TELKOMNIKA Indonesian Journal of Electrical Engineering
Vol. 13, No. 2, February 2015, pp. 257 ~ 263
DOI: 10.11591/telkomnika.v13i2.6987

Impact Analysis of Midpoint Connected STATCOM on Distance Relay Performance

R. Ilango[1*], T. Sree Renga Raja[2]
[1]MAM School of Engineering, Tiruchirappalli, Tamil Nadu, India, 621105
[2]Anna University, Anna University BIT Campus, Tiruchirappalli, Tamil Nadu, India, 620024
*Corresponding author, e-mail: ilangorengaraju@gmail.com

Abstract

This paper presents the impact of the Static Synchronous Compensator (STATCOM) on the performance of distance protection of EHV transmission lines. A 400kV transmission system having midpoint connected STATCOM with its control circuit is modeled using MATLAB/SIMULINK software. The impact of STATCOM on distance relay for different fault conditions and different fault locations is analyzed. Simulation results indicate that the presence of the STATCOM in the transmission system significantly changes the line impedance seen by the distance relay to be lower or higher than the actual line impedance. Due to this the performance of the distance relay changes, either overreaches or under reaches.

Keywords: *distance relay protection, flexible AC transmission system (FACTS), static synchronous compensators (STATCOM), EHV transmission line*

1. Introduction

The demand of electrical power is growing day by day with a very fast rate. To meet out this a significant modification in the conventional power system is required. The recent development of power electronics provides a solution by the way of using FACTS devices in the power systems. The FACTS devices which are connected in parallel, series or combination of both in the power system, enhance the system controllability and also increasing power transfer capability [1, 2]. Static synchronous compensator (STATCOM) is the most used shunt connected FACTS device which controls the connecting point bus voltage near stable and also enhance system stability by injecting or absorbing reactive power into the transmission system [3, 4].

Impedance based distance protection relays are widely used for protecting EHV/HV transmission lines due to their simple operating principle. The relay measures the apparent impedance of the fault loop by considering the voltage and current signals at the relay location, then the relay calculates the fault location by using this apparent impedance [5, 6]

In distance relay due to the presence of STATCOM in the fault loop the measured voltage and current signals are changed. The measured current at the relay point decreases when the STATCOM injects reactive power into the power system and increases when the STATCOM draws reactive power from the system. Due to this change in the voltage and current signals the apparent impedance calculated by the distance relay changes. The distance relay will be over reach if the measured impedance is less than the actual measurement and the relay will be under reach when the impedance is greater than the actual measurement. So due to the presence of STATCOM in the fault loop the distance relay characteristics will be affected. Therefore, nowadays it is important to analyze the impact of STATCOM on the distance relay to design an adaptive protective scheme to get accurate fault location.

Some researches have been done on the impact of different FACTS devices on the distance relay. K. El-Arroudi, G. Joos, and D. T. McGillis [7] present the analytical results based on the steady - state model of STATCOM, and outline the impact of STATCOM on different load levels. In [8] and [9] a comprehensive analysis of the impact of thyristor-controlled series capacitor (TCSC) on the protection of transmission lines has been presented showing that TCSC not only affects the protection of its line, but also the protection of adjacent line. The study in [10], demonstrates the impact of FACTS controllers and their location in the

Received November 7, 2014; Revised December 25, 2014; Accepted January 10, 2015

transmission line on the trip boundary of a digital multifunctional protective relay. The work in [11], derivates apparent impedance calculation seen by a distance relay in the presence of a unified power flow controller (UPFC) based on the power frequency sequence component and also explains the effect of UPFC operational mode as well as its control parameters. Previous work [12] presents the Impact analysis of static synchronous series compensator (SSSC) on the performance of the digital distance relaying. In [13] various distance protection schemes for a midpoint compensated transmission line has been compared. The work reported in [14], demonstrates the impact of TCSC on the parameters of protective transmission line during a single phase to ground fault conditions.

In this paper, the impact of midpoint connected STATCOM of the transmission line on distance relay protection is analyzed. First, a detailed model of STATCOM is presented then the performance of the distance relay for different fault conditions at different fault locations in the presence of STATCOM is analyzed and finally the results have been presented.

2. Study Test System

The impact of the STATCOM on the performance of distance relays is studied using the model developed by the MATLAB/SIMULINK software [15]. The test transmission system model with STATCOM and distance relay are described in this section.

2.1. Transmission System Model with STATCOM

The simulation diagram of the test system under analysis is shown in Figure 1. The test system consists of a 400kV 50 Hz, 300 km length transmission line, with two equivalent sources, source 1 and source 2 connected at the sending and receiving end respectively. The positive sequence resistance and zero sequence resistance of the line is 0.03 ohm/km and 0.25 ohm/km respectively. Similarly the positive sequence inductance and zero sequence inductance of the line is 1.01 mH/km and 3.73 mH/km respectively. The distance relay connected near the sending end source is considered for analysis.

A 100 MVA, 48 pulse voltage source inverter based STATCOM is connected at the midpoint of the transmission line. The main objective of the STATCOM controller is to regulate the connecting point voltage of the transmission line to the setting value (Vref) by supplying or absorbing the reactive current [16, 17].

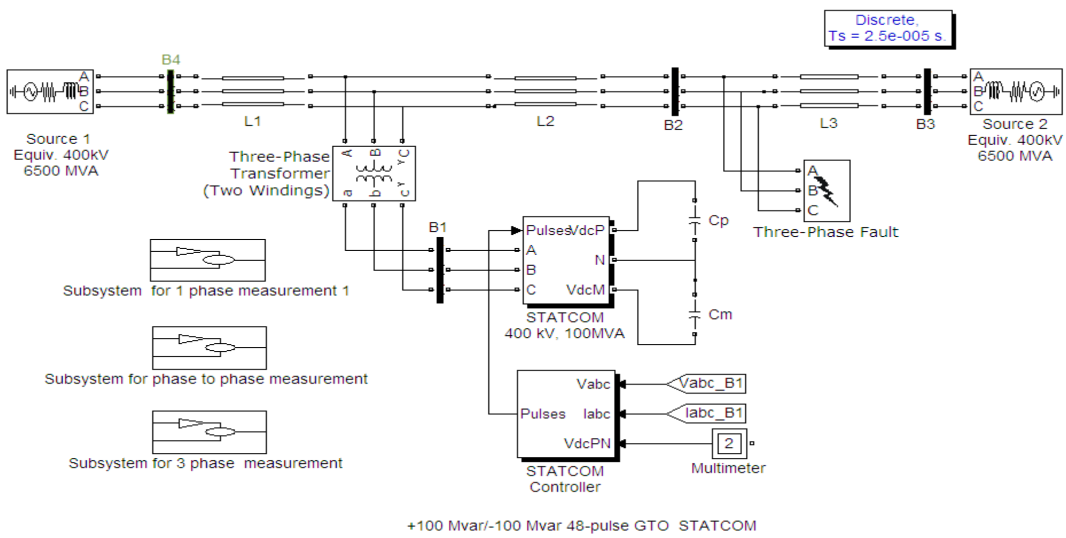

Figure 1. Test transmission simulation system implemented in MATLAB

2.2. Distance Relay model

The distance relay model used for this analysis consists of six Mho distance elements, three elements for phase-to-phase loops and three elements for the phase- to-ground loops.

The distance relay calculates the apparent impedance of the fault line considering the voltage and current signals at the relay location, then the fault location is calculated by considering the positive sequence impedance of the line [18]. The relay is assumed to be set to protect 80% (240km) of the transmission line. The Figure 2 shows the modeling of one element (“A” phase-to-ground element) of the distance relay used to locate the faults which occur in “A” phase.

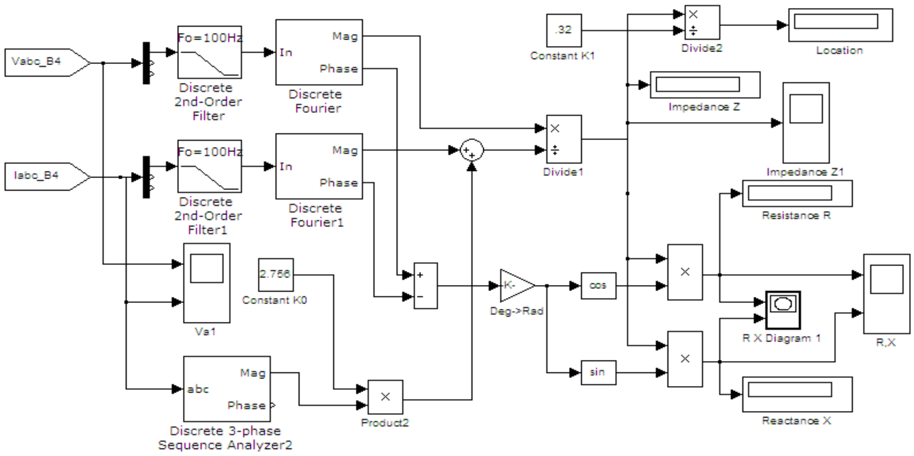

Figure 2. One element of the distance relay model

3. Simulation Results and Analysis

To study the impact of STATCOM on the performance of distance relay various types of faults have been applied on the test transmission system at various locations. Although several cases involving all types of faults with different fault resistances at different locations of the transmission line have been simulated, only two cases, namely, “A” phase to ground fault with a fault resistance of zero ohm and three phase to ground fault with a fault resistance of zero ohm are presented.

3.1. The Effect of Single Phase Fault

The test results of the test system with STATCOM and without STATCOM for “A” phase to ground fault is shown in Table 1. It clearly shows that, when the fault occurs between the relay point and the STATCOM location (between 10 and 150 kilometers in this case), there is no much change on the apparent impedance, measured by the distance relay i.e. the measured impedance is almost the same as that for the system without STATCOM.

Table 1. Variations of the apparent impedance for single phase-to- ground fault

Fault location in Km	Apparent impedance in ohms Without STATCOM	Apparent impedance in ohms With STATCOM
20	06.35	06.37
40	12.69	12.73
60	19.00	19.08
80	25.28	25.42
100	31.53	31.53
120	37.77	37.75
140	43.28	43.43
160	50.18	51.05
180	56.59	58.01
200	62.59	65.11
220	68.83	72.38
240	75.15	79.94
260	81.65	87.94
280	88.54	96.80

For example, when the fault is occurring at 140 km, the apparent impedance measured by the distance relay without connecting the STATCOM in the fault line is 43.28 ohms, and with the STATCOM is 43.43 ohms. This is due to the fact, that when the STATCOM is not present in the fault loop for zero fault resistance, the measured impedance is equal to the actual line impedance of the line section between the relay point and the fault point.

When the fault (‘A’ phase-to-ground fault) occurs beyond the STATCOM location, (between 150 and 300 kilometers in this case) the apparent impedance of the system is greater than that for the system without STATCOM, since the STATCOM involves in the fault loop; the injected/absorbed current of the STATCOM changes the apparent impedance measured by the distance relay.

The apparent impedance seen by the distance relay with STATCOM and without STATCOM for single phase fault occurring for fault distance of 240 km is shown in Figure 3; from this it is evident that the apparent impedance seen by the distance relay is higher than that of the system without STATCOM. So the protection zone of the distance relay under reaches its setting and does not give the trip signal.

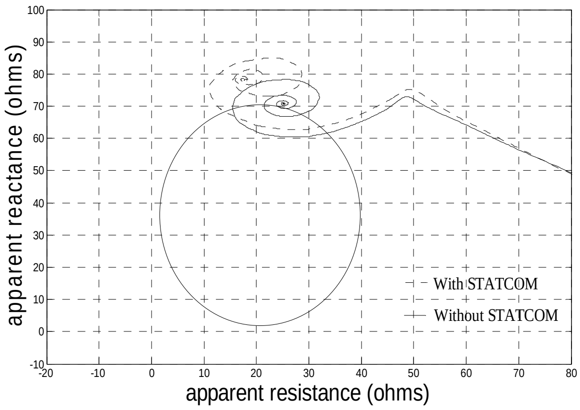

Figure 3. The apparent impedance seen by the relay for single phase fault

The plot of apparent resistance measured at the relay location for “A” phase to ground fault created at various locations of the transmission line with STATCOM and without STATCOM is depicted in Figure 4. It shows that when the fault occurs before the STATCOM location (i.e., <150km), the apparent resistance is almost same as that of the apparent resistance without STATCOM, but when the fault occurs after the STATCOM location the apparent resistance decreases.

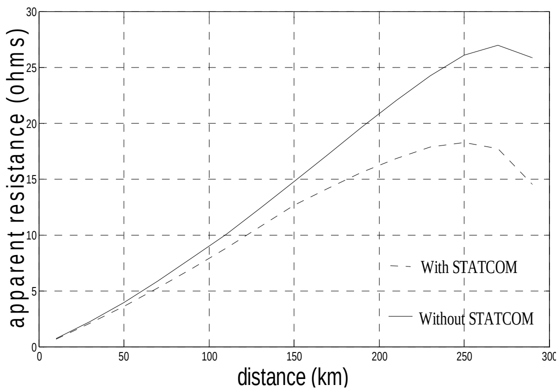

Figure 4. Apparent resistance versus fault location plots for single phase fault

Figure 5 shows the plot of apparent reactance measured at the relay location for “A” phase to ground fault created at various locations of the transmission line with STATCOM and without STATCOM. It is apparent that when the fault occurs before the STATCOM location the apparent reactance is almost same, but when the fault occurs after the STATCOM location the apparent reactance increases compared to the apparent reactance of the system without STATCOM.

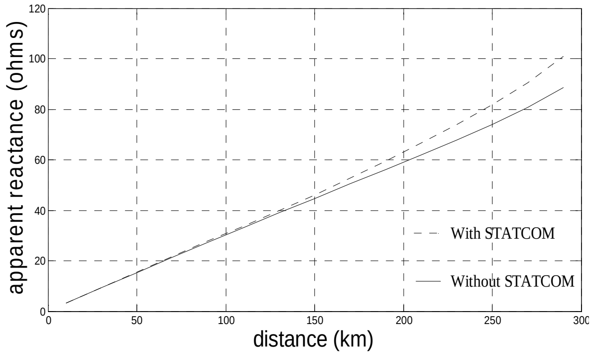

Figure 5. Apparent reactance versus fault location plots for single phase fault

This is mainly due to the fact that when the fault occurs after the STATCOM location the STATCOM supplies the reactive power to the connecting point, so the apparent reactance of the transmission line increases and the apparent resistance of the transmission line decreases.

Further from analysis, it is apparent that the presence of the STATCOM in the transmission system significantly affects the apparent resistance and apparent reactance measured by the distance relay under single phase fault conditions.

3.2. The Effect of Three Phase Fault

When three phase fault is created at a distance of 240 km, the apparent impedance measured by the distance relay with STATCOM is 83.40 ohms, and without STATCOM is 78.75 ohms respectively.

The impedance trajectory of the distance relay for three phase faults created at a distance of 240 km with STATCOM and without STATCOM is shown in Figure 6; it clearly shows that the apparent impedance seen by the relay is greater than that of the system without STATCOM. So the protection zone of the distance relay under reaches its setting and does not give the trip signal.

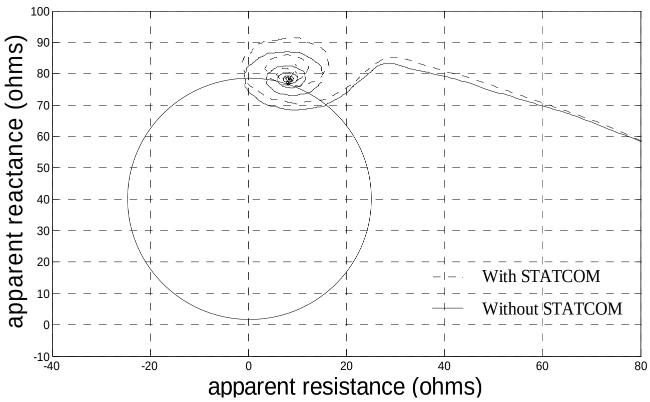

Figure 6. The apparent impedance seen by the relay for three phase fault

The apparent resistance versus fault location and apparent reactance versus fault location plots of transmission system with and without STATCOM for three phase fault are shown in Figure 7 and Figure 8 respectively.

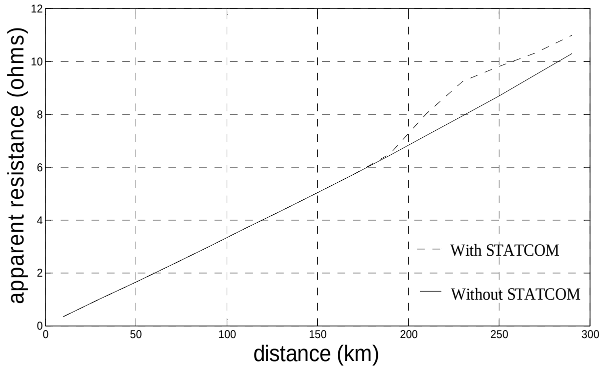

Figure 7. Apparent resistance versus fault location plots for three phase fault

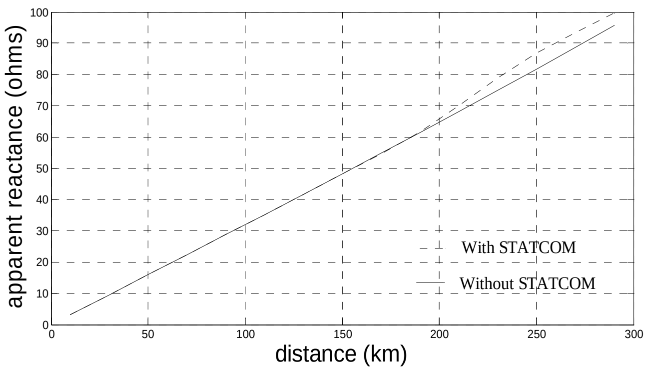

Figure 8. Apparent reactance versus fault location plots for three phase fault

The inference of the Figure 7 and Figure 8 shows that, when the three phase fault occurs between the relay point and the STATCOM location the measured apparent resistance and reactance of the system are almost same as that of the system without STATCOM. However, when the fault occurs beyond the STATCOM location, both the apparent resistance and reactance of the system are greater than that of the system without STATCOM.

It is evident that like single phase fault the three phase fault also having the same impact on the performance of the distance relay in the presence of the STATCOM in the transmission system.

4. Conclusion

The performance of the distance relay in the presence of STATCOM has been analyzed for different fault conditions and different fault locations. From the simulation results it is evident that during a fault, the injected or absorbed current of the STATCOM produces an error in impedance measurement and because of this under /over reach of the distance relay happens.

The results clearly show that the connection of the STATCOM at the midpoint of the transmission line affects the performance of the distance relay. Therefore, when a transmission line system is connected with STATCOM, the conventional distance relay characteristics are not usable. So there is a need for distance relay to adjust to new settings in its characteristics and to be adapted to the system conditions in order to avoid mal operation.

References

[1] Hingorani NG, Gyugyi L. Understanding FACTS: Concepts and Technology of Flexible Transmission Systems. New York: IEEE Press. 2000.
[2] Hingorani NG. *FACTS-Flexible AC Transmission System*. Proceedings of 5th International Conference on AC and DC Power Transmission. IEE Conference. 1991; 345: 1-7.
[3] Adido MA. Power System Stability Enhancement Using FACTS Controllers: A Review. *The Arabian Journal for Science and Engineering*. 2009; 34 (1B): 153-172.
[4] Haniyeh Marefatjou, Mohammad Sarvi. Power Flow Study and Performance of STATCOM and TCSC in Improvement Voltage Stability and Loadability Amplification in Power System. *International Journal of Applied Power Engineering*. 2013; 2(1):15-26.
[5] Phadke AG, lbrahim M, Hblika T. Fundamental Basis for Distance Relaying with Symmetrical Components. *IEEE Transactions on Power Apparatus and Systems*. 1977; 635-676.
[6] AREVA TD. Network Protection & Automation Guide. Second edition. France. AREVA. 2010.
[7] El-Arroudi K, Joos G, McGillis DT. Operation of impedance protection relays with the STATCOM. *IEEE Transaction on Power Delivery*. 2002; 17(2): 381–387.
[8] Khederzadeh M, Sidhu TS. *Impact of TCSC on the protection of transmission lines. IEEE Transaction on Power Delivery*. 2006; 21(1): 80–87.
[9] Sidhu TS, Khederzadeh M. *TCSC impact on communication aided distance protection schemes and its mitigation*. IEE Proc. Generation, Transmission and Distribution. 2005; 152(5): 714– 728.
[10] Khederzadeh M. *The impact of FACTS device on digital multifunctional protective relays*. T & D Conference and Exhibition IEEE/PES. Asia Pacific. 2002; 3: 2043–2048.
[11] Zhou X, Wang H, Aggarwal RK, Beaumont P. Performance evaluation of a distance relay as applied to a transmission system with UPFC. *IEEE Transaction on Power Delivery*. 2006; 21 (3):1137– 1147.
[12] Khederzadeh M, Ghorbani A, Salemnia A. *Impact of SSSC on the digital distance relaying. IEEE/PES, Power &Energy Society General Meeting. PES'09.* 2009; 1-8.
[13] Albasri FA, Sidhu TS, Varma RK. Performance comparison of distance protection schemes for shunt-FACTS compensated transmission lines. *IEEE Transaction on Power Del*. 2007; 22(4): 2116-2125.
[14] Mohamed Zellagui, Abdelaziz Chaghi. Impact of Thyristor Controlled Series Capacitor Insertion on Short-Circuit Calculation in Presence Phase to Earth Fault. *International Journal of Applied Power Engineering*. 2012; 1 (2): 93-104.
[15] Sybille G, Le-Huy, Hoang. *Digital simulation of power systems and power electronic using the MATLAB/Simulink Power System Blockset*. Power Engineering Society Winter Meeting. 2000; 4: 2973-2981.
[16] El-Moursi MS, Haraf AM. Novel controllers for the 48- pulse VSC STATCOM and SSSC for voltage regulation and reactive power compensation. *IEEE Transaction on Power System.* 2005; 20(4):1985-1987.
[17] Pranesh Rao, Crow ML, Zhiping Yang. STATCOM Control for Power System Voltage Control Applications. *IEEE Trans. On Power Delivery*. 2000; 15(4): 1311-1317.
[18] Zigler G. Numerical Distance Protection: Principles and Applications. Third edition. Germany. Publics Corporate. 2008.