Comparison of Output Active Power Using Facts Devices SSSC and STATCOM

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ABSTRACT

In this paper, the use of a two different FACTS devices in which one is chosen as series (SSSC) and another in shunt (STATCOM) with generation lines with incorporated energy storage technology to see if significant improvement to power system stability can be achieved. With and without facts devices on the basis of active power on the load side of the system the rotor speed, rotor speed deviation and output active power SSSC and STATCOM are compared using MATLAB.

Keywords — SSSC, STATCOM, rotor speed

I. INTRODUCTION

In today’s technology and the future world power systems are large, and are interconnected and contains thousands of buses and hundreds of generators. Power system protection devices form a large part of the power system. Environmental as well as economic factors govern the basic installation of power system and also transport this, new transmission line construction are required to sustain increasing load demand. Other than from these factors, constructions are costly and take huge amount of time. Limitation on the expansion of system and its network has resulted in reduction of stability margin and therefore the risk of voltage collapse increases. Voltage collapse occurs in system when system is faulted, heavily loaded and a sudden increase in the demand of reactive power. Voltage instability is the prime cause of system voltage collapse. Voltage collapse occurs when the system voltage decreases to a level from which it is unable to recover. The outcomes of voltage collapse involve partial or full power interruption in the system. One of the main reason of voltage instability in a system is the occurrence of reactive power imbalance in the system. Reactive power imbalance occurs when there is a sudden increase or decrease in reactive power demand in the system. The only way to prevent the occurrence of voltage collapse is either to reduce the reactive power load or to provide the system with additional supply of reactive power before the system reaches the point of voltage collapse. This can be done by connecting sources of reactive power, i.e., shunt capacitors and/or Flexible AC Transmission System (FACTS) controllers at appropriate locations in the system. Flexible AC Transmission Systems (FACTS) technology helps in reducing transmission congestion and utilizing it efficiently in transmission system without neglecting the reliability and security of the system. The sudden response provides high potential for power system stability improvement apart from the steady state flow control. The benefits of implementing FACTS are many: improvement of the dynamic and transient stability, voltage stability and security improvement, less active and power loss, voltage and power profile improvement, power quality improvement, increases power flow capability in transmission line, voltage regulation and efficiency of power system improvement, steady state power flow improvement, voltage margin improvement, loss minimization, line capacity and loading ability of the system. The first generation of FACTS devices was mechanically controlled capacitors and inductors. The second generation was replaced by mechanical switches of the thyristor valve control. The second generation gave a noticeable improvement in the speed and the enhancement in concept to mitigate the disturbances. The third generation uses the concept of voltage source converter based devices. These devices provide multi-dimensional control of the power system parameters. The use of FACTS (flexible AC transmission system) devices in a power system can overcome limitations of the present mechanically controlled transmission systems. By introducing bulk power transfers, these interconnected networks help us to minimize the need to enlarge power plants and enable neighboring utilities and regions to exchange power.

II. STATCOM

The static synchronous compensator (STATCOM) is another shunt connected GTO based FACTS device. It is a static synchronous generator operated as a static VAR compensator which can inject lagging either leading Var into the system. This device can provide reactive support to
a bus. It consists of voltage sourced converters connected to an energy storage device. It has several advantages. It has no rotating parts, very fast in response, requires less space as bulky passive components are eliminated and relocate-able, less maintenance and no problem as loss of synchronism. The dc source voltage is converted into ac voltage by the voltage source converter using GTO and ac voltage is inserted into the line through the transformer. In heavy load condition if the output of VSC is more than the line voltage, converter supplies lags VARs to the transmission line. During low load condition if line voltage is more than then converter absorbs lagging VAR from the system. If output voltage of

converter is equal to line voltage, then the devices is in floating condition and being a shunt device it does not supply or absorb reactive power to the system or from the system. The simple diagram is shown in figure1.1. The GTO inverter in the Figure 1.2 consists of several six step voltage sourced inverters.

III. SSSC

SSSC is one of the most important FACTS controllers that are used for series compensation of power. In series compensation the capacitor which is connected in series compensates the inductive reactance of the transmission line. Its output voltage (Vc) is in quadrature with the line current (I). The voltage across series capacitor is −jXc (where Xc is the capacitive reactance of the series capacitor) and voltage drop across line inductance (XL) is +jXL.

(Inductance) cancel each other thus reducing the effect of line inductance. Due to this, power transfer capability is increased. Supply voltage from a dc source is converted into ac voltage using VSC (voltage source converter). Quadrature voltage and is injected into the line through a coupling transformer. This injected voltage (Vc) lags the line current (I) by 90° and series compensation is done. SSSC controls the flow of real and reactive power through the system. The symbolic representation of SSSC using voltage source converter is shown in Figure1.3.

IV. MATHEMATICAL MODEL

First consider a simple single machine infinite bus (SMIB) system, without any FACTS device, as shown the equivalent circuit of the system. In this where X1 represents the equivalent reactance between the machine internal bus and the intermediate bus m, and X2 represents the equivalent reactance between bus m and the infinite bus. The magnitude of the machine internal voltage and infinite bus voltage is represented by E ′ and V respectively. The dynamics of the machine, in classical model, can be represented by the following differential equations.

\[
\frac{d\delta}{dt} = \omega
\]

\[
\frac{d\omega}{dt} = \frac{1}{M} (P_m - P_e - D\omega)
\]

Here δ, ω, M, D, Pm and Pe are the angle, speed, moment of inertia, damping coefficient, input mechanical power and output electrical power, respectively, of the machine. 

\[
P_{\text{eo}} = E \left( \sin \delta \Delta_p \frac{P_{\text{max}} \sin \delta}{(X_1 + X_2)} \right)
\]

Note that, with the help of a FACTS device, Pe of the machine can dynamically be controlled to improve the dynamic performance of the system. These are the main basic equations that are involved in representation of the behavior of SSSC.

The further figure below tells us the representation of SSSC and also its equivalent circuit that is designed in the improvement of the voltage profile in the coming time and the future prospects to improve it.
PROPOSED WORK

The control of active power and reactive power exchange between grid connected converters and the utility grid is an important factor when considering the operation of ac power systems that employ distributed generation. The call for a sustainable society with renewable and distributed resources has driven the implementation of power electronic technology into ac power systems. Recently a power electronic converter called the static var compensator (STATCOM) has been employed to provide reactive power support to the ac power system. We have considered STATCOM for shunt controlling, Similarly SSSC has been considered to study the series attachment of control with generation lines. This strategy is based on injecting the series voltage in quadrature with the transmission line current allowing it to function similar to that of a variable series capacitor. This fixes the phase angle of the series injected voltage to be in quadrature with the transmission line current. By varying the magnitude of the series injected voltage that is in quadrature with the transmission line current, the real power flow can be controlled [45]. The reactive power flow/transmission line side voltage is controlled by adjusting the phase angle of the series injected voltage. This has been achieved by introducing a component of the series injected voltage to be in-phase with the transmission line current.

RESULT AND DISCUSSIONS

As our main focus is to consider the changes in active power of load side of the system and corresponding output at different locations using STATCOM and SSSC, we consider two 3-phase permanent magnet synchronous machines modeled in the dq rotor reference frame. Stator windings are connected in wye to an internal neutral point. In this synchronous machine one is set to produce 2100MVA active power and synchronous machine two is set to produce 1400MVA active power. After that a step up transformer has been used to scale down the output voltage of 13.8KV to 500KV.
As we seen from above images, we have cut-off the FACTS devices which results in proportional increase in both stator voltages Vd and Vq. As we are running the rotor on constant rotor speed of \( W_m \), Their needs to be constant stable line for both the voltages, as there is no FACTS device in the transmission system, it increases oscillations in the system and after some time. System stops operating as there is no stability in system due to effect of variable loads in the system.

As seen in above figures it has been found that, there is increase in reactive power at all bus locations when there is fault in the system. It has also been noticed that SSSC recovers early from oscillations as compared to statcom.

In this work we have proposed a distributed generation and transmission system which has two generation units each producing 2100 MVA and 1400MVA power for the consumer load. In this two fix loads of 100MW and 50MW are used along with a three phase dynamic load. In this we have studied and compared the damping oscillations at different points of the transmission system with and without using FACTS devices. In this a three phase fault has been introduced in the system at some point of running and corresponding output waveforms has been studied. We have used two FACTS devices in which SSSC is used in series and STATCOM is used in shunt on the two generation lines. These key FACTS devices are power electronic GTO converters connected in parallel or series with the power system grid and are controlled by novel decoupled controllers. The complete digital simulation of the STATCOM and SSSC within the power system is performed in the MATLAB/Simulink environment using the power system block set. The STATCOM scheme and the electric grid network are modeled by specific electric blocks from the power system block set while the control system is modeled using Simulink. Two novel controllers for the STATCOM and SSSC are presented in this paper based on a decoupled current control strategy to ensure stable operation of the STATCOM under various load excursions. A novel control scheme for the static synchronous series compensator (SSSC) is also implemented to provide a full controllable series compensating (buck/boost) injected voltage over a specified capacitive and inductive range, independently of the magnitude of the transmission line current. It has been found that SSSC behaves better than STATCOM in terms of stability and recovers earlier from oscillations when we remove the fault from the system.

**REFERENCES**


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