Static Synchronous Series Compensator (SSSC) as Stability Booster of a Power System

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Abstract —*The continuous demand in electric power system network has caused the system to be heavily loaded leading to system instability. Under the faulty conditions power system observes transients (oscillations) with major changes in active and reactive power flow. To compensate these transients, within the safe time and also to improve active and reactive power flow various compensation methods like using FACTS controller are used in power system. In this paper the effect of Static Synchronous Series Compensator (SSSC) is presented. The dynamic performance of SSSC is presented by real time waveforms using MATLAB software for IEEE 4 bus system. Comparison of simulation results are presented with normal system without SSSC, with SSSC and with Fuzzy controller.*

Keywords —*Dynamic Load (DL), FACTS (Flexible AC Transmission System), Static Synchronous Series Compensator (SSSC)*

I. Introduction

There is steep increase in energy day by day. This increased in energy demand has raised the need of flexible and reliable power flow, better power quality and stability in all conditions [1],[2], sudden change in loading conditions found under faulty conditions and system exhibits less security and thereby increases power quality issues and diminishes overall stability. Nowadays the power system, by large, are controlled by mechanical system [1], which creates major problems such as effective control over power flow, reduces transient stability becomes sluggish. Advances in power electronics, FACTS devices have gained good popularity during the last few years. FACTS devices have been mainly used for solving various power system control problems such as voltage regulation, power flow control, and power system stability. The FACTS controllers are very fast and capable of controlling network condition and this unique feature is used to improve the power system stability. Static synchronous series compensator is one of the facts devices used to improve the overall performance of power system in the stability aspects [3],[4],[5].

In this paper, a comparative study of power system behaviour is presented without compensation and using FACT device SSSC with two types of controllers.

a. SSSC with PI Controller
b. SSSC with Fuzzy Controller

The Static Synchronous Series Compensator (SSSC) is the voltage-sourced converter-based series compensator used to control active and reactive power flow and improve transient stability of power system [5].

II. Control Scheme of SSSC

A. *Operation of SSSC*

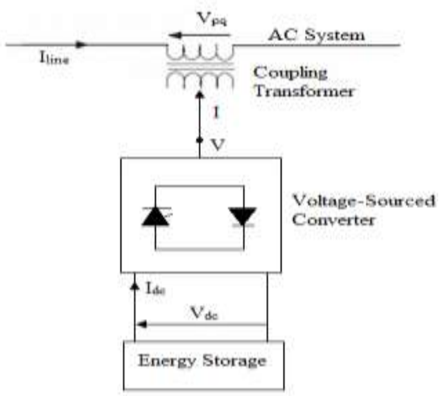

Fig.1. Functional model of SSSC

A static synchronous generator is a series compensator whose output voltage is in quadrature with, and controllable independently of, the line current for the purpose of increasing or decreasing the overall reactive voltage drop across the line and thereby controlling the transmitted power. When the phase difference between voltage to the current is -900 or voltage lags the line current by 900, it will behaves as a series capacitor and , phase difference between them is +900 or voltage leads the line current by 900 ,it behaves as a series inductor.

The Fig.1 shows a functional model of the SSSC [4] where the dc capacitor has been replaced by an energy storage device to allow active as well as reactive power exchanges with the ac system. SSSC consist of a solid state voltage source converter (VSC) which generates a controllable AC voltage at fundamental frequency and is connected in series with transmission line.

B. Control Scheme of SSSC

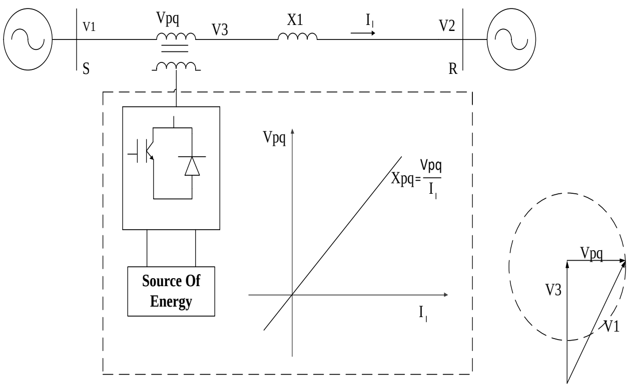

Fig.2. control scheme of SSSC

Fig.2 shows the control scheme and behaviour of SSSC. AC source is applied at the input side of SSSC and Capacitor with DC battery is connected at the other end of SSSC. Following steps are followed to control SSSC [6].

1. First Sample three phase-voltages and currents from the bus where SSSC is connected is find out
2. Convert three-phase voltages and currents to d-q-0 parameters
3. Active and reactive power is calculate
4. Calculated value with reference value is compared to generate error signal
5. Zero signal error is achieved using controllers
6. First With PI Controller
7. Transfer d-q-0 output of controller to a-b-c
8. Using this a-b-c sequences generate PWM signals to SSSC
9. Procedure 6,7 and 8 is repeated for Fuzzy Controller

The active and reactive power flow (P and Q) of the receiving end is given by,

$$P = \frac{V_1 V_2}{X_L}\sin(\delta_1 - \delta_2) = \frac{V^2}{X_L}\sin\delta \quad (1)$$

$$Q = \frac{V_1 V_2}{X_L}(1 - \cos(\delta_1 - \delta_2)) = \frac{V^2}{X_L}(1 - \cos\delta) \quad (2)$$

Where, V_1 and V_2 are the voltages source magnitudes and δ_1 and δ_2 are the phase angles of the voltage sources V_1 and V_2 respectively.

For the simplicity, the voltage magnitudes are taken constant that is,

$$V_1 = V_2 = V$$

Therefore the distance between the phase angles will be,

$$\delta_1 - \delta_2 = \delta$$

To control the power flow, compensating reactance X_q (capacitive as well as inductive) is utilized. Therefore, the equations of power flow (equations 1 & 2) in terms of X_q can be written as,

$$P_q = \frac{V^2}{X_{ref}}\sin\delta = \frac{V^2}{X_L(1-X_q/X_L)}\sin\delta \quad (3)$$

$$Q_q = \frac{V^2}{X_{ref}}(1 - \cos\delta) = \frac{V^2}{X_L\left(1-\frac{X_q}{X_L}\right)}(1 - \cos\delta) \quad (4)$$

where, X_{ref} effective reactance of transmission line including variable resistance inserted by the injected voltage source of SSSC. The compensating reactance Xq will be negative when the Series Compensator is operated in an inductive mode and will be positive when the Series Compensator is operated in a capacitive mode.

III. Power System Under Study

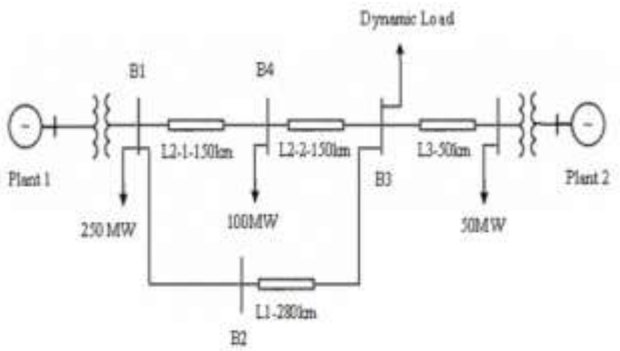

Fig.3 (a) Two Machine System without SSSC

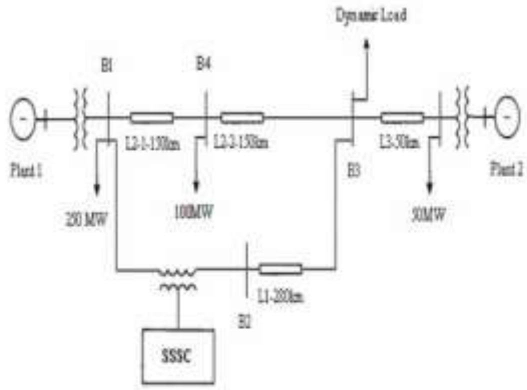

Fig.3 (b) Two Machine System with SSSC

Fig.3 (a) and (b) represents standard 2-machine 4-bus system with and without SSSC. The ring mode system consist of 4-buses (B1 to B4) connected by three phase transmission lines with different sections L1-1=150 km, L1-2=150 km, L2=280 km and L3=50 km. A Three Phase Source 1 and 2 (plant 1 and 2) generates voltage at 13.8 kV between lines. The base parameters are base voltage (V_b) = 400 KV, total power (S_b)=100 MVA, step up transformer having ratings 13.8/400 kV. In bus B2 SSSC is connected.

IV. Simulation Results

Fig.4 shows the simulation result for Active and Reactive Power without using SSSC. Fig.5(a) and Fig.5(b) shows the Simulation Result for Active Power with and without SSSC using PI Controller. Fig.6(a) and Fig.6(b) shows the Simulation Result for Active Power with and without SSSC using Fuzzy Controller.

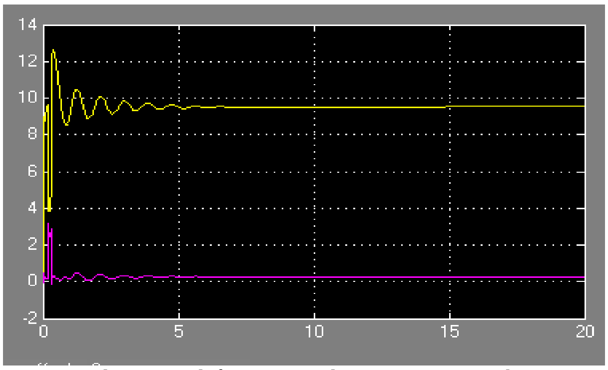

Fig.4 Simulation Result for Active and Reactive Power without using SSSC

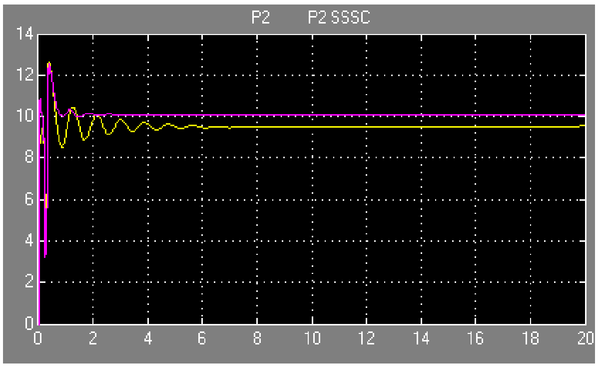

Fig.5(a) Simulation Result for Active Power with and without SSSC (PI Controller)

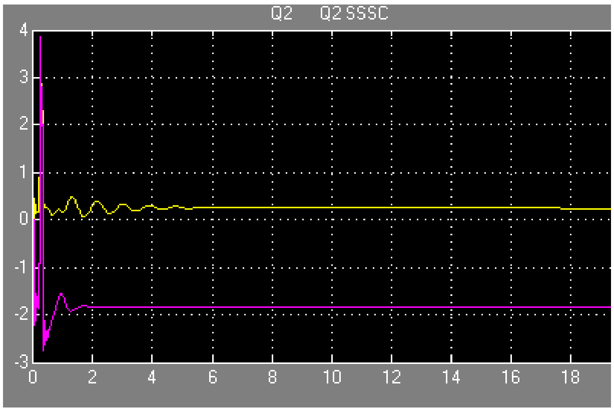

Fig.5(b) Simulation Result for Reactive Power with and without SSSC (PI Controller)

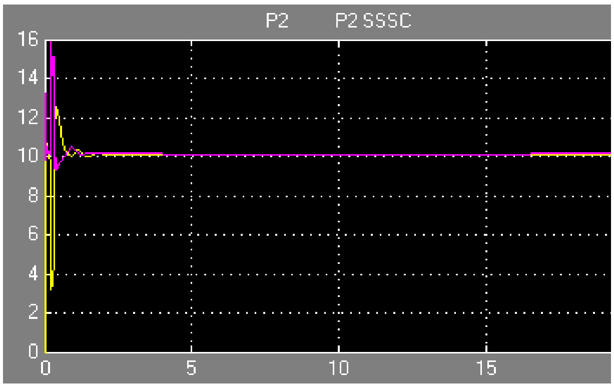

Fig.6(a) Simulation Result for Active Power with and without SSSC (Fuzzy Controller)

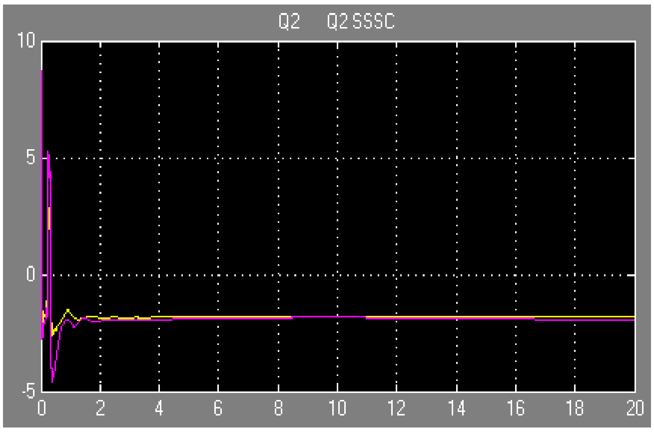

Fig.6(b) Simulation Result for Reactive Power with and without SSSC (Fuzzy Controller)

V. Conclusion

Comparing the results of system without SSSC , with SSSC using PI Controller and using Fuzzy Controller, it can be concluded that the settling time is reduced with the use of SSSC using PI Controller and further this time is reduced using Fuzzy Controller. Hence the systems Stability is improved.

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