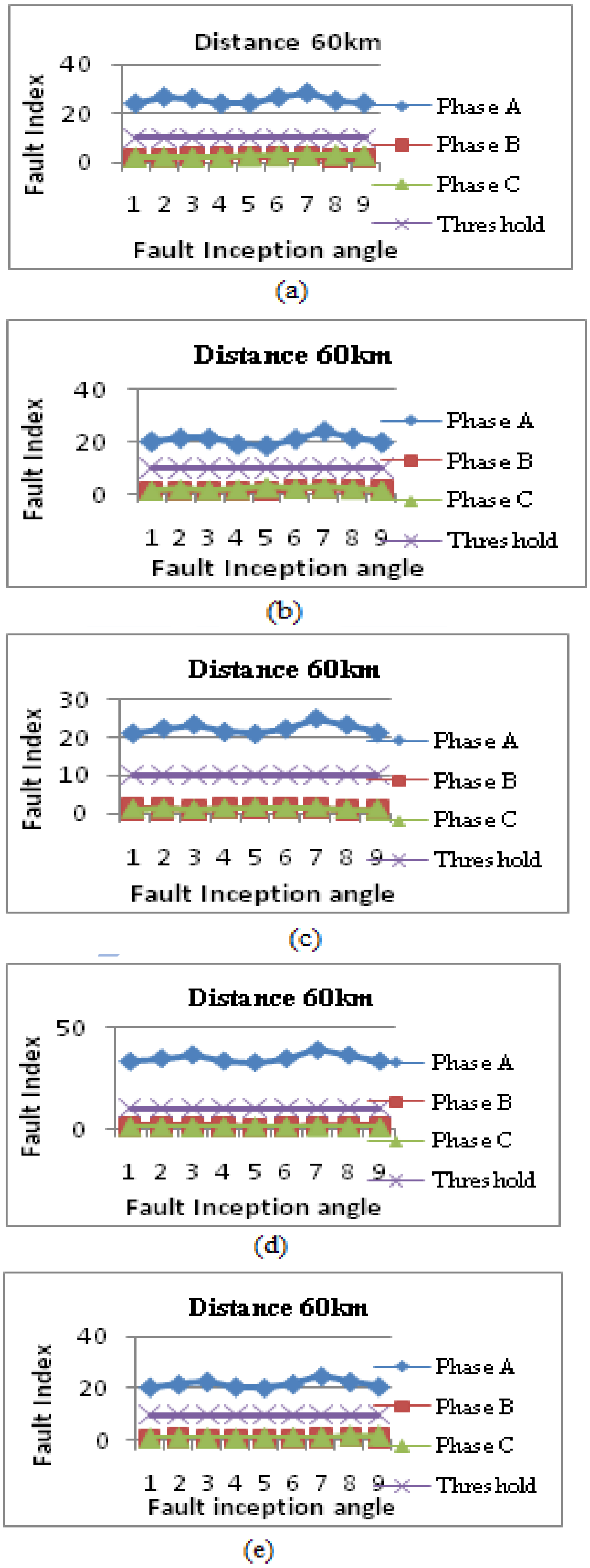
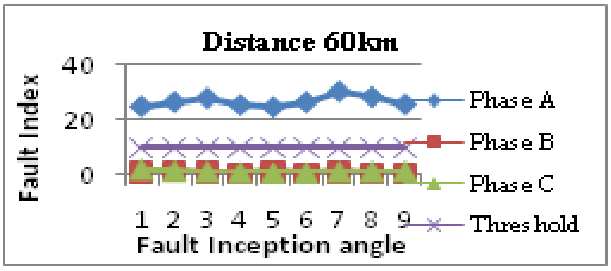


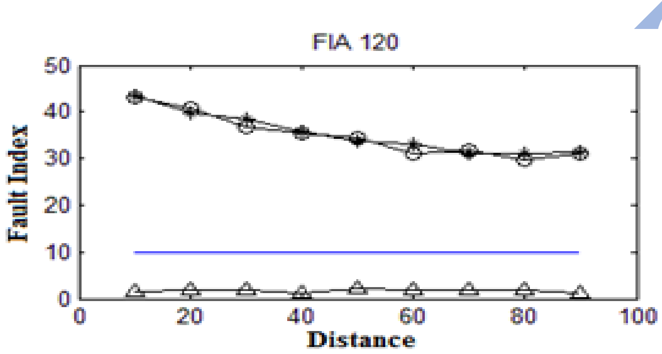
Fig. 6 Fault index and variation of fault inception angle of 3ph Currents for constant distance of 60km of Multiterminal transmission system with SVC for LG fault at (a)Terminal1 (b)Terminal3 (c)Terminal4 (d)Terminal5 (e) Between Terminal3&4 (f) Between Terminal 4 & 5.



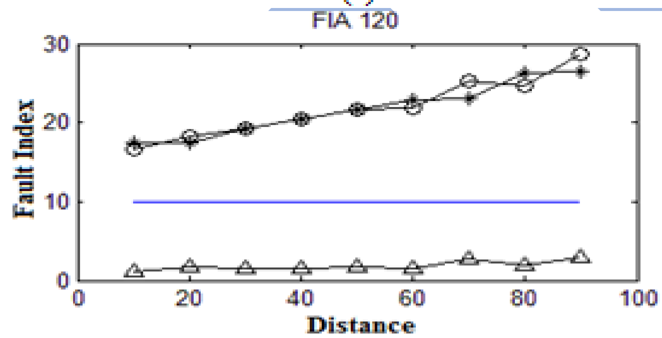
(f)

B. Test results of Phase to Phase faults (LL)

The Fault index and variation of distance of Three Phase Currents for incidence angle of 120^0 transmission line with SVC at terminals 1,3,4,5 of all combinations of Phase A, Phase B and Phase C . It is observed that fault index I_{f1} of all Phases A & B is greater than Threshold T_{h1} value. The fault Index of healthy phases remains less than the threshold value and faulty phases is more than the threshold value is shown in fig.7.It is observed that the proposed algorithm detects the fault less than half cycle using wavelet analysis.



(a)



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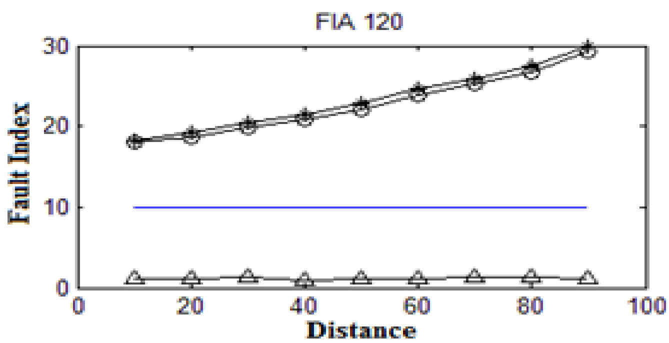

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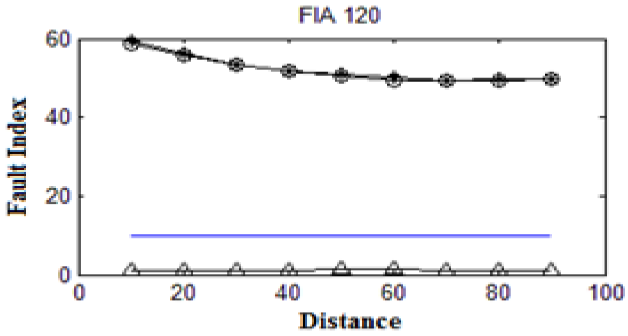
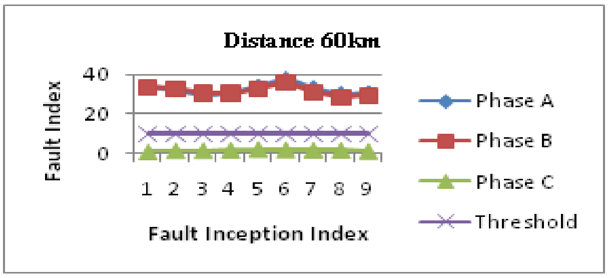


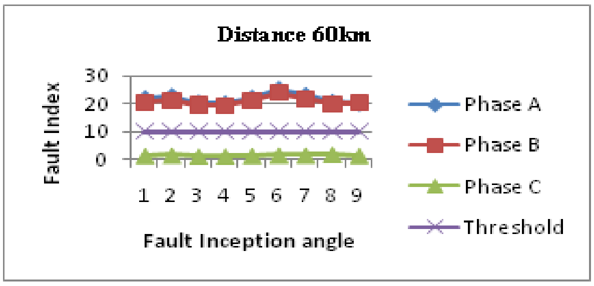
(d)

Fig. 7 Fault index and variation of distance of 3ph Currents for Fault inception angle of 120^0 of Multiterminal transmission system with SVC for LL fault at (a)Terminal1 (b)Terminal3 (c)Terminal4 (d)Terminal5.

Variation in fault index and incidence angle of Three Phase Currents at Terminals 1,3,4,5 for 60% of the transmission line with SVC for phases A & B fault is shown in fig.8.



(a)



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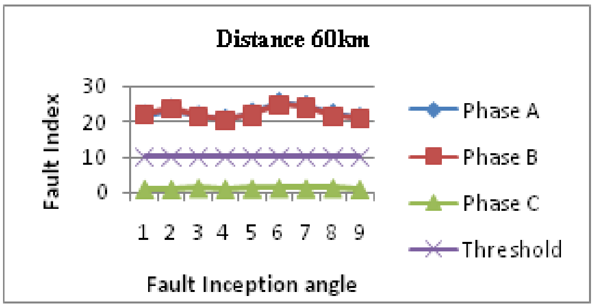
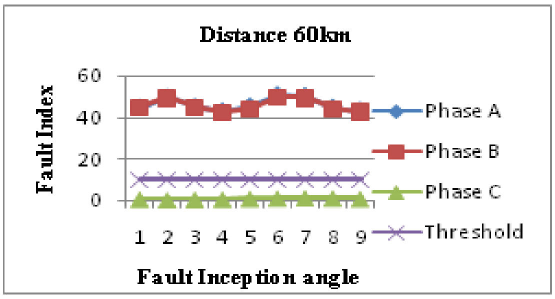


(c)

Fig. 8 Fault index and variation of fault inception angle of 3ph Currents for constant distance of 60km of Multiterminal transmission system with SVC for LL fault at (a)Terminal1 (b)Terminal3 (c)Terminal4 (d)Terminal5



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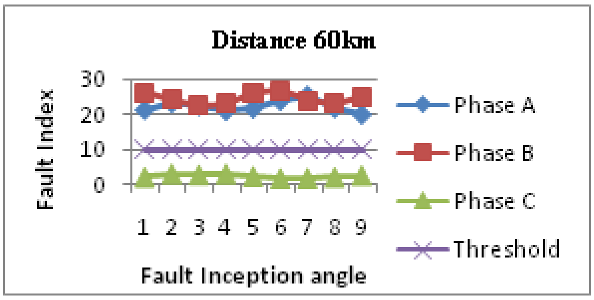
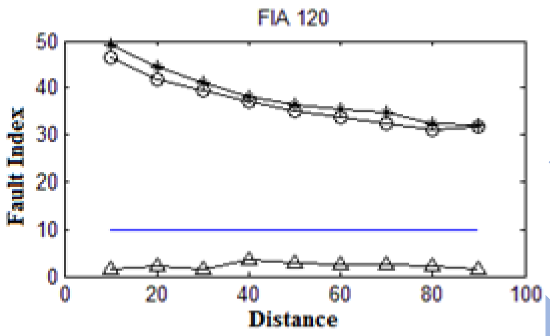


(b)

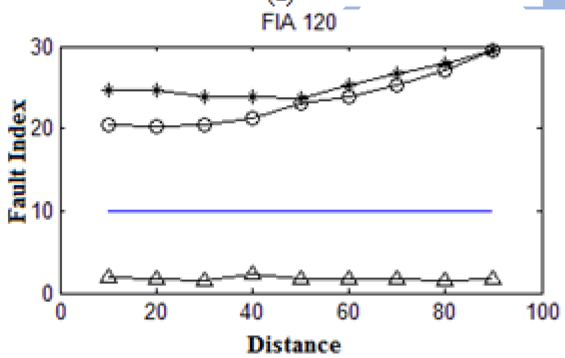
Fig. 10. Fault index and variation of fault inception angle of 3 ph Currents for constant distance of 60km of Multiterminal transmission system with SVC for LLG fault at (a) Terminal1 (b)Terminal3.

C. Test results of Double Phase to ground faults (LLG)

The variation of Fault distance from 0 to 100 km in steps of 10 with constant Fault Inception angle (FIA) at 120^0 and Fault inception angle with constant distance at 60km for fault inception time 15ms (Φ1= 120°) and fault resistance Rf = 5Ω of Double Line to ground (DLG) fault at terminal1 and terminal3 is shown in fig9 and fig.10.

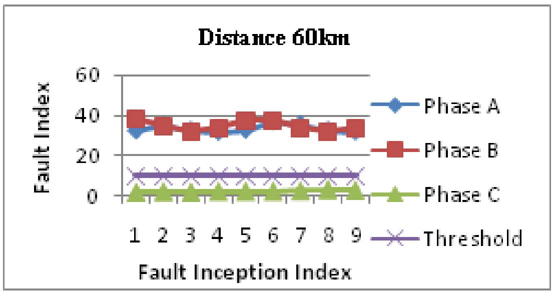


(a)



(b)

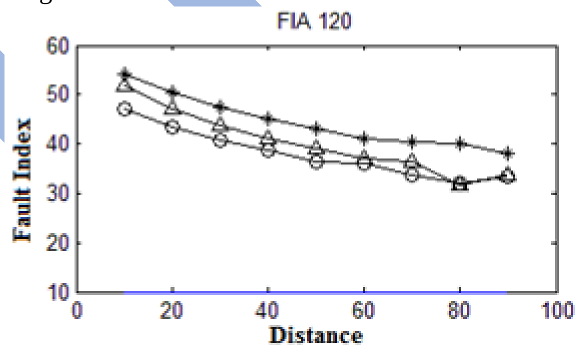
Fig. 9 Fault index and variation of distance of 3ph Currents for Fault inception angle of 120^0 of Multiterminal transmission system with SVC for LLG fault at (a)Terminal1 (b)Terminal3.



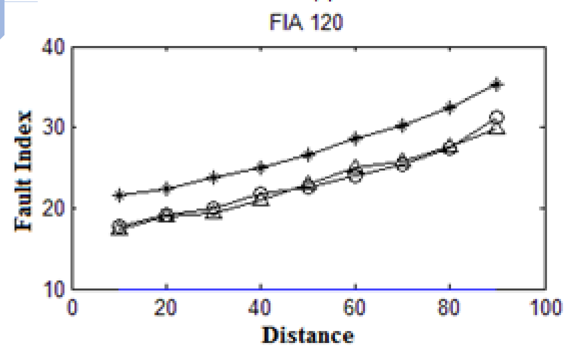
(a)

D. Test results of Three Phase faults (LLL)

The variation of Fault distance from 0 to 100 km in steps of 10 with constant Fault Inception angle (FIA) at 120^0 and Fault inception angle with constant distance at 60km for fault inception time 15ms (Φ1= 120°) and fault resistance Rf = 5Ω of three phase fault at terminal1, terminal3 is shown in fig11 and fig.12.



(a)



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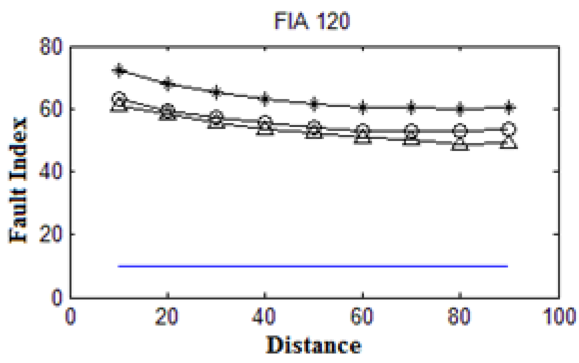
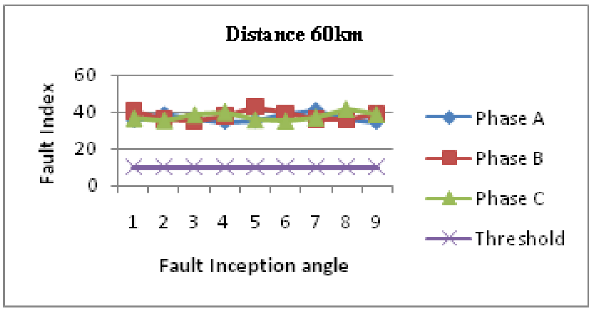
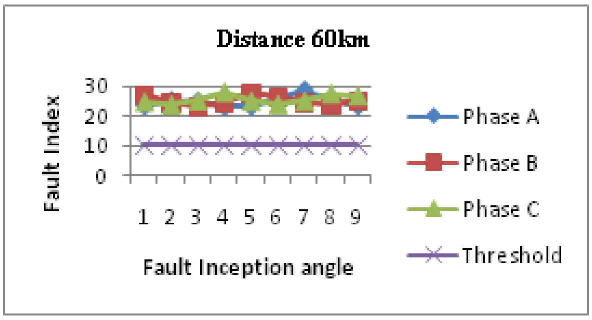


(c)

Fig. 11 Fault index and variation of distance of 3ph Currents for Fault inception angle of 120^0 of Multiterminal transmission system with SVC for LLL fault at (a)Terminal1 (b)Terminal3 (c)Terminal5.



(a)



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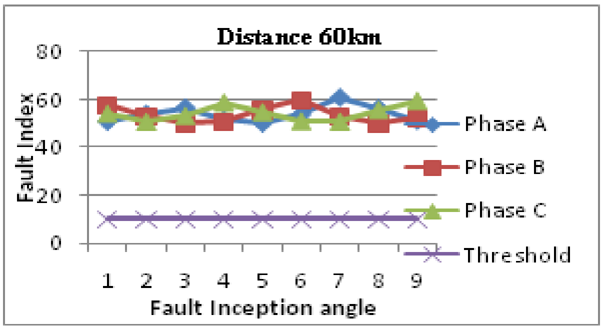

(c)

Fig. 12. Fault index and variation of fault inception angle of 3ph Currents for constant distance of 60km of Multiterminal transmission system with SVC for LLL fault at (a)Terminal1 (b)Terminal3 (c)Terminal5.

8. Conclusion

This research presents the implementation in a computational routine of algorithms for fault detection and discrimination in five terminal transmission lines compensated with SVC. The algorithm employs the fundamental components of three phase currents of each section measured at all the terminals. The wavelet detailed coefficient based classification algorithm provides automatic detection and discrimination of fault type and compensation by SVC is provided. The reliability of wavelet analysis for fault classification of shunt faults on five terminal transmission line fed from sources with two end terminals and hybrid energy sources like wind and PV system at other terminals is presented. The variation of fault parameters such as line distance, fault inception angle and fault resistance on multi terminal transmission with hybrid energy system protection scheme by a number of classified short circuit fault conditions is effectively done with less than half cycle. The difficulty of the possible types of faults of transmission line from 0 to 180° angle, fault resistance (0-50Ω) are identified and tested at different distances and various fault inception angles.

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