Wavelet-Based Protection Scheme for SVC Compensated Multi-terminal Transmission System with Hybrid Generation

Y. Manju Sree, G. Ravi Kumar and R. Kameswara Rao

Abstract The majority of transmission system development is easily affected to several temporary and permanent faults due to transients and short circuits. These faults can destroy the transmission network internally and can lead to power system instability. It is necessary to clear these faults within the permissible operating time and have high degree of reliability and security for protective systems. This paper deals about wavelet-based protection scheme for SVC compensated multi-terminal transmission system in presence of hybrid generation. Fault indices are determined by detailed coefficients of current signals at all three terminals using Bior 1.5 mother wavelet. To discriminate the fault on the transmission system, fault indices are compared with a threshold value. The proposed algorithm is found to be reliable, accurate and fast as compared to conventional methods for different types of faults on SVC compensated multi-terminal transmission system with hybrid generation at various terminal locations and fault inception angles.

Keywords Multi-terminal transmission lines · Hybrid generation · Wavelet analysis · SVC

1 Introduction

There is a significant need to prevent damage of highly sophisticated and widely used equipment from electrical failures, fault, and discontinuities. The protective scheme to fulfill the above need should ensure high degree of continuity with

Y. Manju Sree (✉) · G. Ravi Kumar
Kakatiya Institute of Technology and Science, Warangal, India
e-mail: manju547sree@gmail.com

G. Ravi Kumar
e-mail: goli.ravikumar@yahoo.com

R. Kameswara Rao
Raghu Engineering College, Visakhapatnam, India
e-mail: rkameswara@gmail.com

S.C. Satapathy et al. (eds.), *Proceedings of 2nd International Conference on Micro-Electronics, Electromagnetics and Telecommunications*,
Lecture Notes in Electrical Engineering 434, DOI 10.1007/978-981-10-4280-5_27

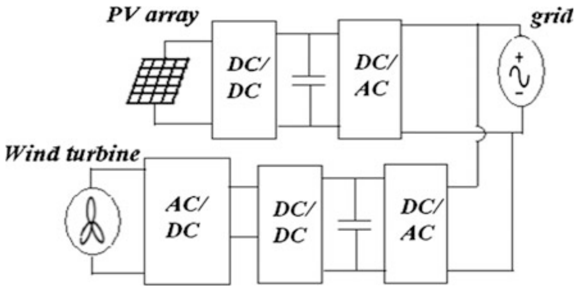

Fig. 1 Block diagram of hybrid PV and wind energy system

electrical supply. The technique lies in designing a system that monitors the power systems for its failures at times. The design should intuitively respond to the fault characteristics, which help in identifying the same. Protection is needed not only against short circuits but also against any other abnormal conditions which may arise on a power system. Most of the faults on transmission and distribution lines are caused by overvoltage resulting in short circuits [1]. Three terminal and multi-terminal line projects generally have protection complexities and lead to compromises in reliability. In the recent past, there is a huge advancements with used in utilizing renewable energy sources. The hybrid energy system [2] is capable of providing electricity to remotely located areas. Wind turbines and solar panels are some to exemplify such systems. The wind turbines operate only during the winter season where there is a possibility of huge wind. Similarly, the solar panel is functional during summer when there is abundant sunlight. If any fault occur on the transmission line due to bad weather or any other condition, hybrid system are present to continue the supply [3]. The proposed system configuration and control scheme provides integration of PV source and wind energy source as illustrated in Fig. 1. The proposed research work is carried out to protection of multi-terminal transmission system with SVC in presence of hybrid system which is the combination of wind, PV generation using wavelet-based multi-resolution analysis. The system with hybrid generation [4] and three terminal transmission systems are tested with various combinations of faults on the phases with respect to the distance.

2 Multi-terminal Transmission Line Protection Scheme

Transmission system typically connects the generation plants to the remotely located region. These are further classified based on their individual voltage levels. This paper describes the most common types of three terminal protection scheme [5] for various types of faults. At a point where permanent fault occurs in the lines it takes huge amount of time to detect the fault, meanwhile the reliability of the system diminishes. There is a financial advantage in the development of three terminal transmission systems since it stays away from the cost of all or a segment of a substation and normally decreases the transmission line losses.

The technique of using a differential current relay (DCR) circuits is often considered as the simplest way of detecting faults and protecting the electrical system. The sensed imbalance forces a signal to trip, at the terminals with respect to its preset value and give the trip signal received at the terminals will immediately activate the local breaker. In such protection scheme is proposed which is capable of covering the entire length of multi-terminal transmission line protection (MTL) [6].

3 Wavelet Analysis

Wavelet analysis is a versatile tool which is extensively signal processing applications [7]. In this work such wavelet analysis is employed to detect as well as to discriminate the faults in transmission lines. The wavelet transform is one of the method which involves in sensing the electromagnetic transients which are possibly generated during the power system failures at the time of switching instants. The technique is similar to application of Fourier transform for fault analysis. However, wavelet-based application is more reliable and is capable of analyzing nonperiodic signals.

Wavelet transform allows the decomposition of a signal into different levels of resolution. The signal characterization is better and more reliable, thus discrimination can be obtained by using wavelet transform. It is a unique method for

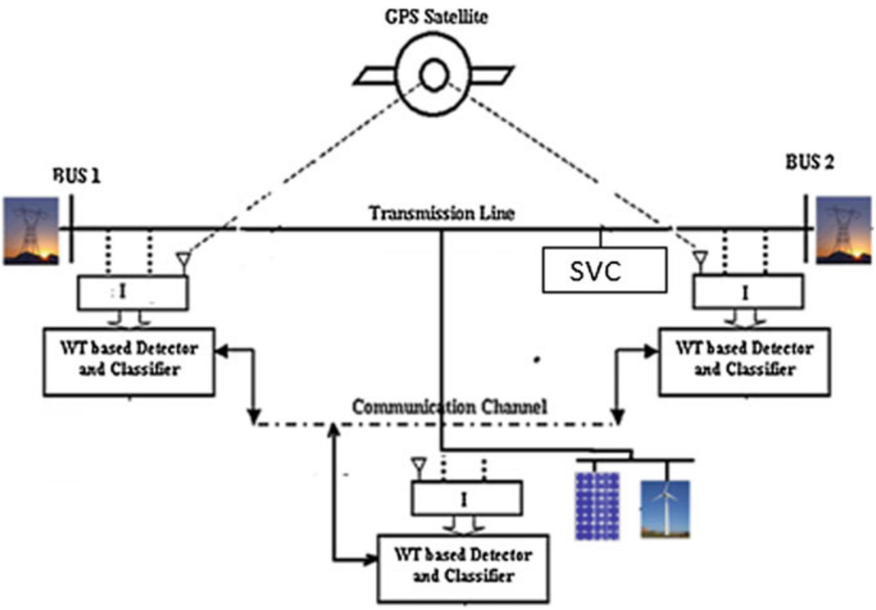

Fig. 2 Single line diagram of SVC compensated multi-terminal transmission system with hybrid energy source

Table 1 Power system specification and corresponding wavelet characteristics

Generator 1		500 kV, 9000 MVA Y-g, X/R = 10, phase angle = 0°
Generator 2		500 kV, 9000 MVA Y-g, X/R = 10, phase angle at A = 20°
Hybrid system	Wind	10.5 MVA
	PhotoVoltaic	1.25 MVA
Distributed transmission line		R = 0.01273 Ω/km, R_0 = 0.3864 Ω/km L = 0.9337e−3 H/km, 4.1264e−3 H/km C = 12.74e−9 F/km, C_0 = 7.751e−9 F/km
Static var compensator (SVC)		Rating: 300-Mvar Coupling transformer: 500 kV/16-kV 333-MVA One 109-Mvar thyristor-controlled reactor bank (TCR) Three 94-Mvar thyristor-switched capacitor banks
Mother wavelet		Bior 1.5
Sampling frequency		216 kHz
Information analyzed		Detail at 1, D1
Frequency band		108–54 kHz
Number of samples per cycle		21,600
Occurrence of fault		Second cycle
Data window length		One cycle/17.7 ms

evaluating transient signal [8] at different frequencies with resolutions can be effectively studied by wavelet multi resolution analysis of power system transients.

4 Description of the Proposed System

Figure 2 describes single line diagram of static var compensator compensated multi-terminal transmission system with hybrid energy source with all terminals of the proposed scheme (Table 1).

5 Proposed Scheme for MTL Protection

Synchronized sampling at all the three terminals of three-phase currents is carried out with the help of a global positioning system. The absolute values of the detailed coefficients for three-phase currents of all the three terminals are determined using Bior 1.5 mother wavelet. The detail coefficients are used for discriminations of fault in the MTL system [9]. The detail coefficients generated from phase currents of each terminal and then sum of the detailed coefficients are calculated. The number of faulty phases is discriminated by using the sum of the detailed coefficients [10] with a fault threshold value of three-phase currents. The proposed scheme is tested for various types of faults at different locations and fault inception angles in the range 0–180°. It is possible to state that the technique is effectively working in detecting and discriminating all possible types of faults.

6 Simulation Results

The fault indices of three-phase current signals are obtained by using wavelet first level detail coefficients of Bior 1.5 mother wavelet. The number of faulty phases can be identified by comparing fault index I_{f1} of each phase current with the predetermined threshold value $Th_{1.}$ It is observed that the fault index of phase A is very large compared to that of other phases as illustrated in Fig. 3. Thus, Phase A to ground fault at 40 km distance from terminal-1 of transmission system. Figure 4 shows that three-phase currents and Local D1-coefficients at terminal-1 multi-terminal transmission system with SVC (Fig. 5).

The Fault Index I_{f1} is calculated with various locations from 10 to 100 km with step size is 10 km up to middle point of the transmission line from terminal-1 is illustrated for SLG, DL of all combinations of phase A, phase B and phase C. It is observed that fault index If1 of all faulty phases is greater than Threshold T_{h1} value. The fault Index of healthy phases remains less than the threshold value. So that the faulty phases determined effectively which are illustrated in Figs. 6, 7 and 8 and it describes that the Fault index and variation of distance of 3ph Currents for SVC

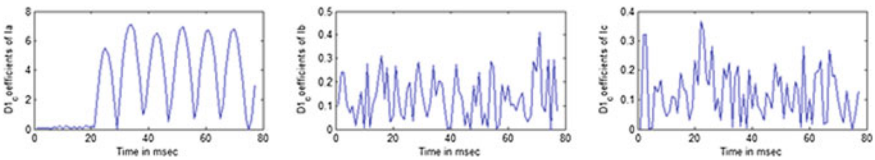

Fig. 3 Phase A to ground fault at 40 km distance from terminal-1 of transmission system with deviation of effective coefficients

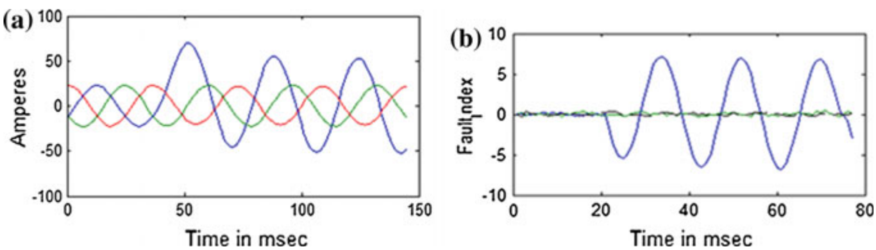

Fig. 4 **a** Three-phase currents at terminal-1 of Phase A to ground fault at 40 km distance of the line with SVC. **b** Local D1-coefficients of terminal-1 for Phase A to ground fault with SVC

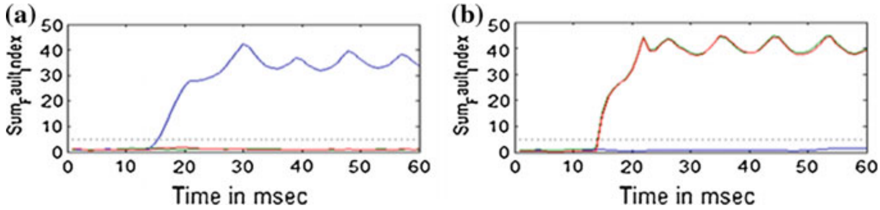

Fig. 5 Sum of detailed coefficient index varying at terminal-1 from 40 km distance with **a** single line to ground **b** double line

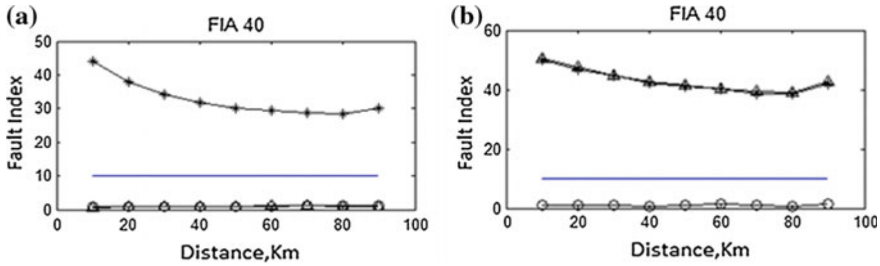

Fig. 6 Fault index and variation of distance of 3ph currents for fault inception angle of 40° for SVC compensated multi-terminal transmission system with hybrid generation at terminal-1 **a** SLG fault **b** DL fault

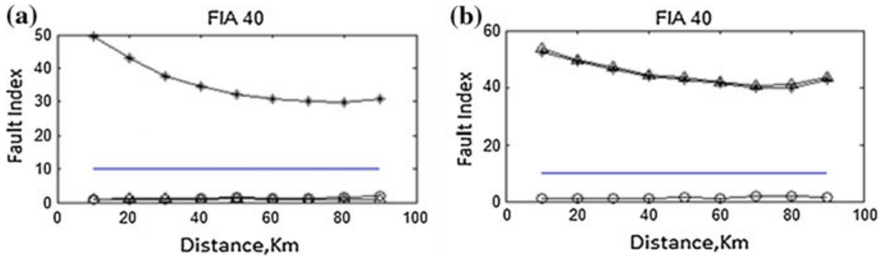

Fig. 7 Fault index and variation of distance of 3ph currents for fault inception angle of 40° for SVC compensated multi-terminal transmission system with hybrid generation at terminal-2 **a** SLG fault **b** DL fault

compensated multi-terminal transmission system with hybrid generation of 40° at terminal-1 for SLG, DL. The effect of variation fault index is studied by varying the fault inception angle ranging from 0° to 180° in steps of 20° at various locations. In all the cases I_{f1} is always less than T_{h1}. Figures 9, 10 and 11 illustrates variation in fault index and incidence angle of three-phase currents at terminal-1 for 40% of the transmission line with SVC at line to ground fault and double line fault. It is observed that the proposed algorithm detects the fault less than half cycle using wavelet analysis.

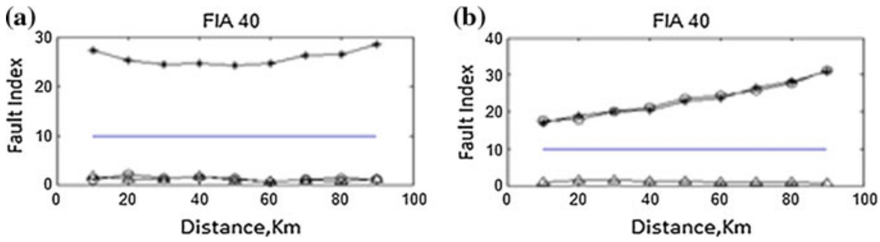

Fig. 8 Fault index and variation of distance of 3ph currents for fault inception angle of 40° at terminal-3 **a** SLG fault **b** DL fault

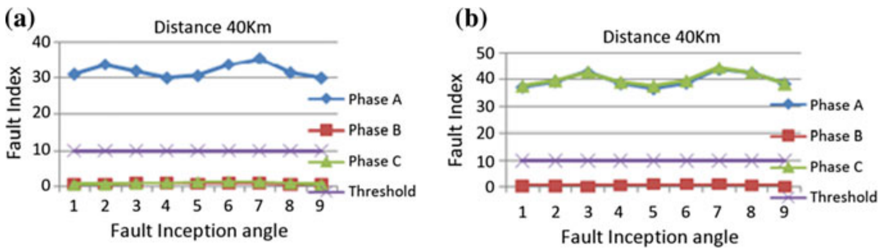

Fig. 9 Variation in fault index and incidence angle of three-phase currents at terminal-1 for 40% of the transmission line with SVC. **a** SLG fault **b** DL fault

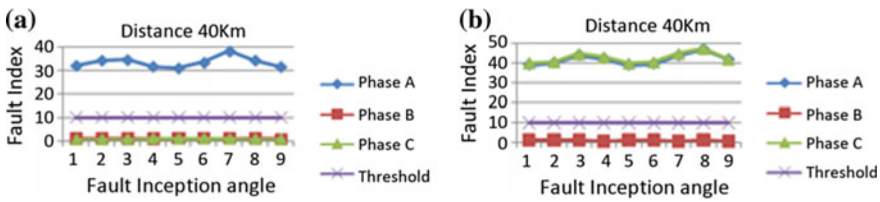

Fig. 10 Variation in fault index and varying incidence angle of three-phase currents at terminal-2 for 40% of the transmission line with SVC **a** SLG fault **b** DL fault

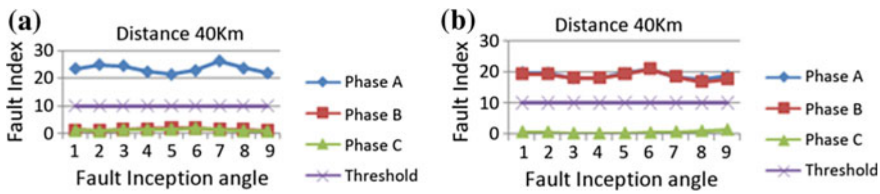

Fig. 11 Variation in fault index and varying incidence angle of three-phase currents at terminal-3 for 40% of the transmission line with SVC. **a** SLG fault **b** DL fault

7 Conclusions

The proposed system is developed for multi-terminal transmission system with hybrid PV and wind energy source with static var compensator using simulation software. The paper describes the protection algorithm for detection and classification of short circuit faults using wavelet-based multi-resolution analysis approach. The fault Indices are calculated with various locations at all the three terminals by analyzing the detailed coefficients of the current signals. Detection and discrimination of the fault in the system is analyzed by the wavelet coefficients of current signals which are greater than the threshold value which indicates the type of fault is observed. It is found that the scheme is working reliable and accurate for several types of faults at different locations and at different fault inception angles with and without SVC.

References

1. Giovanni Manassero, Jr., Eduardo Cesar Senger, Renato Mikio Nakagomi, Eduardo Lorenzetti: Fault-Location System for Multiterminal Transmission Lines, IEEE Transactions on Power Delivery, Vol. 25, July (2010).
2. Bikash Narayan Panda: Microgrid- A Smart Grid for Community Users. Proceedings of National Seminar on Dispersed Generation and Smart Grid.
3. Aditi, Dr. A.K. Pandey: Performance Analysis of grid connected PV Wind Hybrid Power System. International Journal of Applied Engineering Research ISSN 0973-4562 Volume 11, pp 706–712 © Research India Publications (2016).
4. Kola Venkataramana Babu, Manoj Tripathy and Asheesh K Singh: Recent techniques used in transmission line protection: a review. International Journal of Engineering Science and Technology, Vol. 3, pp 1–8 (2011).
5. M. A. Redfern, J. Lopez, and R. O'Gorman: A Flexible Protection Scheme for Multi-Terminal Transmission Lines. pp. 7803–9156. IEEE (2005).
6. Peyman Jafarian and Majid Sanaye-Pasand: High-Frequency Transients-Based Protection of Multiterminal Transmission Lines Using the SVM Technique, IEEE Transactions On Power Delivery, pp. 885–8977, IEEE(2012).
7. Liang Feng, Jeyasura B: Transmission line distance protection using wavelet transform algorithm, IEEE Trans Power Delivery, pp. 545–53, IEEE (2004).
8. Ravi Kumar Goli, Abdul Gafoor Shaik, S.S Tulasi Ram: A transient current based double line transmission system protection using fuzzy-wavelet approach in the presence of UPFC Electrical Power and Energy Systems, pp. 91–98 (2015).
9. Y. Manju Sree G. Ravi Kumar Abdul Gafoor Shaik: Multi-Terminal Transmission Line Protection using Wavelet Based Digital Relay in the Presence of Wind Energy Source ICEEOT (2016).
10. Osman AH, Malik OP: Transmission line distance protection based on wavelet Transform, IEEE Trans Power Delivery, pp. 515–523(2004).