DOI: 10.5370/JEET.2010.5.4.522

Setting Considerations of Distance Relay for Transmission Line with STATCOM

Wen-Hao Zhang†, Seung-Jae Lee* and Myeon-Song Choi*

Abstract - Distance relay plays an important role in the protection of transmission lines. The application of flexible AC transmission systems (FACTS) devices, such as the static synchronous compensator (STATCOM), could affect the performance of the distance relay because of compensation effect. This paper analyzes the application of distance relay on the protection of a transmission line containing STATCOM. New setting principles for different protection zones are proposed based on this analysis. A typical 500 kV transmission system employing STATCOM is modeled using Matlab/Simulink. The impact of STATCOM on distance protection scheme is studied for different fault types, fault locations, and system configurations. Based on simulation results, the performance of distance relay is evaluated. The setting principle can be verified for the transmission line with STATCOM.

Keywords: Distance Relay, Power System Protection, Flexible ac transmission system (FACTS), STATCOM, Setting Principle

1. Introduction

The use of FACTS devices in power system transmission to increase the power transfer and optimum utilization of power system capability has been of a worldwide interest in the recent years [1], [2]. FACTS devices are used for voltage regulation at the midpoint in order to segment the transmission line, and at the end of the line to prevent voltage instability. However, other problems emerge in the field of power system protections. Distance protection systems have simple operating principle and are capable to work independently under most circumstances. For these reasons, these systems have been used in several countries to protect their high voltage transmission lines. However, with FACTS device installed in the transmission line, the efficiency of distance relay performance should be studied. The location of the shunt FACTS device depends on the application at which it is installed [3]. Shunt compensation FACTS devices are installed at the endpoints of transmission lines when used to improve system stability while at the midpoint of the lines when used to control the power flow or increase the power transfer capability. STATCOM is widely used at the midpoint of a transmission line or heavy load area in order to maintain the connecting point voltage by supplying or absorbing reactive power into the power system. In this paper, the performance of distance relays with the effect of STATCOM on midpoint compensated line is mainly studied.

Several works have been conducted to test the performance of the distance relay of a transmission system with FACTS devices. Previous works [4], [5] present detailed test results of systems with SVC and STATCOM and have compared the performances between the two devices; however, they failed to give any information on the setting rules. Reference [6] presents the results based on steady-steady model of STATCOM, and studied the impact of STATCOM on distance relay at different load levels. In [7] and [8], the voltage-source model of FACTS devices is used in determining the impact of FACTS on the tripping boundaries of distance relay. Reference [9] examines the influence of STATCOM for distance relay in a parallel line system.

The impact of STATCOM on distance relay performance will be analyzed in this paper. A detailed model of STATCOM and its operation principle are first introduced. Next, the apparent impedance of distance relay for different system configurations with STATCOM at the end of the line and at midpoint are analyzed individually. Setting principles are proposed based on the theoretical analysis. Then, a simulation model for a typical 500 kV system is built in Matlab/Simulink. Simulation results clearly show the impact of STATCOM devices on the performance of distance relay. Settings of the distance relay under influence of STATCOM can be achieved from the simulation results based on the proposed principles

2. Power System with STATCOM

STATCOM is a shunt device of FACTS family using power electronics to control power flow and improve transient stability on power grids [1].

† Corresponding Author: Dept. of Electrical Engineering, Myongji University, Korea. (xiwen_ren@hotmail.com)
* Dept. of Electrical Engineering, Myongji University, Korea. (sjlee@mju.ac.kr, mschoi@mju.ac.kr)
Received: September 26, 2009; Accepted: July 26, 2010

2.1 STATCOM Configuration

STATCOM regulates voltage at its terminal by controlling the amount of reactive power injected into or absorbed from the power system. The variation of reactive power is performed by means of a voltage-sourced converter (VSC) connected on the secondary side of a coupling transformer. In Fig. 1, V_1 represents the system voltage to be controlled and V_2 is the voltage generated by the VSC. The VSC uses forced-commutated power electronic devices to synthesize voltage V_2 from a DC voltage source. The principle of operation of the STATCOM is explained below showing the active and reactive power transfer between a source V_1 and a source V_2.

$$P = \frac{V_1 V_2 \sin\delta}{X} \quad (1)$$

$$Q = \frac{V_1(V_1 - V_2\cos\delta)}{X} \quad (2)$$

where

V_1 is the line to line voltage of source;
V_2 is the line to line voltage of STATCOM;
X is the equivalent reactance between transformer and filters;
δ is the angle of V_1 with respect to V_2.
Since δ is very small, if we set δ=0,

$$P = 0 \quad (3)$$

$$Q = V_1\frac{V_1 - V_2}{X} \quad (4)$$

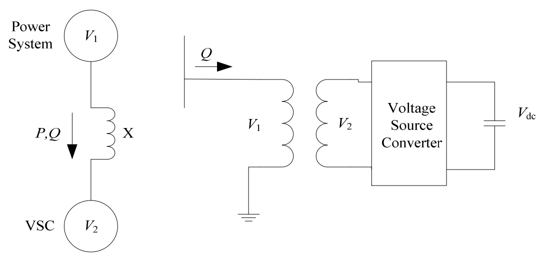

Fig. 1. Operating Principle of the STATCOM.

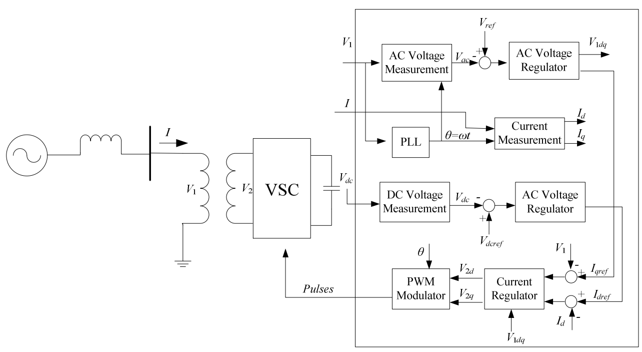

Fig. 2. Single-line Diagram of a STATCOM and its Control System.

If V_1 is higher than V_2, Q is flowing from V_1 to V_2 (i.e., STATCOM is absorbing reactive power). On the reverse, if V_1 is lower than V_2, Q is flowing from V_2 to V_1 (i.e., STATCOM is generating reactive power) [10], [11].

The control system is made up of phase-locked loop (PLL), measurement system, voltage regulators, firing pulses. To explain the regulation principle, it is assumed that the system voltage becomes lower than the reference voltage V_{ref}. The voltage regulator will then ask for a higher reactive current output (positive I_q=capacitive current). The current regulator will increase α phase lag of inverter voltage with respect to system voltage to generate more capacitive reactive power. It results in an active power temporarily flowing from AC system to capacitors, thus, increasing DC voltage, and consequently, generating a higher AC voltage.

A set of voltage-current characteristics for a range of target voltage settings with constant slope is shown in Fig. 3. At reduced voltage, the STATCOM can continue to be operated at rated leading (or lagging) current, with a constant transient overload current margin. These capabilities are available down to very low voltages.

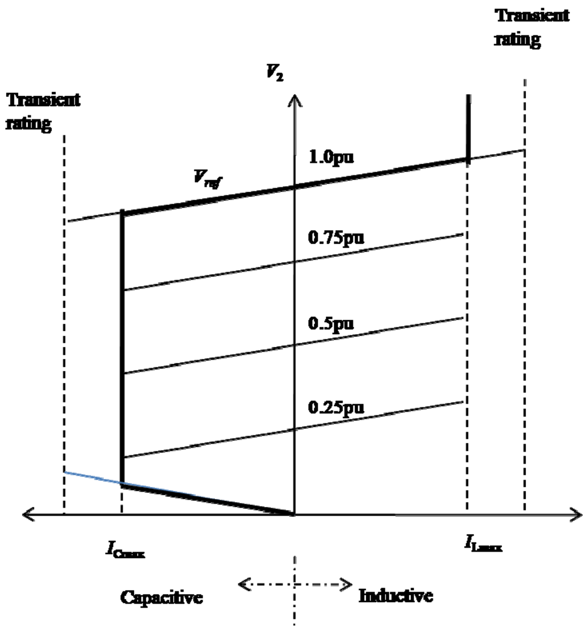

Fig. 3. V/I Characteristic of STATCOM.

2.2 Apparent Impedance of Distance Relay

When a fault occurs on a transmission line, distance relay protection would trip according to its measured impedance. In the absence of fault resistance, measured impedance for the system without STATCOM equals the actual impedance from relaying location and the fault. However, with the existence of STATCOM, the apparent impedance seen by the distance relay needs to be observed to clarify the performance of distance relay. The different installation locations of STATCOM would have varying effects on apparent impedance.