A wavelet based protection scheme for micro-grid with multiple distributed generations and Static Var Compensator

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Abstract— Microgrid technology can effectively integrate the advantages of distributed generation, and also provide a new technical way for large scale application of grid-connected generation of new energy and renewable energy. Microgrid combines distributed power, load, energy storage devices and control devices, forming a single and controllable power supply system. Protection must respond to both utility grid and Microgrid faults. If the fault is on the utility grid, the desired response may be to isolate the Microgrid from the main utility as rapidly as necessary to protect the Microgrid loads. If the fault is within the Microgrid, the protection coordinator isolates the smallest possible section of the Microgrid to eliminate the fault. In order to cope with the bi-directional energy flow due to large numbers of micro sources new protection schemes are required. This paper proposes a protection scheme for microgrid with multiple distributed generations and Static Var Compensator using Wavelet based multi-resolution analysis is used to find the detailed coefficients of the signals to calculate the fault index. Fault indices of all phase currents at each terminal are obtained by analyzing the detail coefficients of current signals using bior 1.5 mother wavelet. The approximate decomposition of the current signals is utilized to detect and discriminate the faults from their respective terminals. This scheme is tested for various types of faults in the proposed system and it is found effective for detection of faults with various fault inception angle, the fault impedance at different distances with and without static var compensator.

Index Terms—**Microgrid, SVC, renewable energy sources, solar PV, wind and solar PV system, wavelet, Protection scheme.**

I. Introduction

In recent years, the distributed generation (DG) and the Micro-grid (MG) system, represented by photovoltaic generation and wind power generation[1]. The most widely accepted definition of micro-grid is states that one of the key features of the MG is its capability to raise the utilization rate of new energy sources and to enhance the power supply reliability of critical loads. The power system components with the highest fault incidence rate, since they are exposed to the environment. Faults may have very serious consequences. Therefore, faults must be removed from the system as rapidly as possible. The function of power system protection is to detect and remove faults from the system as rapidly as possible while minimizing

The disruption of service [2]. Micro-grid protection scheme implementation poses great technical challenges, such as the protection system for micro-grid which must respond to both main grid and micro-grid faults. Using the techniques demonstrated in this paper for determining the currents in different parts of the system model under faulted condition, and the short circuit analysis are performed.

The applications of Wavelet transform were improved from past few years for the improvement of fault analysis in the power system. Though, the work rarely indicates about the microgrid with multiple distributed generations several ruling algorithms have different solutions and techniques being proposed [3-5].

The objective of FACTS controllers is to improve the power transmission capability and the control of the power flow over chosen transmission routes from generators to the loads. The SVC come into Shunt Controllers group and it function as a fast generators so as to control precise parameters of the electric power systems [6,7]. The SVC contains of a Thyristor Controlled Reactor (TCR) and a Fixed Capacitors (FC) banks. The TCR is a Thyristor controlled inductor whose effective reactance is varied in a continuous way by partial conduction control of thyristor valve. The increasing demand for conventional energy sources like coal, natural gas and oil is forcing people towards the research and development of renewable energy sources or non-conventional energy sources. Renewable energy is catching up faster pace in the present community [12]. The increase in demand for renewable energy sources like wind, solar etc are now well developed, cost effective and extensively used. A wind turbine converts mechanical energy into electrical energy and it produces ac output voltage and this ac output voltage is converted to dc by the help of ac to dc converter or rectifier. A PV cell converts the light energy into electrical energy and produces dc output voltage.

The solution of over current related failure problems is to limit the magnitude and fault can be detected within the prescribed time. Wavelet based ANN approach has been adopted in [8,9] for fault detection and classification of a two terminal network.

The proposed algorithm describes the protection scheme for micro-grid with PV and wind source compensated with Static Var Compensator using wavelet analysis. An operating current signals are identified and then sum of the detailed coefficients are calculated by make use of bior1.5 mother wavelet at each terminal. This is compared to a threshold value of current signal in order to provide protection against short circuit faults. The test results can clearly shows that the variation in the value of fault index of the healthy phase is below the threshold value of all the terminals by varying fault inception angle, distance and fault resistance.

II. Proposed System Model and Description

The micro-grid is connected to utility grid is more reliable to carry continuous power to the grid because if there is any shortage of power or fault in the renewable energy sources then the loads are directly connected to the grid. The microgrid of three energy sources which are solar energy, wind energy and energy storage system are used as a input sources as illustrated in Fig. 1.

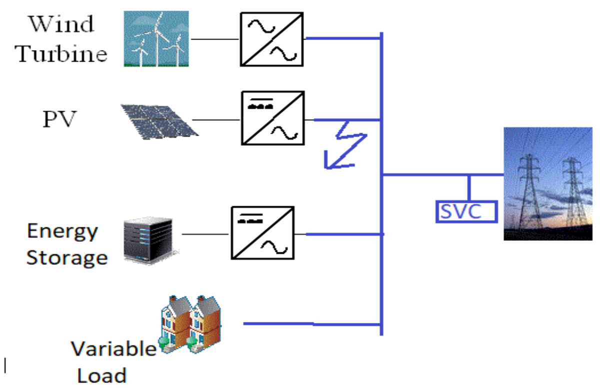

Fig. 1 Block diagram representation of proposed system with Energy source connected to utility grid

A. *Solar PV System Modeling*

A solar cell is a fundamental block of solar photovoltaic (PV) technology. The solar cell is a device that converts sunlight into electricity directly without any other intermediate conversion steps. DC/AC converter converts the DC to commercial frequency AC. The diode determines the current voltage characteristic of the cell. The output of the current source is directly proportional to the light falling on the cell.

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The current through diode and solar cell output current is given by,

$I_D = I\,(e^{\frac{q(v+IRs)}{kT}} - 1)$ (1)

$I = I_L - I_D - I_{Sh}$

(2)

$I = I_L - I(e^{\frac{q(v+IRs)}{kT}} - 1) - \frac{v+IRs}{Rsh}$

(3)

I : Solar cell current (A)

B. *Wind Energy Conversion System Modeling*

The conversion of wind energy to electrical energy is one of the most successful renewable energy technologies[17].Wind energy system converts the kinetic energy of wind into the form of electrical energy. The kinetic energy of air of mass (m) moving at speed (v) can be expressed by the equation.

$E=1/2\ m\upsilon^2$

(4)

where $m=\rho A\upsilon t$

The power of wind is given by,

$P_w=1/2\ \rho Av$

(5)

The specific power or power density of a wind is given by,

$P_d=1/2\ \rho v^3$

(6)

C. *Static VAR Compensator Modeling*

The SVC consists of a Thyristor Controlled Reactor (TCR) and a Fixed Capacitors (FC) banks. The thyristor conduct alternates half-cycles of supply frequency depending of the firing angle α, which is measured from a zero crossing of voltage. The effect of increasing the firing angle is to reduce the fundamental harmonic component of the current. The SVC controls voltage where it is connected in order to supply or absorb the required reactive power (Q_{SVC})[7]. The controlling system operates to control the voltage at its connecting point, according to its controlling strategy within its operational limits. It is connected in shunt with the line through a shunt transformer.

D. *Wavelet Analysis*

Wavelet transform is a mathematical tool used in signal analysis. Wavelet coverts a continuous time signal into different scale of components [10]. It is a tool that splits up data into different frequency components, and study each component with a resolution matched to its scale. Multi resolution analysis is carried at different frequencies with different resolutions [11].The wavelet transform can be described in both time domain and the frequency domain.

III. System Model and Proposed Scheme

The System model of comprises of 1000KW$_p$ solar PV system, 2MW wind source and 500KW Energy storage has been connected to variable load and utility grid with SVC Compensation.

In Table I the parameters of proposed system are described as follows.

TABLE I

Parameters of the Proposed Scheme

BUS 1	PV	1000KW$_P$, 470V
BUS 2	Wind	2MW, 580V
BUS 3	Energy Storage	500KW
BUS 4	Variable Load	2MW, 25KV
BUSl 5	Utility Grid	500MW ,25KV
Transmission line (Distributed)		R=0.1153 Ω/Km R_0 = 0.413Ω/Km L=1.05mH/Km L0=3.32mH/Km C=11.33n F/km C0 = 5.01n 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

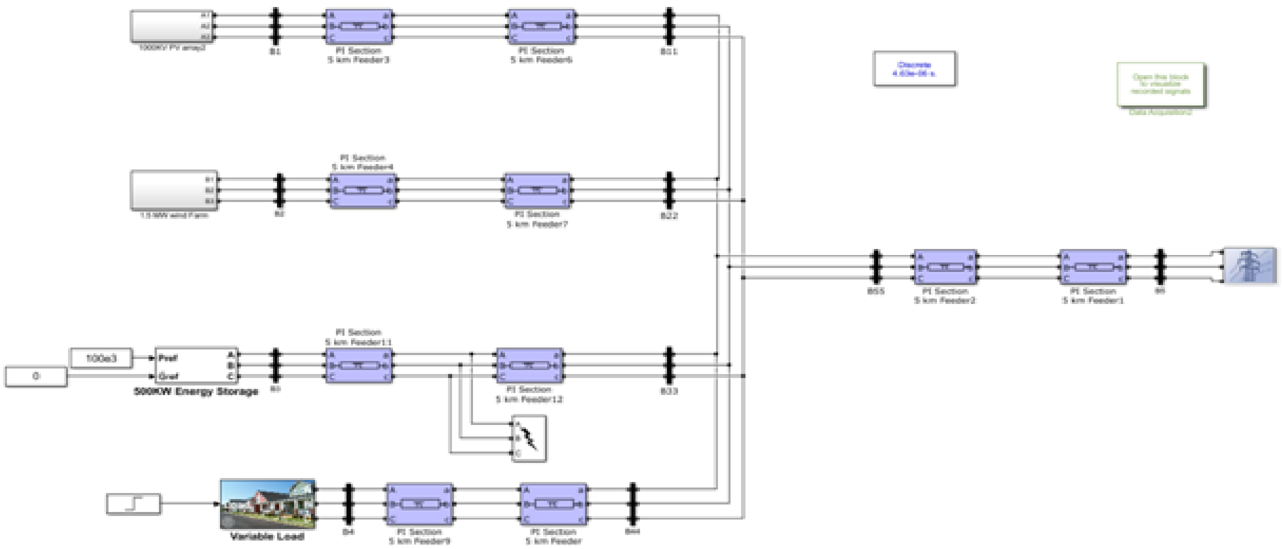


Figure 2: simulation diagram of proposed system

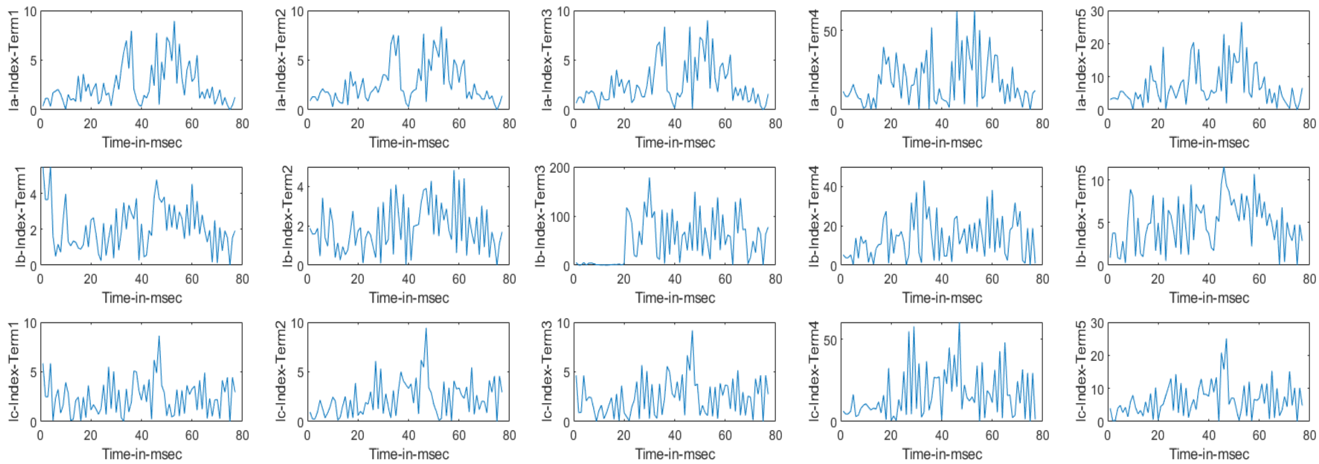
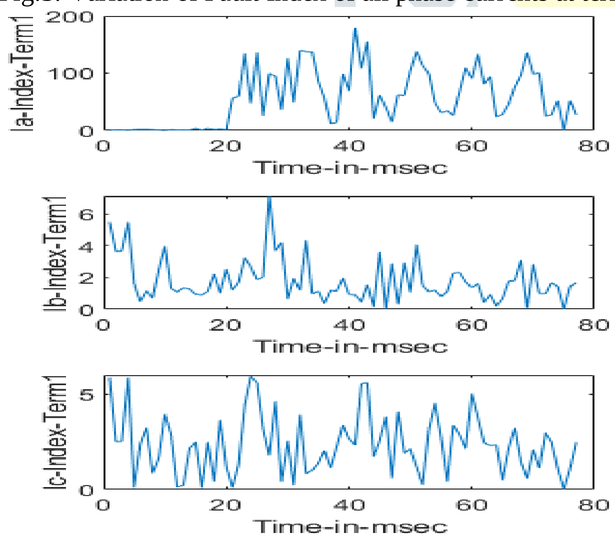
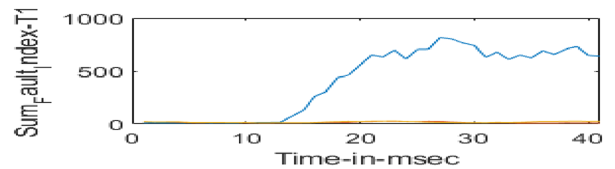


Fig.3: Variation of Fault Index of all phase currents at terminal1 to terminal 5.

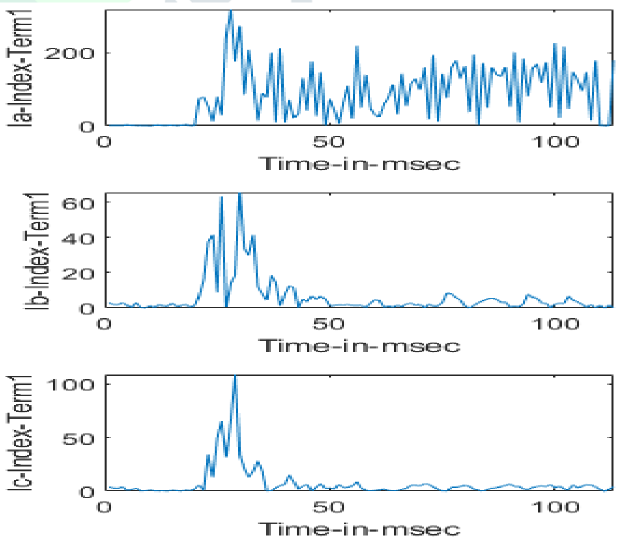


(a)



(b)

Figure4: Detection of LG fault at Phase A of the wavelet based fault classifier module at terminal1using (a) detailed coefficients (b) Sum of the detailed coefficients.



(A)

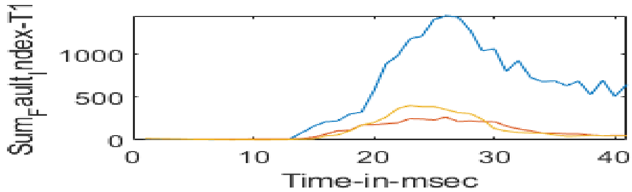
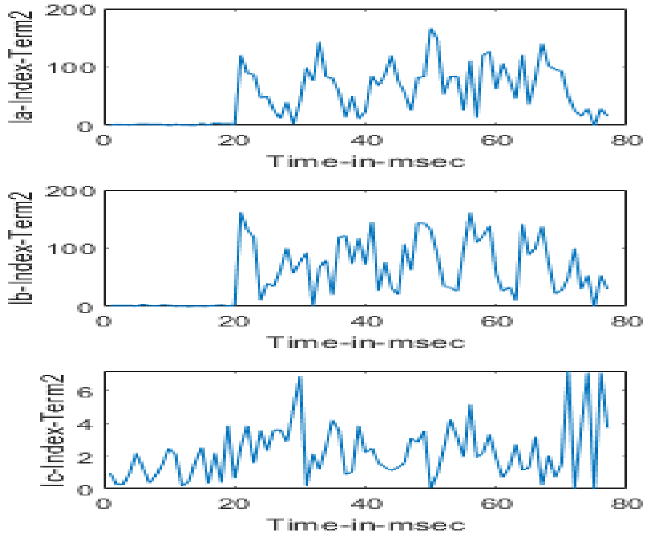


Figure5: Detection of LG fault at Phase A of the wavelet based fault classifier module at terminal1 at SVC compensation using (a) detailed coefficients (b) Sum of the detailed coefficients.



(a)

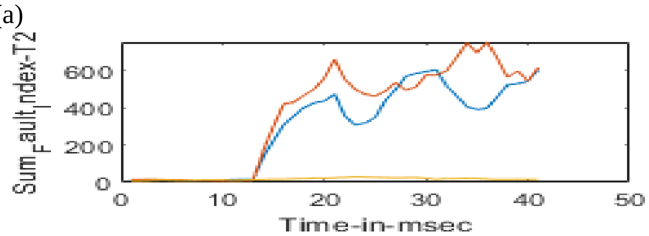
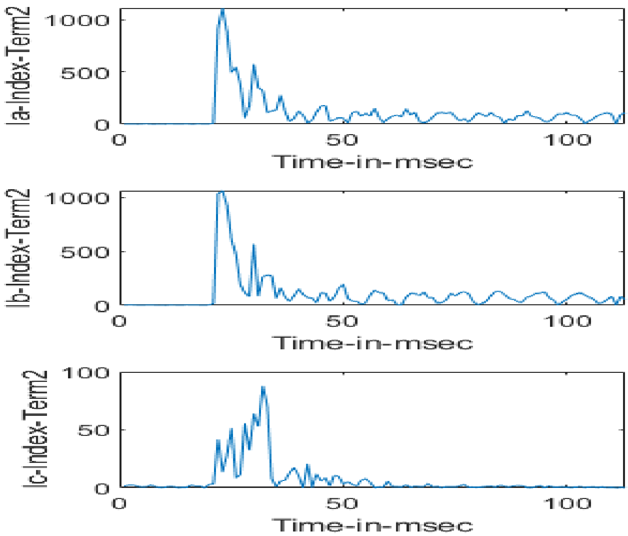


Figure6: Detection of LLG fault at Phase A&B of the wavelet based fault classifier module at terminal-2 using (a) detailed coefficients (b) Sum of the detailed coefficients.



(a)

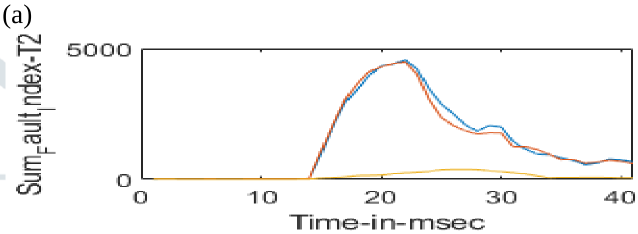
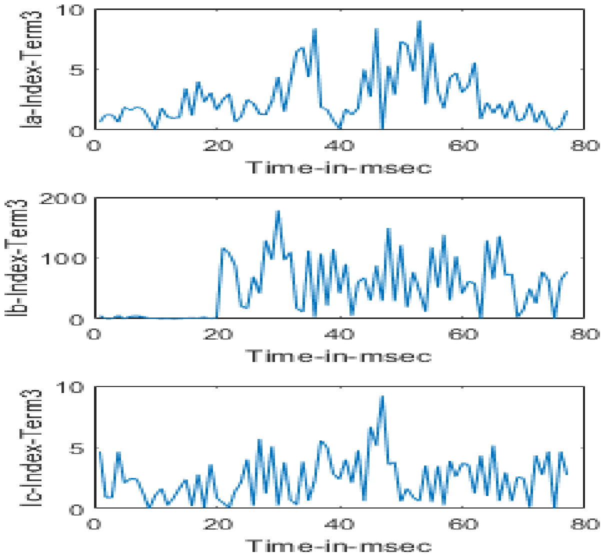
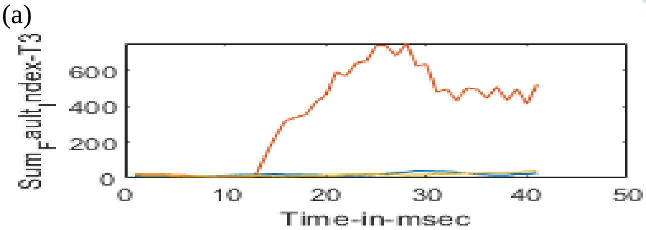


Figure7: Detection of LLG fault at Phase A&B of the wavelet based fault classifier module at terminal-2 with SVC compensation using (a) detailed coefficients (b) Sum of the detailed coefficients.

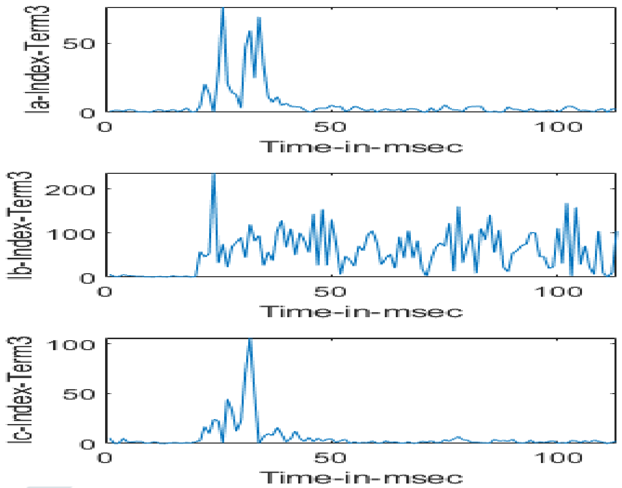


(a)

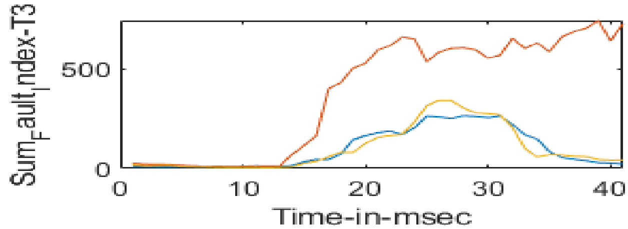


(b)

Figure8: Detection of LG fault at Phase B of the wavelet based fault classifier module at terminal-3 using (a) detailed coefficients (b) Sum of the detailed coefficients.

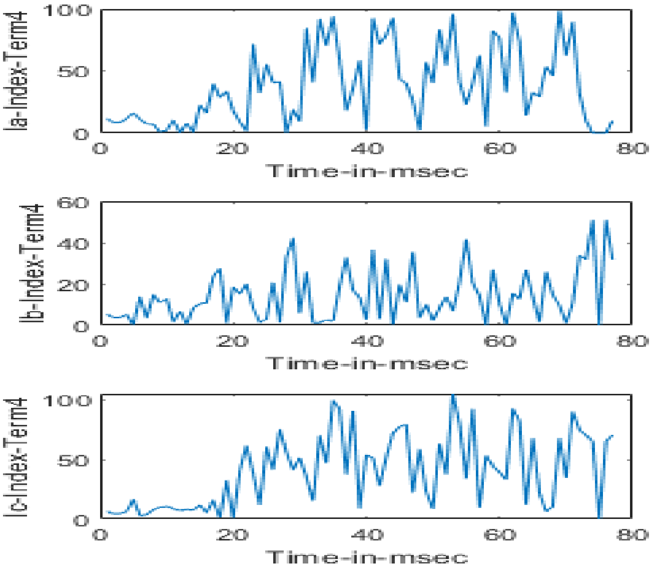


(a)

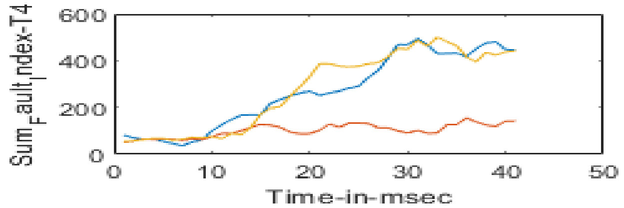


(b)

Figure9: Detection of LG fault at Phase B of the wavelet based fault classifier module at terminal-3with SVC compensation using (a) detailed coefficients (b) Sum of the detailed coefficients.

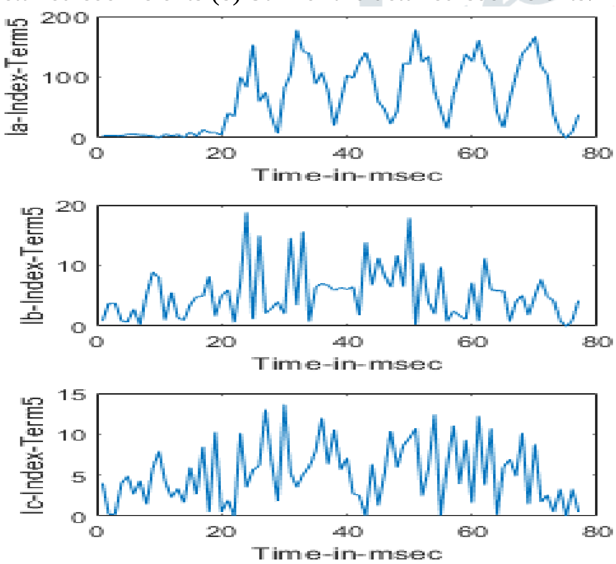


(a)

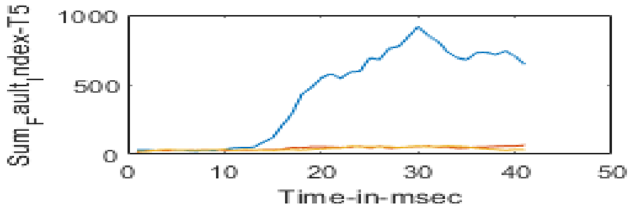


(b)

Figure10: Detection of LLG fault at Phase A&C of the wavelet based fault classifier module at terminal-4 using (a) detailed coefficients (b) Sum of the detailed coefficients.

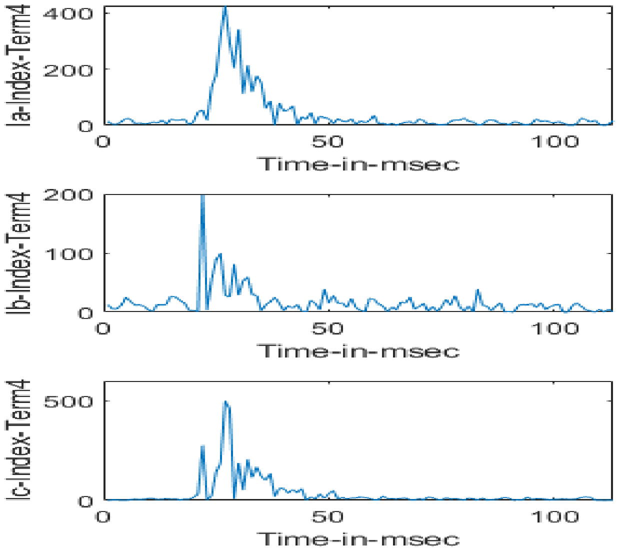


(a)

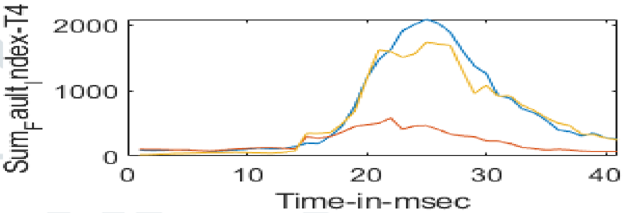


(b)

Figure11: Detection of LG fault at Phase A of the wavelet based fault classifier module at terminal-5 using (a) detailed coefficients (b) Sum of the detailed coefficients.



(a)



(b)

Figure11: Detection of LLG fault at Phase A&C of the wavelet based fault classifier module at terminal-4with SVC compensation using (a) detailed coefficients (b) Sum of the detailed coefficients.

IV. Results and Discussion

The wavelet based Fault classifier modules are tested using data sets consisting of fault cases. Fault index, fault inception angle, distance and fault resistance were changed to investigate the effects on the performance of the proposed algorithm. Fig.3 shows the variation of fault index of all Phase Currents at terminal1 to terminal6. Here this waveform represents fault current index of terminal3 in Phase B to ground which shows the highest value compared all other values. Figure 4 &5 indicating that LG fault case under with and without SVC compensation. Various types of faults under compensation as well as normal case are illustrated from figure-6 to figure-11 and utility grid fault case shown in figure-11.

The network was tested by presenting different types of fault cases with varying fault inception angles from 0^0 to 180^0 with steps of 20. The analysis of detailed coefficients of different types of faults are tested and observed that the faulty phase detailed coefficient values are greater than the healthy phase index values..

V. Conclusion

This research paper describes the implementation of algorithm for fault detection, discrimination of micro-grid connected system compensated with SVC in the presence of solar, wind and energy storage. The algorithm employs the fundamental component of three phase currents of each section measured at all the terminals. The wavelet detailed coefficient based algorithm provides automatic detection and discrimination of fault type. The reliability and accessibility of wavelet analysis for fault classification of shunt faults of micro-grid connected to utility grid is interconnected with 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 proposed 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 various distances and fault inception angles.

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