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Effect Analysis of Shunt Device on Distance Protection in PSCAD and MATLAB for L-G Fault

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Abstract—**This paper presents analytical procedure and simulation results of distance relay for the application of protection of transmission line with STATCOM and simulation results for investigating the operation of Distance relay in a power system containing flexible alternating current transmission (FACTS) controller such as static synchronous compensator (STATCOM) in PSCAD and MATLAB. An apparent impedance calculation procedure for transmission line incorporating STATCOM based on the power frequency sequence circuits has been explored. When STATCOM is connected at the midpoint and fault is after STATCOM have great impact on distance relay tripping characteristics. The simulation results show the impact of STATCOM on distance relay during phase to ground fault condition. In the presence of STATCOM, its controlling parameters as well as its installation location also affect the tripping characteristics. Here, simulate the Distance Relay and plot the zones and create fault in different zones and show the result with and without STATCOM. The simulation results are presented in relation to typical 300km transmission line, 400KV transmission system employing STATCOM.**

Keywords—Apparent Impedance Calculation, Distance protection, MHO Characteristics, STATCOM.

I. INTRODUCTION

Power system protection is the process of making the production, transmission, and distribution of electrical energy as safe as possible from the effects of failures and events that place the power system at risk When the faults occur in such power system, protection systems are required to isolate faulted part of the power system, and leave the healthy parts of the system connected in order to insure the continuity of the power supply. The operational security of the power system depends upon the successful performance of the thousands of relays that protect equipment's and hence protect the whole system from cascading failures [1].

Updating of a transmission system by constructing new transmission lines becomes not easy because of economic and environmental conditions. High efficiency in terms of better utilization of existing transmission lines, without compromising on the quality and reliability of electrical power apply has thus to be found via alternative means. And the alternative means are as -high power semiconductor technology and Flexible AC Transmission System (FACTS) technology has been developed to solve this problem. However, because of the added complexity due to the interaction of FACTS devices with the transmission system, the transients superimposed on the power frequency voltage and current waveforms particularly at the occurrence of fault can be significantly different from those systems not connected FACTS devices and it will result in rapid changes in system parameters like line impedance and power angle. Therefore it is very important to study the impact of the FACTS devices on the traditional protection relay scheme such as distance protection relay [3]-[4].

STATCOM is one of the most important and widely used FACTS devices. It is based on a voltage source convert and can inject an almost sinusoidal current with variable magnitude and in quadrature with the connecting line voltage .It is widely used at area to maintain the reactive power into the power connecting point voltage by injecting or absorbing system. Because of the presence of STATCOM devices in a fault loop, the voltage and current signals at relay point will be affected in both steady and transient state. This impact will affect the performance of distance relay.

II. STATIC SYNCHRONOUS COMPENSATOR (STATCOM)

STATCOM is one of the key FACTS Controllers. It can be based on a voltage sourced converter (VSC) or current-sourced converter (CSC). The voltage-sourced converters are most preferable device as compare to current sourced converter by considering overall cost and will be the basis for presentations of most converter-based FACTS Controllers. STATCOM can be designed to also act as an active filter to absorb sys-tem harmonics [5].

STATCOM is capable of generating and /or absorbing reactive power whose output can be varied so as to maintain control of specific parameters of electrical power system. On transmission level, Systems are normally balanced, but during fault condition system get disturbed.
In this paper three level three phase IGBT type STATCOM is used. The controller input is an error signal obtained from the reference voltage and the rms value of the terminal voltage measured. Such error is processed by a PI controller the output is the angle **δ**, which is provided to the PWM signal generator.

III. SIMULATION SCHEME

Simpower Systems is a design tool using Simulink in MATLAB to model and simulate a power system. It has been used to study a PWM Converter based STATCOM. In this study, this tool is used to model the 400kV parallel transmission system with STATCOM installed in the mid-point of one transmission line. The system configured with this tool is shown in figure 1. Two 300km parallel transmission lines connect two 400kV source. The VSC based STATCOM is installed in the middle of the second transmission line.

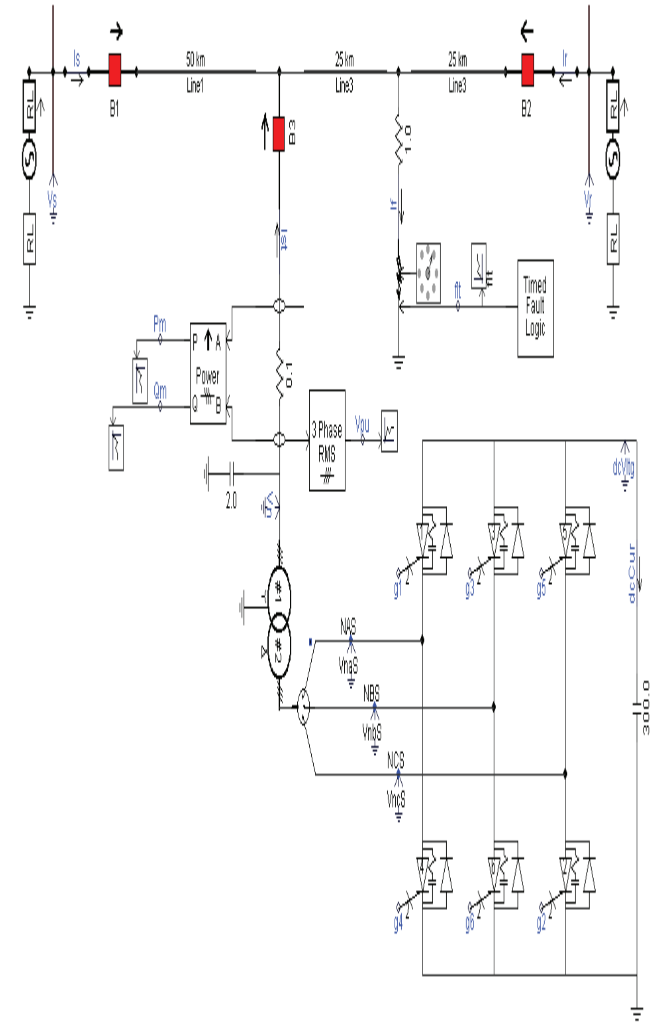


Fig.1: Power System with STATCOM at the mid-point in PSCAD

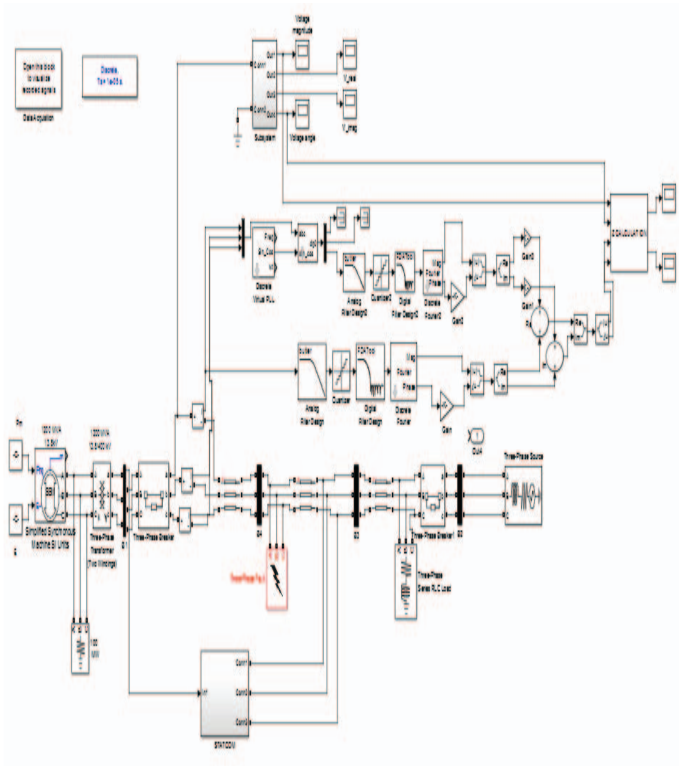


Fig.2: Simulation Model of Distance Relay with STATCOM in MATLAB

IV. SIMULATION RESULTS IN MATLAB

If fault occurs in zone one then results with and without STATCOM are:

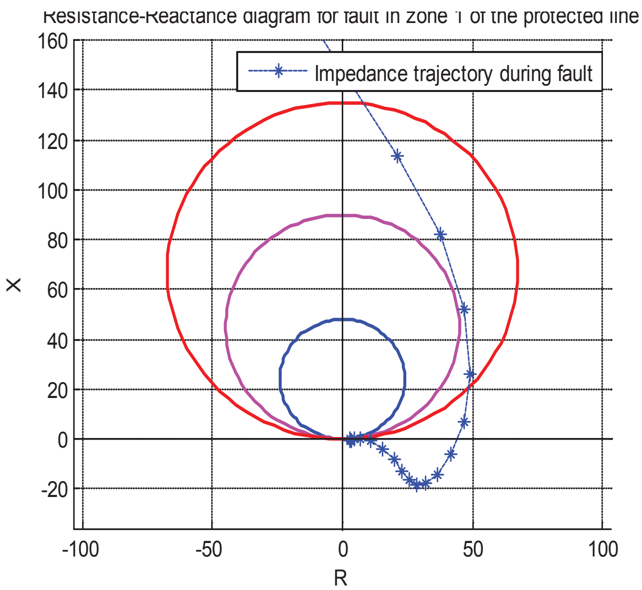


Fig.3. Impedance trajectory without STATCOM

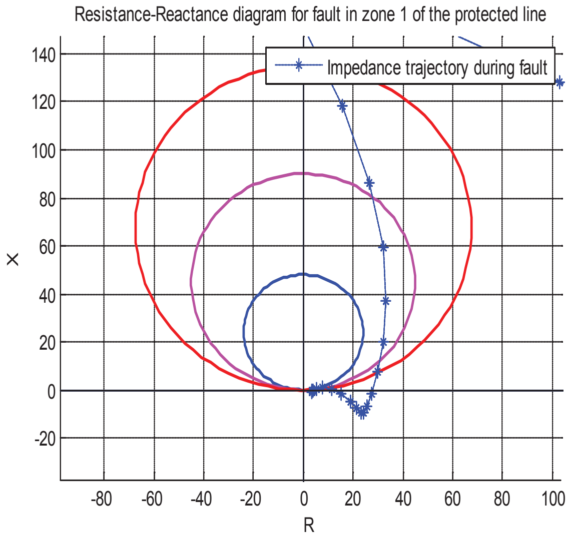


Fig.4. Impedance trajectory with STATCOM

It is seen that, the fault is in zone 1 but the characteristics shows it is just out of zone 1, STATCOM is not in fault zone that's why there is no more effect.

If fault occurs in zone 2, the characteristic are as shown below:

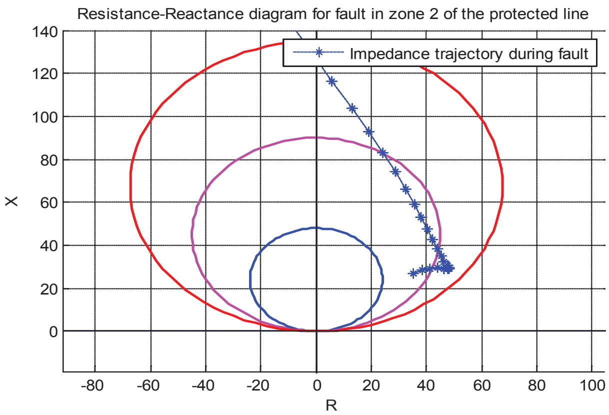


Fig.5. Impedance trajectory without STATCOM

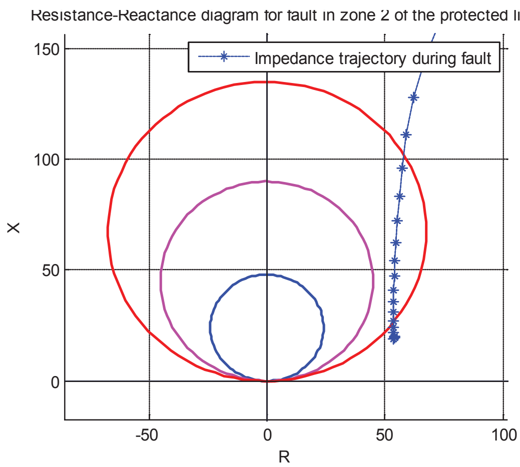


Fig. 6. Impedance trajectory with STATCOM

It is seen that the fault occurs in zone 2 but characteristics sows it is out of zone when STATCOM is connected in the line. STATCOM is in fault loop therefore it has great impact on distance relay, distance relay get mal-operate. The fault resistance 0.01 is taken.

If the fault occurs in zone 3 the characteristics are as follows:

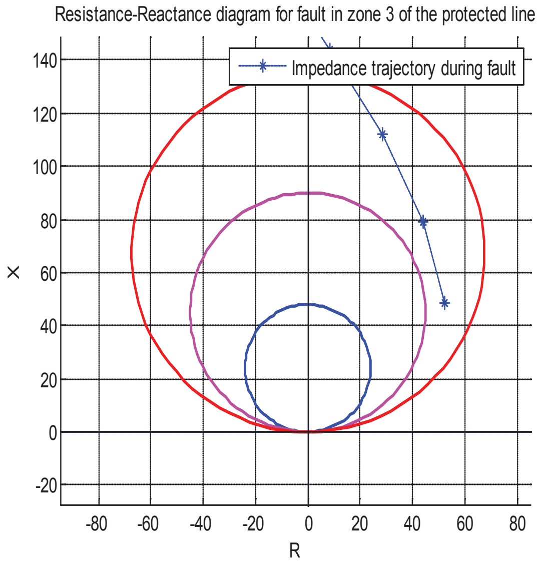


Fig.7. Impedance trajectory without STATCOM

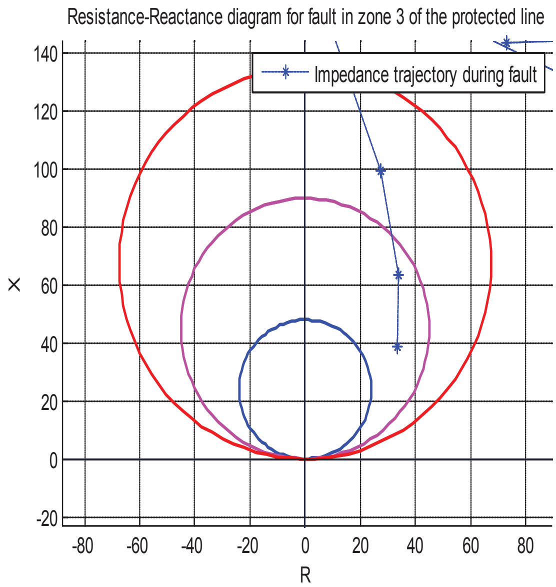


Fig.8.Impedance trajectory with STATCOM

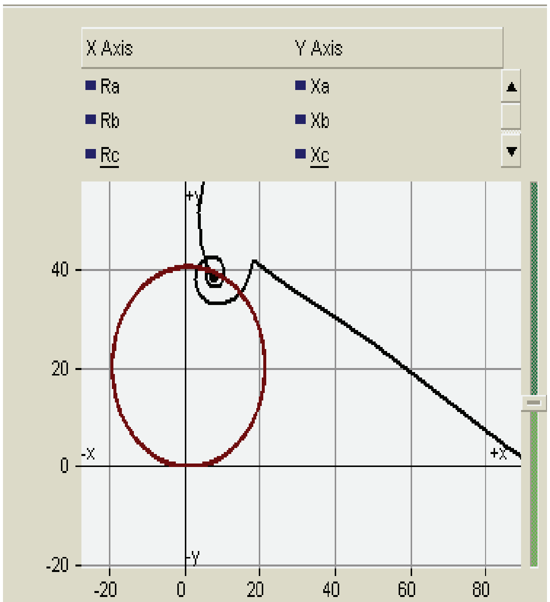
It is seen that when STATCOM is connected in the line, the fault occurs in zone 3 but characteristics shows it is in zone 2. Distance relay get mal-operate [7]-[9].

V. Simulation Results in PSCAD

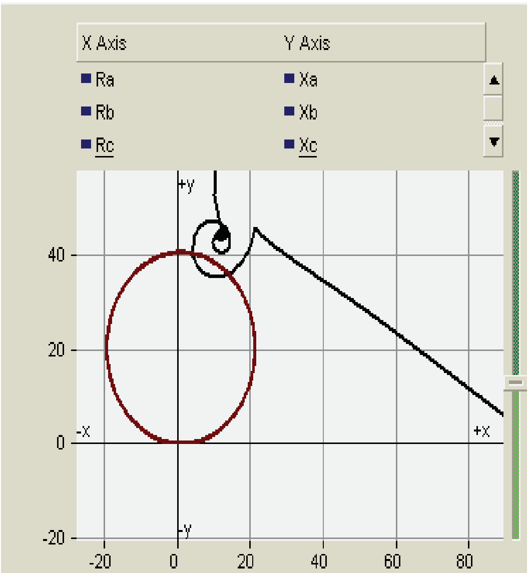
A. PHASE TO GROUND (L-G) FAULT

In the system shown in the Fig.8, an A-phase to ground fault occurs on the right side of STATCOM and the fault distance to relay point is 75km; the setting value in terms of the desired voltage for STATCOM is 1.0pu. The apparent impedance trajectories of the system with and without STATCOM together with the distance relay mho characteristic are shown in Fig.9.

From above, it can be seen that both the resistance and reactance of the apparent impedance of the transmission system with STATCOM are larger than those for the system without STATCOM; the protection zone of the distance relay will thus decrease i.e. it will under reach.



(a)



(b)

Fig.9: Apparent impedance seen by the relay during L-ground fault (a) without STATCOM (b) with STATCOM.

Figure.9 show the results of simulation the units of line-line impedance calculation during L-ground fault for both the conditions which are with/ without STATCOM, it is clear that only the impedance of the faulted phases will be calculated by relay and never take place in the circle and only the element 'L-ground' of the distance relay will calculated and cross the Mho characteristics [16] [17].

It is clearly evident that when the fault is on the left side of STATCOM, the apparent impedance seen by the distance relay is almost identical to that for the system without STATCOM. However when the fault is on the right side of STATCOM, both the apparent resistance and reactance of the system with STATCOM are larger than that for the system without STATCOM

According to different system conditions, STATCOM may have different setting values for desired voltage, and this setting will also affect the performance of the distance relay. The next study shows the apparent impedance and during a single phase to ground when the STATCOM settings are 1.2, 1.0 and 0.8 pu respectively.

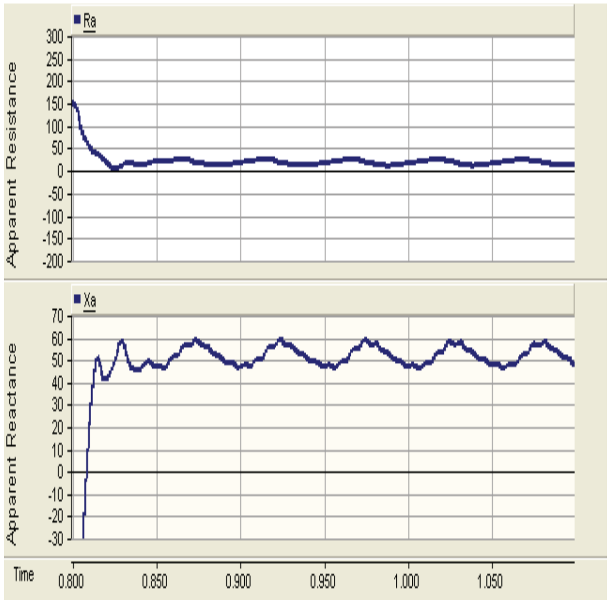


Fig.10: (a) Apparent resistance (b) Apparent reactance; when the setting of STATCOM is 1.2 pu.

As seen from the figures 10, 11 and 12, both the apparent resistance and reactance seen by the distance relay for a single phase to ground fault will increase with the increase of STATCOM setting reference voltage. This can be explained by the different reactive power injection. When the setting voltage is high, as seen from figure 9 during the fault, to keep the higher desired voltage, the STATCOM will inject more reactive power; in other words, the reactive current injection of STATCOM Ish is high; this will increase and the apparent impedance seen by the distance relay will increase.

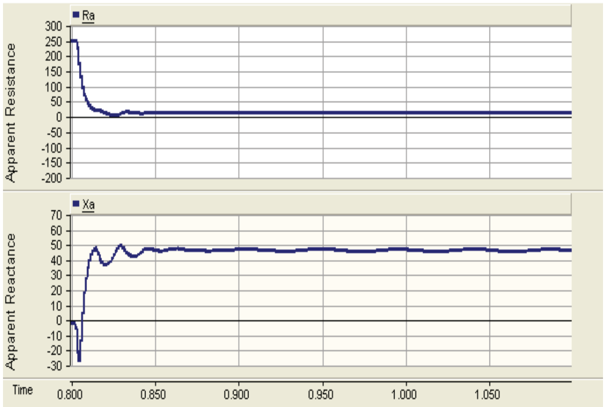


Fig.11: (a) Apparent resistance (b) Apparent reactance; when the setting of STATCOM is 1.0 pu.

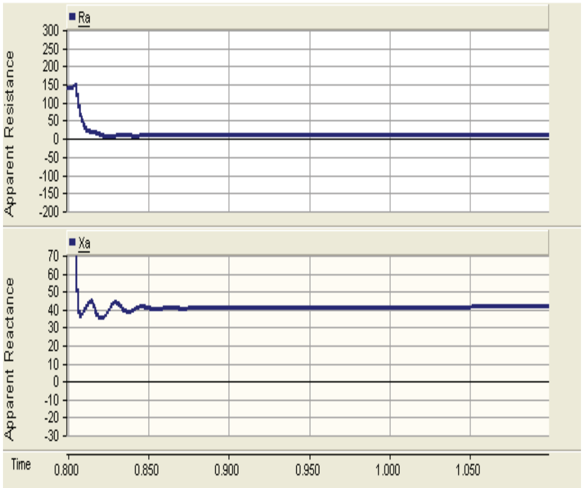


Fig.12: (a) Apparent resistance (b) Apparent reactance; when the setting of STATCOM is 0.8 pu.

It is worth mentioning that for certain conditions, when the system capacity is high and the STATCOM voltage setting value is low, if a single phase-ground fault occurs outside zone 1, the STATCOM connecting point voltage may be higher than the setting value, in this case the STATCOM will absorb reactive power in the system, the current Ish will become inductive, the influence ratio Ish/Irelay will become negative rather than positive and the apparent impedance seen by the distance relay will decrease compared to the system without STATCOM. This may lead to over-reaching of distance relay, and this is clearly undesirable.

CONCLUSION

The simulation results show clearly the distance relay get maloperated by the impact of STATCOM. The apparent impedance is influenced by the reactive power injected by the STATCOM resulting in either under reaching or over reaching of the distance relay. Two installation positions have been considered for the STATCOM; at the mid-point of the line, and at the remote end bus. For the installation at the midpoint, the measured impedance at the relaying point is evaluated. This impedance depends on the controlling parameters of STATCOM, as well as the system operational and structural conditions.

In the cases of installation of STATCOM at the line end, STATCOM is not present in the fault loop that's why it has no more adverse effect on relay. Therefore, when STATCOM is installed at the line end, the conventional distance relays operation would be acceptable.

When STATCOM is installed at the mid-point, if the fault locates between the relaying point and the mid-point, in this case STATCOM is not present in the fault loop; otherwise STATCOM would be included in the fault loop. When STATCOM is not present in the fault loop for zero fault resistance, the measured impedance is equal to the actual impedance of the line section between the relaying and fault points. On the other hand, when STATCOM involves in the fault loop, even in the case of zero fault resistance, the measured impedance would be deviated from its actual value. When STATCOM located at the mid-point of the transmission line, the conventional distance relays are exposed to the mal-operation, in the form of overreaching or under-reaching.

In this case, the effect of STATCOM on the protective zones should be considered. Since deviation of the measured impedance is not constant, because of the varying parameters of STATCOM, adaptive methods should be utilized [12]-[14].

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