Micro-Grid Protection Schemes and the Role of UPFC Controller

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Abstract— **The increasing demand for electrical energy has led to the emergence of renewable energy sources paving path for the concept of microgrid in recent years. The integration of microgrid with renewable energy is facing challenges with the protection issues which need to be concentrated. These challenges are a result of failure in coordinating with protection devices. They include change in the fault level and network topologies. The faults are intermittent in nature and the conventional protection schemes may fail to operate because of their pre-set condition. In order to cope with the bi-directional energy flow due to large number of micro sources new protection schemes are required. The protection scheme must be in such a way to detect short circuit and clear faults in both the grid connected and islanded mode. In order to ensure the higher power flow with enhanced voltage profile and reduced power loss, it is proposed to integrate microgrid with FACTS controllers like Unified Power Flow Controller. Wavelet based multi-resolution analysis is used to find the detailed coefficients of the signals to calculate the fault index. The proposed scheme is tested and found effective for detection of faults with and without Unified Power Flow Controller.**

Keywords— Microgrid, UPFC , renewable energy sources, solar PV, wind and solar PV system, wavelet, Protection scheme.

I. INTRODUCTION

As conventional power systems are struggling to meet the consumers increasing demand of electric power, renewable energy resources are being installed to mitigate the energy short fall. Microgrid idea is a way of integrating multiple renewable energy sources as well as conventional sources and energy storage devices and loads into electric power system [14].Among different sources of renewable energy, wind and solar are two promising alternatives to meet the future electricity needs for mankind [13]. In recent years, the distributed generation and the Micro-grid system are represented by photovoltaic generation and wind power generation [2]. Microgrids have several advantages such as reduced costs, increased system efficiency, reliability and better power quality. Apart from the advantages, associated with microgrid, one major challenge it faces is with its protection. Microgrid protection scheme implementation poses great technical challenges, such as the protection system for microgrid which must respond to both main grid and micro grid faults. Therefore, design and selection of proper protection schemes are very much essential for control and operation of power systems. The function of power system protection is to detect and remove faults from the system as rapidly as possible while minimizing.

The techniques demonstrated in this paper are for determining the currents in different parts of the system model under faulted condition, and the short circuit analysis is performed.

The Wavelet transform technique applications were improved from past few years for the improvement of fault analysis in the power system [1].

In order to improve the power flow with enhanced voltage profile and reduced power loss, it is proposed to integrate microgrids with FACTS Controllers. The SVC is a Shunt-connected static var generator that comes into Shunt controller’s group and it functions as a fast generator so as to control precise parameters of the electric power systems [7,8]. The SVC consists of a Thyristor Controlled Reactor (TCR) and a Fixed Capacitors (FC) banks. Depletion of the fossil fuels in the environment is mainly driving people towards renewable energy sources at a faster pace 12].

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 for fault detection and classification of a two terminal network.[9,10]

The proposed algorithm describes the protection scheme for micro-grid with PV and wind source compensated with Unified Power Flow controller using wavelet analysis. Operating current signals are identified and then sum of the detailed coefficients are calculated by making 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 clearly show 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

As micro-grid is connected to utility grid it 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 micro-grid with three energy sources which are solar energy, wind energy and energy storage system are used as a input sources as illustrated in Fig. 1.

A. Solar PV System Modelling

A solar cell or photovoltaic cell that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon. DC/AC converter converts the DC to commercial frequency AC. The diode determines the current voltage characteristics of the cell. The output of the current source is directly proportional to the light falling on the cell.

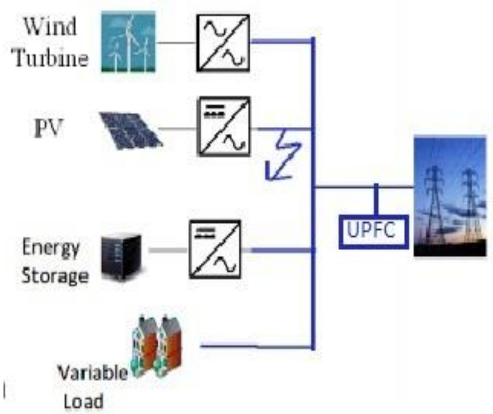

Fig.1 Block diagram representation of proposed system with Energy source connected to utility grid

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

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

$$I = I_L - I_D - I_{Sh} \qquad (2)$$

$$I = I_L - I(e^{\frac{q(v+IRs)}{kT}} - 1) - \frac{v+IRs}{Rsh} \qquad (3)$$

I : Solar cell current (A)

B. Wind Energy Conversion System Modelling

The conversion of wind energy to electrical energy is one of the most successful renewable energy technologies [7]. Wind energy system converts the kinetic energy of wind into electrical energy. The kinetic energy of air of mass (m) moving at speed (v) can be expressed by the equation.

$$E = 1/2\, m\upsilon^2 \qquad (4)$$

Where $m = \rho A \upsilon t$

The power of wind is given by,

$$P_w = 1/2\, \rho A v \qquad (5)$$

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

$$P_d = 1/2\, \rho v^3 \qquad (6)$$

C. Static Var Compensator Modelling

The SVC consists of a Thyristor Controlled Reactor (TCR) and a Fixed Capacitors (FC) banks. The SVC controls voltage where it is connected in order to supply or absorb the required reactive power (Q_{SVC}) [7]. The simulation results using SVC were demonstrated in my previous paper [2]. It is shown that number of classified short circuit fault condition is effectively done with less than half cycle using SVC.

D. Unified Power Flow Controller

A Unified Power Flow Controller is an electrical device which provides reactive power compensation on high-voltage electricity transmission networks. It is a combination of a static synchronous compensator (STATCOM) and a static synchronous series compensator (SSSC) coupled via a common DC voltage link. UPFC is known to be utmost versatile device. It consists of two voltage source converters and the other series connected. The DC capacitors of two converters are connected in parallel. It is connected in shunt with the line through a shunt transformer as shown in fig. 1.UPFC can provide instantaneous and self-governing control of significant power system in transmission line.

E. Wavelet Analysis

Wavelet transform is a mathematical means to perform signal analysis. Wavelet converts a continuous time signal into different scale of components [11]. 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 [12].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 UPFC Compensation.

Using these parameters the simulation block diagram was designed and the results were obtained for different faults by using UPFC and without using UPFC. Different terminals was specified in the diagram from terminal 1 to terminal 5. The variation of fault index of all phase currents was captured.

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

BUS 1	PV	$1000KW_P$, 470V
BUS 2	Wind	2MW, 580V
BUS 3	Energy Storage	500KW
BUS 4	Variable Load	2MW, 25KV
BUS 5	Utility Grid	500MW ,25KV
Transmission line (Distributed)		R=0.1153 Ω/KmR_0 = 0.413Ω/Km L=1.05mH/KmL0=3.32mH/Km C=11.33n F/kmC0 = 5.01n F/km
UPFC		Rating: 300-Mvar Coupling transformer: 500kV/16-kV 333-MVA STATCOM: One 475-Mvar, SSSC: 552-Mvar
Mother Wavelet		Bior 1.5
Sampling frequency		216Khz
Frequency band		108Khz-54Khz
Samples/cycle		21600

Table 1. Parameters of the proposed scheme

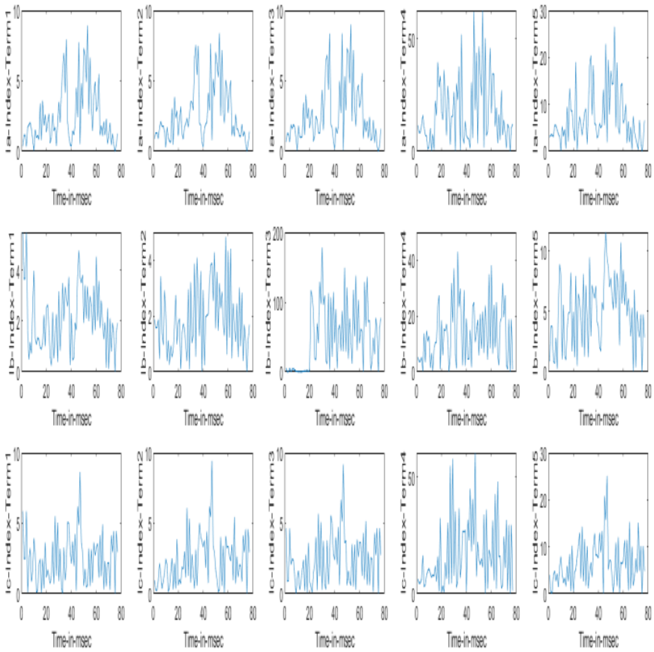

Fig.3: Variation of Fault Index of all phase currents at terminal 1 to terminal 5

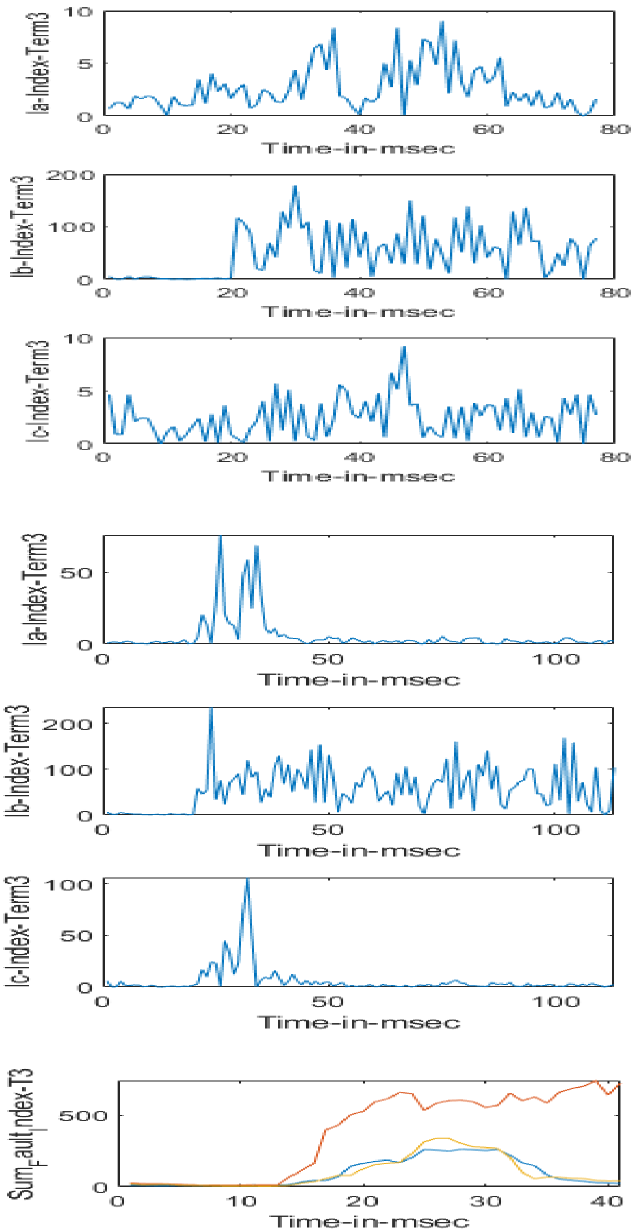

FIGURE 4. DETECTION OF LG FAULT OF PHASE OF THE WAVELET BASED FAULT CLASSIFIER MODULE AT TERMINAL 3 USING A) DETAILED COEFFICIENTS B) SUM OF DETAILED COEFFICENTS

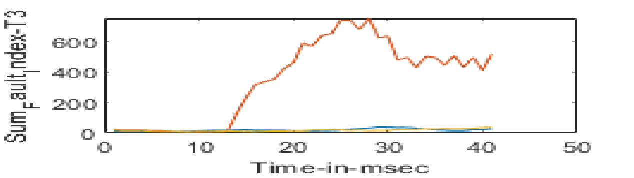

FIGURE 5. DETECTION OF LG FAULT OF PHASE OF THE WAVELET BASED FAULT CLASSIFIER MODULE AT TERMINAL 3 WITH UPFC COMPENSATION A) DETAILED COEFFICIENTS B)SUM OF DETAILED COEFFICIENTS.

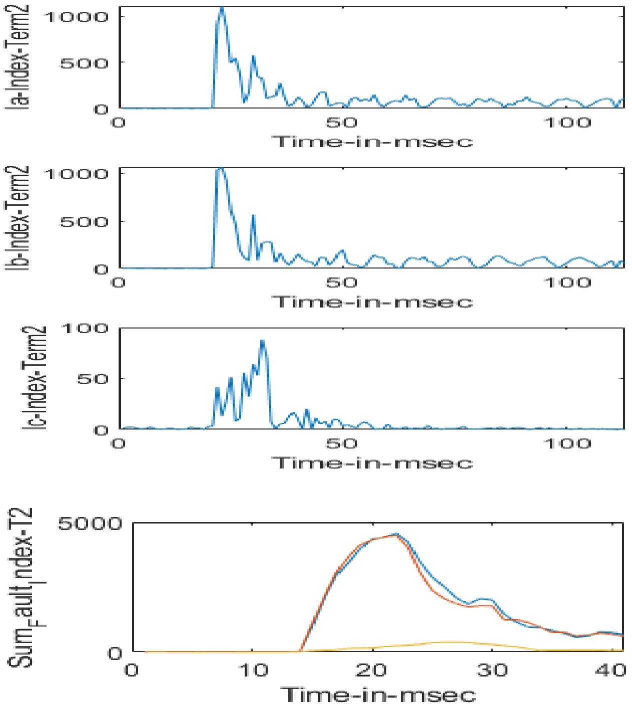

FIGURE 6. DETECTION OF LLG FAULT AT PHASE A & B OF THE WAVELET BASED FAULT CLASSIFIER MODULE AT TERMINAL 2 WITH UPFC COMPENSATION USING A) DETAILED COEFFICIENTS B) SUM OF DETAILED COEFFICIENTS.

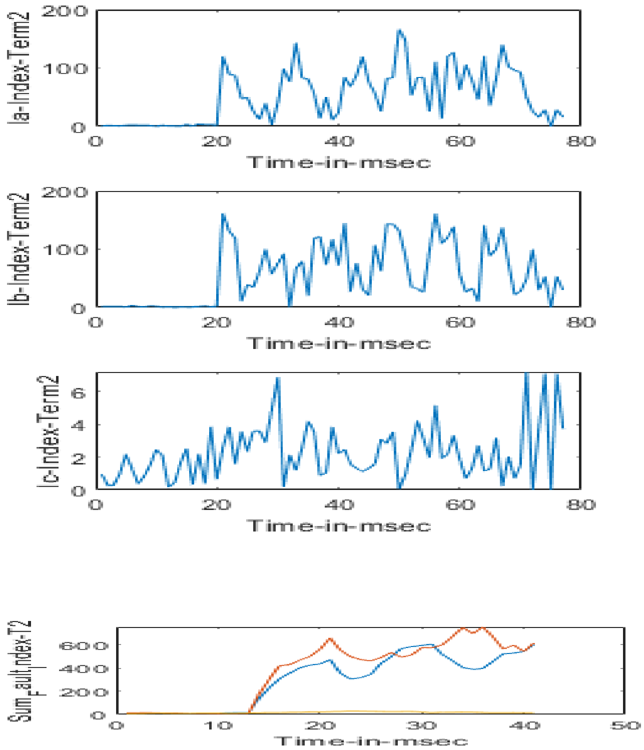

FIGURE 7. DETECTION OF LLG FAULT AT PHASE A & B OF THE WAVELET BASED CLASSIFIER MODULE AT TERMINAL 2 USING A) DETAILED COEFFICIENTS B) SUM OF DETAILED COEFFICIENTS.

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 in order to verify the effects on the performance of the proposed algorithm. The variation of fault index of all phase currents from terminal 1 to terminal 6 is shown in Fig.3. LG fault case without and with UPFC is shown in Figure4 & 5. LLG fault at Phase A&B with and without UPFC is shown in Figure6 and Figure7. The tests were conducted for different types of faults for varying fault inception angles from 0^o to 180^o.It is found that faulty phase detailed coefficient values are greater than the healthy phase index values.

V CONCLUSION

A wavelet detailed coefficient based algorithm in a UPFC compensated line is proposed. This proposed algorithm provides automatic detection and discrimination of fault type by employing the fundamental component of three phase currents of each section measured at all terminals. The Unified Power Flow Controller (UPFC) realizes real-time control over power flow in transmission lines by adjusting the line parameters including line distance, fault inception angle and fault resistance. Compared to Static Var Compensator (SVC), the UPFC is advantageous as it adjust line parameters to control the power flow and its performance is outstanding. The Wavelet technique is used to detect fault at any extreme condition of line parameter variation such as fault inception angle, fault resistance with UPFC operating condition. The important point in all the results shown in Figure.4 to Figure.7 is fault detection time remains less than half-cycle.

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