Enhancement of Power Fluctuations and Voltage Permanence Using Facts Device

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Abstract—In this paper, to damp out power system oscillations, this has been recognized as one of the major concern in power system operation. Low frequency electromechanical oscillations are inevitable characteristics of power systems and they greatly affect the transmission line transfer capability and power system stability. Traditionally, power system stabilizers are being used to damp these oscillations. The power system network is becoming more complex now a days and it is very difficult to maintain the stability of the power system. The continuous demand in electrical power system network may cause the system to be heavily loaded which leads to voltage instability. Under heavy loaded condition there may be insufficient reactive power which leads to voltage drop. Facts controller mainly used for solving various power system stability control problems. Here analyses the performance of SSSC with SMES and without SMES. These devices are controlling active and reactive powers as well as damping power system oscillation in transient mode.

Keywords— Power system stability; SSSC; Damping oscillations

I. INTRODUCTION

The power system network is becoming more complex now a days and it is very difficult to maintain the stability of the power system. The continuous demand in electrical power system network may cause the system to be heavily loaded which leads to voltage instability. Under heavy loaded condition there may be insufficient reactive power which leads to voltage drop. Power electronic devices, which are used for power flow control, are categorized under the generic name of Flexible AC Transmission Systems (FACTS). There are three major facets of FACTS. They are shunt compensation, series compensation and phase angle regulation. Of these three, the series compensation is addressed in this title. In the FACTS technology, there are two controllers which can be used to provide series reactive compensation; the thyristor controlled series capacitor (TCSC) and the static synchronous series compensator (SSSC). A static synchronous series compensator (SSSC) injects a magnitude-controllable, nearly sinusoidal voltage in series with the transmission system. The heart of the SSSC is a voltage source converter (VSC) that is supplied by a DC storage capacitor. The voltage injected by the SSSC is almost in quadrature with the transmission line current such that it emulates the behaviour of a series inductor or capacitor [1]. Instead of using capacitor and reactor banks, a SSSC employs self-commutated voltage-source switching converters to synthesize a three phase voltage in quadrature with the line current and so accomplishes specific compensation objectives. In steady-state applications, the main interest is to use the SSSC for controlling either impedance line or power flow (active and/or reactive) in transmission lines.

SSSC is introduced to the power system to enhance the level of power transfer capability in transmission lines. Using IEEE 9 bus power system network along with SSSC, this project’s goals is to analyze the performance of the power system by introducing SSSC into the system. Both models will be simulated using PSCAD and MATLAB software. The result of the performance will be analyzed and compared to determine the effectiveness of SSSC’s application in power system.

The available power generating plants are often located at distant locations for economic, environmental and safety reasons. For instance, it becomes cheaper to install a thermal power station at pit-head instead of transporting coal to load centres. Hydro power is generally available in remote areas and a nuclear plant may be located at a place away from urban areas. Additionally, modern power systems are highly interconnected. Sharing of generation reserves, exploiting load diversity and economy gained from the use of large efficient units without sacrificing reliability are the advantages of interconnection. Thus power must consequently be transmitted over long distances. To meet the load and electric market demands, new lines should be added to the system, but due to environmental reasons, the installation of electric power transmission lines are often restricted. Hence, the utilities are forced to rely on already existing infra-structure instead of building new transmission lines. In order to maximize the efficiency of generation, transmission and distribution of electric power, the transmission networks are very often pushed to their physical limits, where outage of lines or other equipment could result in the rapid failure of the entire system.

The power system may be thought of as a nonlinear system with many lightly damped electromechanical modes of oscillation. The three modes of electromechanical oscillations are: 1. Local plant mode oscillations 2. Inter-area mode oscillations 3. Torsional modes between rotating plant. The impact of the oscillation is localized to the generator and the line connecting it to the grid. The rest of the system is normally modelled as a constant voltage source whose frequency
is assumed to remain constant. Torsional mode oscillations is associated with a turbine generator shaft system in the frequency range of 10-45 Hz. Usually these modes are excited when a multi-stage turbine generator is connected to the grid system through a series compensated line

II. POWER SYSTEM STABILITY AND FACTS DEVICE

Stability of an interconnected power system is its ability to return the normal or stable condition after has been subjected to some form of disturbance. Since 1920’s the important issue for reliable and secure interconnected power system is identified as power system stability. In a large interconnected power system as the power exchange increases, the importance to the stability problem also increases. In a free deregulated market, utilities are allowed to participate in the market without mandatory upper or lower limits. Thus, a number of highly publicized blackouts happened in the early years. Single disturbance in the power system may cause cascading outages which results in blackouts of the entire system [9]. The adequate level of system security must be maintained to minimize the risk of blackout.

The purpose of system stability is to keep the synchronous operation of power system with adequate capacity that will minimize the fluctuations in electric demand and system topology. Successful operation of a power system mainly depends on the engineer’s ability to provide reliable and continuous service by using available facilities.

Figure 1. Classification of power system stability

The power flow study results in steady state solution of the power network and provides the data of power flow in respective buses and lines as well as provides magnitudes and phase angles of different buses under specified operating condition such studies are needed for the study of power system operational aspects planning, expansion etc., it is usually employ digital computers as basic power flow problems require solving the steady state system equation using an iterative algorithm.

III. STATIC SYNCHRONOUS SERIES COMPENSATOR

The voltage-sourced converter-based series compensator, called Static Synchronous Series Compensator (SSSC), was proposed by Gyugyi in 1989 within the concept of using converter-based technology uniformly for shunt and series compensation, as well as for transmission angle control. The magnitude of control voltage can be controlled to regulate power flow. The winding resistance and leakage reactance of the connecting transformer appear in series with the voltage source [11]- [13].

Figure 2. Generalized series-connected synchronous-voltage source employing a multi-pulse converter with an energy-storage device

Figure 3. Different operating modes for real- and reactive-power exchange
3.1 Principle Operation Of SSSC

A series capacitor compensates the transmission-line inductance by presenting a lagging quadrature voltage with respect to the transmission-line current. This voltage acts in opposition to the leading quadrature voltage appearing across the transmission-line inductance, which has a net effect of reducing the line inductance. Similar is the operation of an SSSC that also injects a quadrature voltage, \( V_C \), in proportion to the line current but is lagging in phase [1]:

\[
V_C = -j k X I_L
\]

The current in a line compensated at its midpoint by the SSSC is expressed as:

\[
I_L = \frac{2V \sin \frac{\delta}{2}}{X} + \frac{V_C}{X}
\]

3.2 Power flow control

The corresponding line power flow is given by,

\[
P = V I_L \cos(\delta/2)
\]

\[
P = \frac{V^2 \sin \delta}{X} + \frac{V V_C}{X} \cos(\delta/2)
\]

A series-compensation scheme using the SSSC is depicted in Fig. Normally, the SSSC-output voltage lags behind the line current by 90° to provide effective series compensation. In addition, the SSSC can be gated to produce an output voltage that leads the line current by 90°, which provides additional inductive reactance in the line. This feature can be used for damping power swings and, if the converter has adequate rating, for limiting short-circuit currents.

![Figure 4. Synchronous-voltage source employing a multi-phase dc/ac converter that is operated as a series-capacitive compensator.](image)

For SSSC control, as for STATCOM control, the inverter is operated with a constant ratio between the dc voltage and the ac output voltage. The magnitude and polarity of the inverter output voltages are the only control inputs. Changes in the magnitude of the output (series injected) voltage are made by charging and discharging the dc bus capacitors. The inverter voltage is kept substantially in quadrature with the line current, which can be done with leading or lagging polarity so that the injected voltage appears in the line as inductive or capacitive respectively.

![Figure 5. SSSC Control Structure for Voltage Injection](image)

Charging of the dc bus capacitors is controlled by allowing the injected voltage to deviate slightly from a quadrature relationship with the line current, thereby changing real power between the inverter (e.g. the dc capacitors) and the line. Clearly, this exchange will only work when there is a sufficient level of line current to allow power exchange. The control scheme thus has a singular region around zero line current that must be avoided. In addition, the dc voltage control loop gain varies with dc voltage and line current. Adaptively changing the loop gain compensates for this problem as shown in the control structure of Fig 3.
IV. SIMULATION AND RESULTS

The performance of SSSC is investigated by voltage and current waveforms using simulation. The simulation diagram for SSSC is used for controlling the power flow in the transmission system. First, the system has been simulated in MATLAB/SIMULINK environment. The converter circuit of SSSC is usually a multi-pulse and/or multilevel configuration.

In this work, SSSC is modelled by a combination of three-level, 24-pulse configuration with TYPE-1 controllers [2]. To control the real and reactive power, transformed into abc to dq0 values. After controlling the power, controllers transformed the variables into abc reference signals and given to the PWM.

4.1 Two machine power system model

The performance of SSSC is presented by voltage and current waveforms in the two machine power system. One SSSC has been utilized for power flow control in the two machine power system model.
According to the Figure 7, current waveforms get oscillated due to fault. After insertion of SSSC, it gets closer to sinusoidal.

4.2 Voltage and current in Bus-1 and Bus-4

First, Power system with two machines, four buses has been simulated in MATLAB/SIMULINK environment and power, voltage, current has been obtained at bus-1 and bus-4. The Voltage and current at each bus will simulated during fault conditions.
The waveforms show the current and voltage at bus-1 and bus-4. System without SSSC voltage and current damping time will be greater transient. The main role of SSSC is improving the transient oscillations of the system. The system with SSSC and the voltage and current respectively had shown in figure 12 and 13.

Figure 13. Simulation result for Voltage & Current without Fault at bus 1

Figure 14. Simulation result for Voltage & Current without Fault at bus 4

The inclusion of SSSC reduces the risk of SSR by detuning the network resonant frequency. Although the introduction of SSSC reduces the peak negative damping, properly designed sub synchronous current suppressor improves the damping of all the critical torsional modes.

Figure 15. Simulation result for Voltage with Fault

Figure 16. Simulation result for Voltage with SSSC
V. CONCLUSION

In this paper, small signal stability performance improvement by a SSSC controller has been investigated. The SSSC is not strictly SSR neutral, however it offers a reactance which remains practically constant with frequency and increases the electrical resonant frequency of the net- work when constant reactive voltage control is adopted. In this paper, the simulation of a transmission power system model with Static synchronous series compensator (SSSC) based damping controllers in the presence of a single phase short circuit fault is considered. The results shows that the power system oscillations are damped out very quickly with the help of SSSC based technique in few seconds. The compensation of the reactive power flow over the power line due to the power line inductance is compensated with the help of series injected voltage. The balance or the stability of the system is not affected and the harmonic distortion is kept to reasonable levels.

REFERENCES


BIBLIOGRAPHY OF AUTHORS

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