Voltage Stability Improvement In Multi-bus System Using Static Synchronous Series Compensator
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Abstract
Today’s power system has become more complex due to open access electricity market activities and an increasing demand, for such network stability is an important issue. Among various types of stability, voltage instability and collapse become a concern problem all over the world. To maintain power system stability issues FACTS devices are used. In this paper a suitable approach to enhance the voltage stability of power system using static synchronous series compensator (SSSC) is studied. IEEE 4 bus system and IEEE 9 bus system is simulated using MATLAB Simulink software to study voltage stability and reactive power compensation. The performance of SSSC on voltage profile is analysed for multibus system. Simulation results demonstrate that voltage stability can be improved using of static synchronous series compensator.

Keywords: Power system stability, FACTS, Reactive power compensation, Voltage stability, SSSC;

1. Introduction
Now a day's power system is more interconnected so stability is the main issue. Continuously changing load demand and fault condition adversely affect the power system stability. Under heavy load conditions or change in system conditions voltages can drop considerably and even collapse. Voltage instability or voltage collapse is due to shortage of reactive power from generators and transmission line [1,2]. Voltage profile can be improved by controlling reactive power using FACTS devices because of several advantages over other controlling devices. Static synchronous series compensator (FACTS device) is shown its performance in terms of stability improvement. The role of SSSC is to control power transfer capability; it can also upgrade stability of power system. SSSC can improve the power transfer capability by adding inductive or capacitive inductance in transmission line [3,4,5].

In recent years various works is done to improve power system stability by using FACTS devices. The static synchronous series compensator (SSSC) is one of the FACTS device used to examine the effect of voltage stability. It consists of voltage source converter and coupling transformer connected in series with the transmission line. For the purpose of increasing or decreasing the overall reactive voltage drops across the line. Its output voltage is in quadrature with the line current. The SSSC can control the current and the power flowing through the line by controlling the reactive power exchange between the SSSC and the AC system. It can improve the voltages profile in the transient state. SSSC investigate the effect on current, voltage, active and reactive power in real time [6-7]. The problem of controlling and modulating power flow in a transmission line using a SSSC is analysed. Which include detailed techniques of twelve pulse and PWM controlled SSSC, are conducted and the control circuits are presented.

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The application of SSSC based power oscillation damping controller to enhance the stability of IEEE 4 bus system is investigated in MATLAB software [8-9]. The problem of controlling and modulating power flow in transmission line under faulty condition is improved by using SSSC [10].

In this paper static synchronous series compensator is studied to improve the voltage stability by continuous voltage injection. The application of SSSC to improve voltage stability is apply to nine bus system. Initially the basic model of four bus system with and without SSSC is analysed. After that IEEE 9 bus system is simulated by using MATLAB software. All the output results of four bus and nine bus system illustrated that voltage profile is increased with the help of static synchronous series compensator.

This paper is structured as follows. The basics of voltage stability are described in section II. In section III, static synchronous series compensator theory concepts and fundamental equations is summarized. In section IV, test system description of IEEE 4 bus and IEEE 9 bus system with and without SSSC is described. Next the simulation and results of multi-bus systems with and without SSSC is demonstrated in section V. Finally section V gives the concluded remark. The IEEE 4 bus and IEEE 9 bus system is studied and voltage stability result are investigated using MATLAB Simulink software.

2. Voltage stability:

Voltage stability is the capability of a power system to sustained steady acceptable voltages at all buses in the system in normal operating conditions and after being subjected to disturbance. A system come into a state of voltage instability when a disturbance, increase in load demand or change in system condition causes a progressive and uncontrollable drop in voltage.

The main factor causing instability is the inability of the power system to meet the demand of reactive power. The bus voltage magnitude increases as the reactive power injection at the same bus is increased. System is voltage unstable if, for at least one bus in the system, the bus voltage magnitude decreases as the reactive power injection at the same bus is increased.

Voltage instability may arise due many reasons, but some significant contributors are:

- Increase in loading
- Generators, synchronous condensers, or SVC reaching reactive power limits
- Action of tap changing transformers
- Load recovery dynamics
- Line tripping or generator outages

Most of these changes have a significant impact on the reactive power production, consumption and transmission in the system. Some counter measures to prevent voltage collapse are:

- Switching of shunt capacitors
- Blocking of tap-changing transformers
- Redispatch of generation
- Load shedding
- Temporary reactive power overloading of generators

3. Static synchronous series compensator:

Static synchronous series compensator SSSC is made up of a capacitor, a converter and a coupling transformer. Converter comprises several gate turn off thyristor switch-based valves to regulate the magnitude and the angle of the injected voltage.

Single line diagram of transmission line with an inductive reactance connecting to sending end voltage source and a receiving end voltage source is shown in figure 1. The real and reactive powers (P and Q) flows at the receiving end voltage source are given by

\[ P = \frac{V_sV_r}{x_L} \sin(\delta_s - \delta_r) = \frac{V^2}{x_L} \sin \delta \]  
(1)
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