

# ***CHAPTER 1***

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## **INTRODUCTION**

### **1.1 Introduction**

The use of flexible alternating current transmission (FACTS) devices in power systems for increasing the power transfer and providing the optimum utilization of system capability by pushing the power systems to their limits has been of worldwide interest in the recent years [1], [2]. 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 under faults) can be significantly different from those systems not employing FACTS devices and it will result in rapid changes in system parameters such as line impedance and power angle. Thus it is vitally important to study the impact of the FACTS devices on the traditional protection relay scheme such as the impedance-based distance protection relay [3].

Static Synchronous Compensator (STATCOM) is one of the most widely used FACTS devices. It is based on a voltage source converter and can inject an almost sinusoidal current with variable magnitude and in quadrature with the connecting line voltage. It is widely used at the mid-point of a transmission line or heavy load area to maintain the connecting point voltage by supplying or absorbing reactive power into the power system [1],[4].

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 existing protection methods, such as distance relay.

## **1.2 Objectives**

The objective of this dissertation is to analyze and explore the impact of STATCOM (one of the most advanced flexible alternating current transmission system controller) when employed in a transmission system on the performance of distance relay.

The PSCAD/EMTC softwares are used to simulate and explore the impact of STATCOM on the distance protection relay during different fault condition. Also, the influence of STATCOM location and the operation mode of STATCOM are studied.

## **1.3 Motivation**

With the increase in the number of Static Synchronous Compensator (STATCOM) which is a type of FACTS devices in transmission lines, operation of distance relays in transmission lines are affected. It is crucial that the distance relays do not mal-operate under system fault conditions. This will result in the loss of stability or the security of the system, which defeats the main objective of installing a STATCOM. As STATCOM is a type of FACTS devices which have fast response and their functional characteristics and control system introduce dynamic changes during fault conditions in a transmission line, it is important that distance relays perform correctly irrespective of such dynamic changes which are introduced during faults. Because of these concerns, the protection relays requirements cannot be clearly defined until a particular FACTS strategy is modeled and analyzed within its power system.

## 1.4 Literature Survey

Distance protection relays have been widely applied for protecting transmission lines. This is due to their simple operating principle and capability to work independently under most circumstances and still provide very good protection for the transmission line [5]. Thus there is a very high probability that the transmission line where the FACTS controller is being installed is being protected by a distance relay. This scenario brings up a question, "will the existing distance protection relay perform well with the new FACTS controller in the transmission line?"

There exists literature on the performance of the protection for a power system containing FACTS devices. There has been considerable work to study the effect of series compensation including series FACTS devices on the performance of distance protection relays [6]–[8]. Though few papers have studied the effect of shunt compensation devices such as STATCOM [10], [11] these references have not considered the effect of the FACTS device characteristics, their control systems, and dynamics during fault. The SVC and STATCOM have fast response time, it is very important to consider the reaction of the FACTS devices to the fault when studying their effect on the distance relay measurements [5].

The location of the shunt FACTS device depends on the application for which it is installed. Shunt compensation FACTS devices are installed at the endpoints of transmission lines (buses) when used for applications, such as, improving system stability, improving HVDC link performance. However, for controlling the power flow or increasing the power transfer capability of very long transmission lines (tie lines connecting two major grids) mid-point of the lines is the best location for shunt connected FACTS devices [2],[4]. In conclusion, the literature studies and the operating experience with static var compensators (SVC) and thyristor controlled series capacitor (TCSC) have demonstrated the need to modify

protective relay operating characteristics [9]. Among the different types of FACTS devices, the static var compensators (SVCs) are devices that control the voltage at their point of connection to the power system by adjusting their susceptance to supply or absorb reactive power [10], [11]. In general, SVCs are characterized by their ability to rapidly vary the reactive output to compensate for changing system conditions [12], [13].

The development in power electronic devices such as gate turn off devices (GTOs) allows implementation of the so-called advanced static var systems (SVS). The static synchronous compensator (SSC or STATCOM) is an example of the advanced SVS. The STATCOM consists of three-phase sets of several gate turn-off switch-based valves and a DC link capacitor and controller thus replacing the conventional reactive power compensators [1], [2], [4].

The objective of this dissertation is to analyze and investigate the impact of midpoint compensation using a STATCOM on the performance of distance relay under normal operation and fault conditions at different load power angles. First, a detailed model of STATCOM is proposed and secondly, the analytical results based on symmetrical component transformation for single phase to ground fault on a transmission system employing STATCOM are presented, the simulation results clearly show the impact of STATCOM devices on the performance of distance relay.

To demonstrate and simulate the power system including STATCOM at the mid-point of the transmission line and DISTANCE RELAY at the sending end, the PSCAD/EMTC software is used.

PSCAD (Power Systems CAD) is a powerful and flexible graphical user interface to the world renowned, EMTDC solution engine. PSCAD enables the user to schematically construct a circuit, run a simulation, analyze the results, and manage the data in a completely integrated, graphical environment. Online plotting functions, controls and meters are

also included, so that the user can alter system parameters during a simulation run, and view the results directly. PSCAD comes complete with a library of pre-programmed and tested models, ranging from simple passive elements and control functions, to more complex models, such as electric machines, FACTS devices, transmission lines and cables. If a particular model does not exist, PSCAD provides the flexibility of building custom models, either by assembling those graphically using existing models, or by utilizing an intuitively designed Design Editor [16].

## **1.5 Dissertation layout**

A brief introduction to the dissertation and Literature survey is presented, justification and motivation are explained, the objective and main contributions are described and the thesis organization is described.

Chapter two presents STATCOM controller' basic principles introduction, applications, design of the STATCOM. Also STATCOM operation and a brief comparison between STATCOM and SVC controllers are explored.

Chapter three provides a brief introduction to the distance relay, its principle of operation and explores the distance protection' Zones. Also it presents the distance relay modeling and simulation of all types of transmission lines faults.

Chapter four introduces the STATCOM modeling and its operation with inductive load and capacitive load.

Chapter five presents the proposed simulation and the obtained results including all type of faults, impact of STATCOM's position and setting.

Chapter six presents the conclusion of the dissertation and the scope of the future researches work.