Design of SSSC to Improve Power System Stability with Fuzzy Logic Controller

Bikash Kumar Panda[1], Sampath Kumar Boini[2]
(PG Scholar,Department of Electrical And Electronics Engineering, Teegala Krishna Reddy Engineering College/JNTU HYDERABAD, INDIA)
(Associate Professor, Department of Electrical and Electronics Engineering, Teegala Krishna Reddy Engineering College /JNTU HYDERABAD, INDIA)

Abstract- **Power system stability enhancement with static synchronous series compensator investigates the enhancement of voltage stability using static synchronous series compensator(SSSC).The continuous demand in electric power system network has caused the system to be heavily loaded leading to voltage instability. Under heavy loaded condition there may be insufficient reactive power causing the voltage drop. This drop may lead to drop in voltage at various buses. The result would be the occurrence of voltage stability control problems. A static synchronous series compensator is used to investigate the effect of the device in controlling active and reactive power as well as damping power system oscillation in transient mode. The dynamic performance of SSSC is presented by real time voltage and current wave forms using MATLAB software for IEEE 2 machine 4 bus system.**

Keywords— StaticSynchronousSeriesCompensator(SSS),Fuzzy Controller, Power System Stability.

I. INTRODUCTION

In recent years, greater demands have been placed on the transmission network and the increase in demands will rise because of the increasing number of non utility generators and heightened competition among utilities themselves. Increasing demands, lack of long-term planning, and the need to provide open access electricity market for Generating Companies and utility customers, all of them have created tendencies toward less security and reduced quality of supply. The power systems of today, by and large ,are mechanically controlled. There is a widespread use of microelectronics, computers and high-speed communications for control and protection of present transmission systems; however, when operating signals are sent to the power circuits, where the final power control action is taken, the switching devices are mechanical and there is little high-speed control. Another problem with mechanical devices is that control cannot be initiated frequently, because these mechanical devices tend to wear out very quickly compared to static devices. In effect, from the point of view of both dynamic and steady-state operation, the system is really uncontrolled. Power system planners, operators, and engineers have learned to live with this limitation by using a variety of ingenious techniques to make the system work effectively, but at a price of providing greater operating margins and redundancies. These represent an asset that can be effectively utilized with prudent use of FACTS technology on a selective, as needed basis.

The FACTS devices (Flexible AC Transmission Systems) could be a means to carry out this function without the drawbacks of the electromechanical devices such as slowness and wear. FACTS can improve the stability of network, such as the transient and the small signal stability, and can reduce the flow of heavily loaded lines and support voltages by controlling their parameters including series impedance, shunt impedance, current, voltage and phase angle. Controlling the power flows in the network leads to reduce the flow of heavily loaded lines, increased system load ability, less system loss and improved security of the system.

The Electric Power Research Institute (EPRI) formulated the vision of the Flexible AC Transmission Systems (FACTS) in which various power-electronics based controllers regulate power flow and transmission voltage and mitigate dynamic disturbances. Generally, the main objectives of FACTS are to increase the useable transmission capacity of lines and control power flow over transmission lines. Hingorani and Gyugyi proposed the concept of FACTS. Stabilizers based on FACTS devices such as UPFC, STATCOM and SCCC can be effectively used for damping oscillations, and because of the fast control response of FACTS devices compared with PSS, they are appropriate to increase the damping power system oscillations and improving voltage profile. FACTS are commonly divided in three groups of in parallel connected devices such as STATCOM, in series connected devices such as SSSC and in parallel-series connected devices such as UPFC. This paper investigates the static synchronous series compensator (SSSC) performances using Fuzzy controller and compare with the other well known controllers. Similar work was conducted formerly for

STATCOM. The SSSC has been applied to different power system studies to improve the system performance. There has been some work done to utilize the characteristics of the SSSC to enhance power system stability.[1]

II. STATIC SYNCHRONOUS SERIES COMPENSATOR (SSSC)

Single line diagram of a SSSC in a two machine system is shown in Figure 1. According to the figure, SSSC injects a series voltage (*Vpq*) into the transmission line. A Static Synchronous Series Compensator (SSSC) is a member of FACTS controllers connecting in series with a power transmission lines. It consists of a solid state voltage source converter (*VSC*) which generates a controllable alternating current voltage at fundamental frequency. When the injected voltage is kept in quadrature with the line current, it can emulate as inductive or capacitive reactance so as influence the power flow through the transmission line.[2]

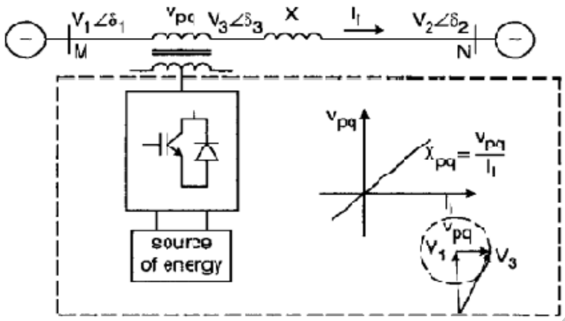

Fig: 1 SSSC Single line diagram

III. SSSC Control System

To respond the dynamic and transient changes caused in system, SSSC utilizes the series converter as shown in Figure 2. One side of the converter is connected to the AC system while the other side is connected to a capacitor and battery. If a change (large load entrance or three phase faults and etc) occurs in system, SSSC control system works such that according to the control system in Figure 3 the energy of battery to be converted to the AC form by converter, and then injecting this voltage to the transmission line causes that the spontaneous demand to be met and properly damping occurs.

Fuzzy controller which is in control system of Figure 2 is shown in Figure 3. To control the active and reactive powers, first, sampling from the voltage and current is done and then it is transformed to the dq0 values. Active and reactive powers of bus-2 are calculated using their voltage and current in dq0 references and compared with the determined reference and the produced error signal is sent to the Fuzzy controllers. Then, the output of the controllers are transformed to the abc reference and given to the PWM so as to adjust properly the IGBTs firing angles. In this paper, to have more control on changes, in addition to error signal, differential of the signal is also used as another input for Fuzzy controller. Consequently, control system is governed only by using a few fuzzy rules and this result in fast response of Fuzzy controllers. To make fuzzy the inputs, Gaussian membership function was utilized .

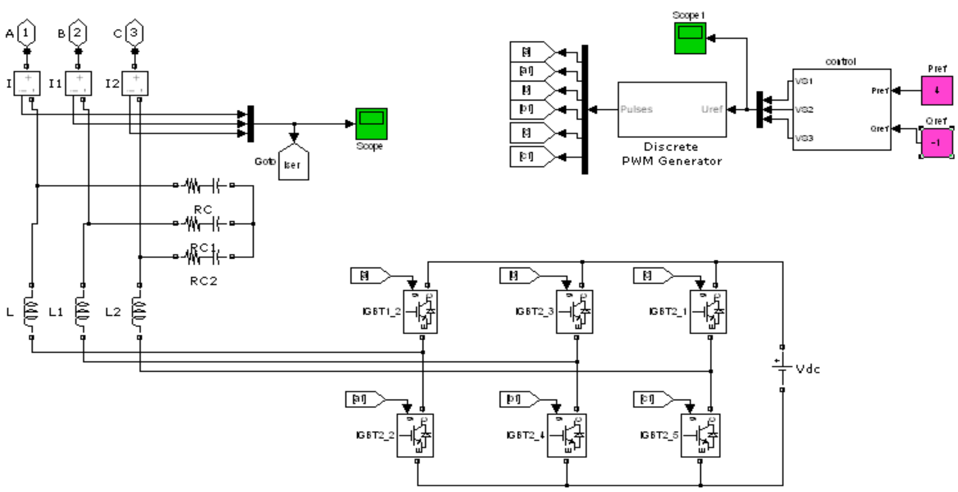

Fig: 2. The Converter of SSSC

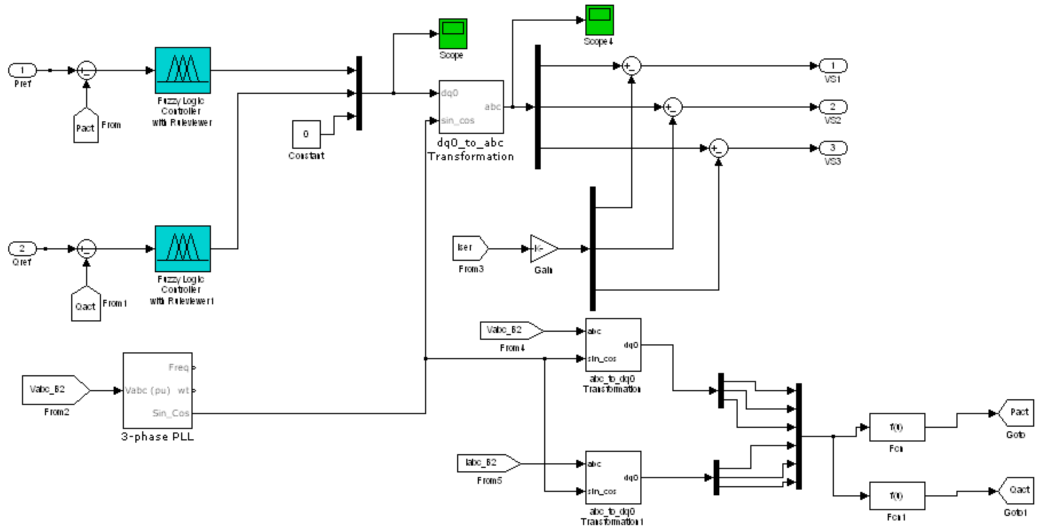

Fig: 3.Control circuit of SSSC

IV.TWO MACHINE POWER SYSTEM MODELING

To examine the performance of controllers a two-machine and four-bus system obtained in MATLAB/SIMULINK environment is used which is shown in Figure. 4. According to the Fig. 3, a 500kV transmission system includes 4 buses (B1 to B4) connected to each other through four three-phase transmission lines L1, L2-1, L2-2 and L3with the lengths of 280, 150, 150 and 50 km, respectively. The system is supplied by two power plants of phase-to-phase voltage 13.8kV. Active and reactive powers injected by these two power plants to the power system are presented in per unit using base values Sb=100MVA and Vb=500kV, which active and reactive powers of power plants 1 and 2 are (24-j3.8) and (15.6-j0.5) in per unit, respectively.

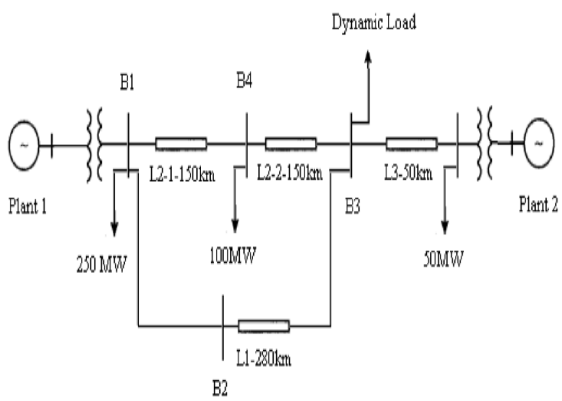

Fig:4.The configuration of two machine power system.

V.SIMULATION MODEL WITHOUT SSSC

First, power system with two machines and four buses has been simulated in MA TLAB environment, and then powers and voltages in all buses have been obtained. The results have been given in Table 1. Using obtained results bus-2 has been selected as a candidate bus to which the SSSC be installed. Therefore, the simulation results have been focused on bus-2.

TABLE 1. OBTAINNED RESULT FROM SIMULATION

BUS NO	Voltage	Current	Active Power	Reactive Power
1	1pu	13.5pu	20.06pu	-3.77pu
2	1pu	6.7pu	9.96pu	-1.82pu
3	1pu	10pu	14.84pu	-0.49pu
4	1pu	5.55pu	8.45pu	-0.59pu

Changes in current, voltage, active and reactive powers of bus-2 have been obtained in real time. According to the fig-8 results at first, due to the large loads of the system active power of bus-2 got oscillations which keep continuing for 3 seconds. However, the controlling systems in power plants land 2 such as

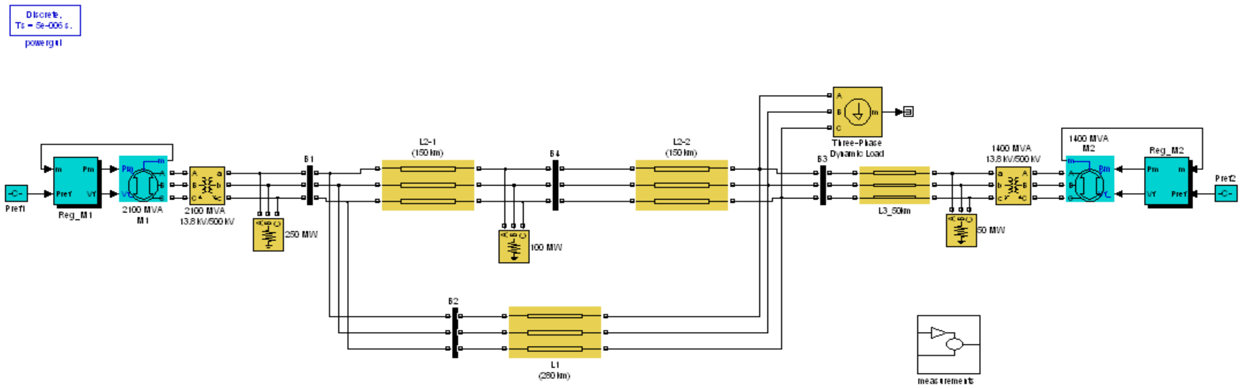

Fig: 5. Simulation model of two machine power system without SSSC.

governor, PSS and other stabilizing devices are used for damping these oscillations. As shown in fig-9 Because of the abovementioned reasons reactive power of bus-2 got oscillations at first and then will be damped properly. Oscillations amplitude for active power is more than reactive power, and this is because the ohmic parts of loads of system are much more.According to fig-6 & fig-7 after transient mode created at first in system, voltage and current waveforms of bus-2 got closer to sinusoidal waveforms. Voltage amplitude is 1 per unit, but, despite the drawn currents by loads in system, current amplitude is 6.7 pu.

Bus 2 with SSSC

The aim is achieving the valves of active and reactive power P(ref)= 4 pu Q(ref) = -1 pu.The main role of SSSC is controlling the active and reactive power.

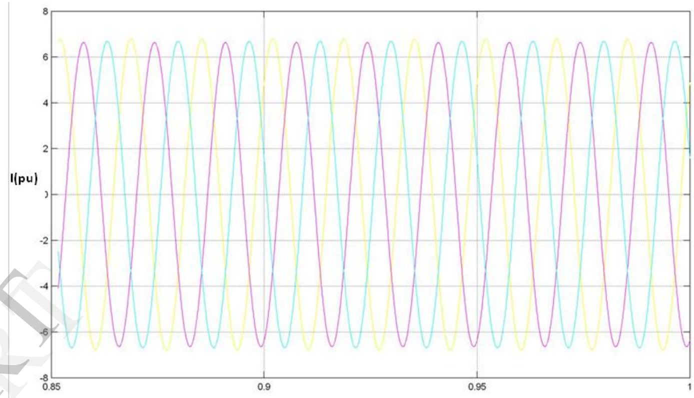

Fig 7 Current of bus-2 without SSSC

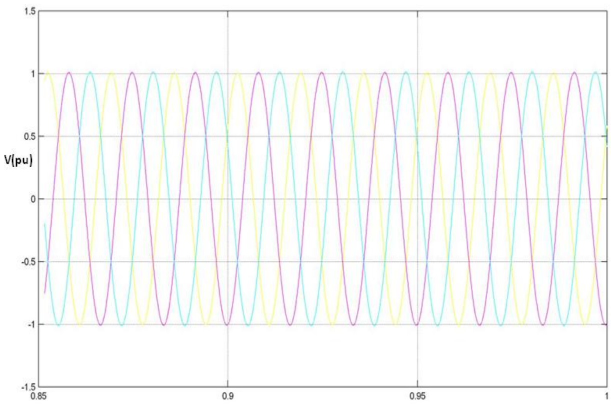

Fig 6.Voltage of bus-2 without SSSC

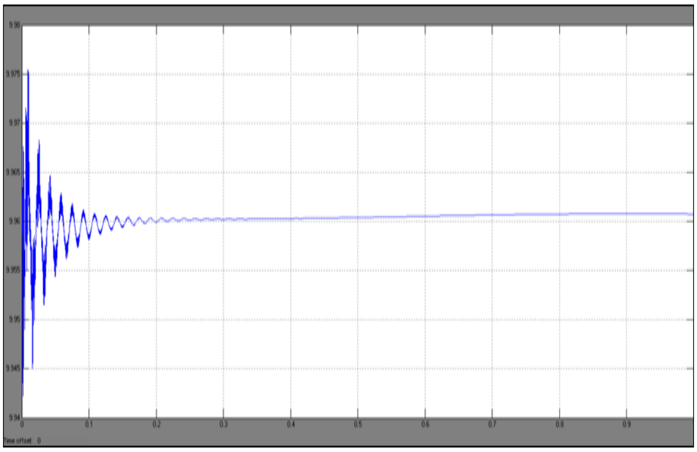

Fig 8. Active power of bus-2 without SSSC

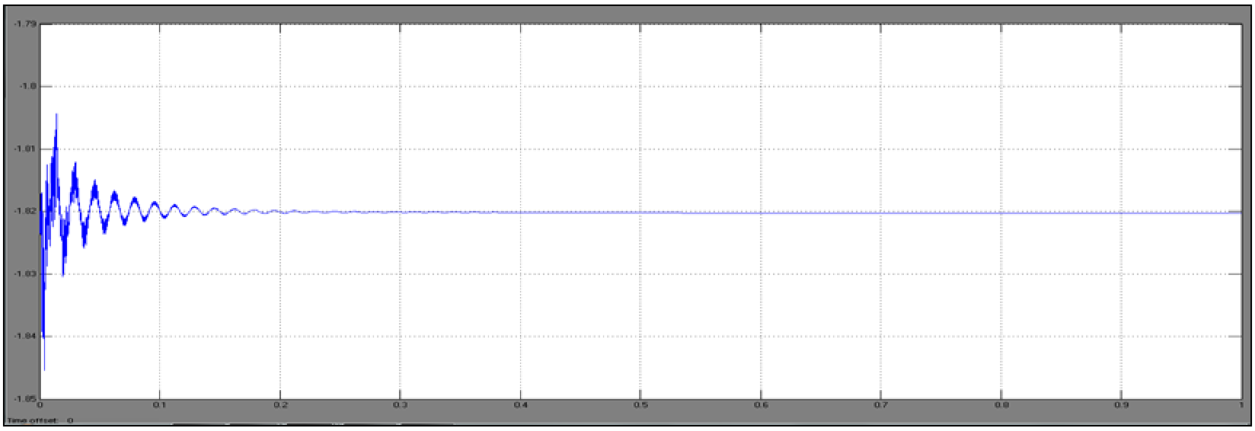

Fig 9,Reactive power of bus-2 without SSSC

VI.SIMULATION MODEL WITH SSSC

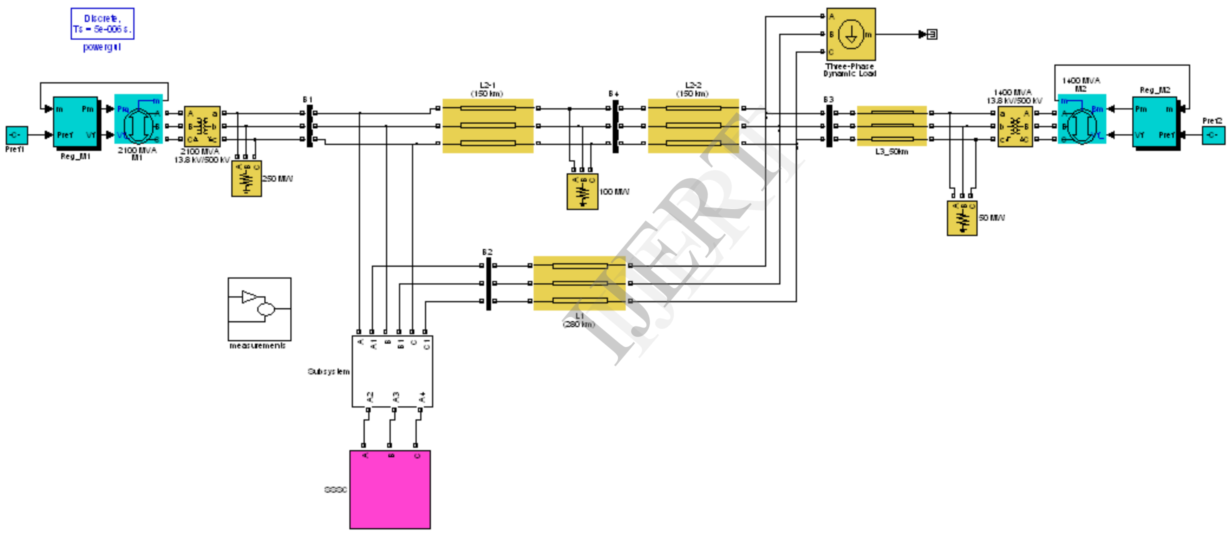

Fig 10. Simulation model of two machine power system with SSSC

SSSC is controlling the active and reactive powers; beside these SSSC could fairly improve the transient oscillations of system. After the installation of SSSC, besides controlling the power flow in bus-2 we want to keep constant the voltage value in 1 per unit, hence the power flow is done in the presence of SSSC and the simulation results are as follows. According to the Fig. 11, by installing the SSSC, active power damping time will be less than the mode without SSSC and it will be damped faster. Also as shown in Fig. 12, reactive power damping time will be decreased.Fuzzy controller not only could reach the steady state value faster than the other controller but also oscillaton amplitude also declined remarkably using this controller.

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TABLE 2.COMPARISON TABLE AT BUS 2

S.NO	PARAMETER	AP(p.u)	RP(p.u)
1	WITHOUT SSSC	9.96	-1.82
2	SSSC WITH PI CONTROLLER	4.094	-1.186
3	SSSCWITH FUZZY	4.049	-1.119

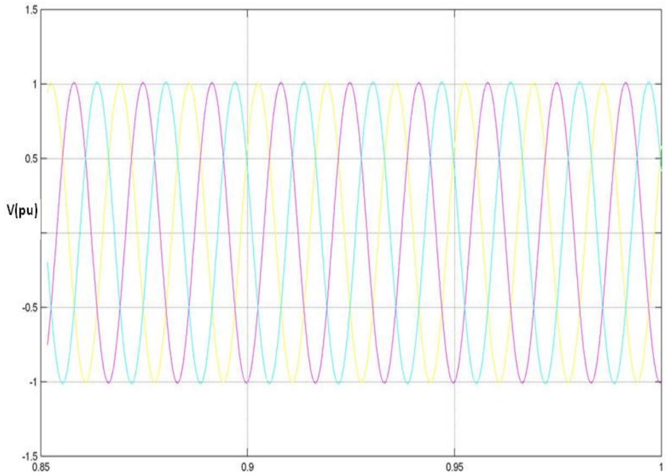

Fig 11. Voltage of bus-2 with SSSC

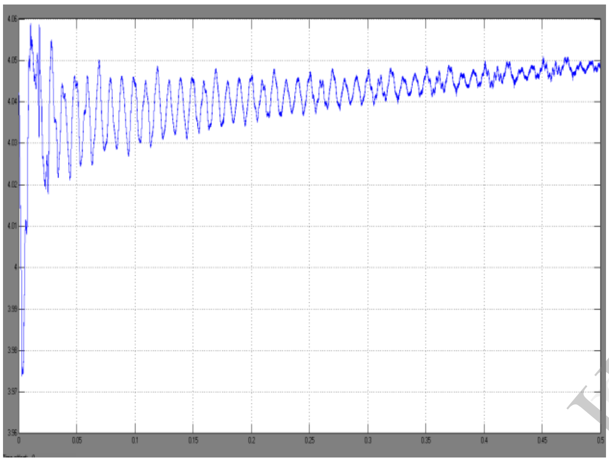

Fig 12. Active power of bus-2 with SSSC

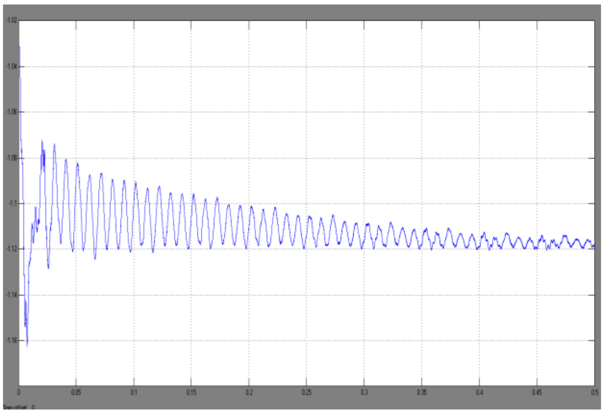

Fig 13. Reactive power of bus-2 without SSSC

VII. CONCLUSION

It has been found that the SSSC is capable of controlling the flow of power at a desired point on the transmission line. It is also observed that the SSSC injects a fast changing voltage in series with the line irrespective of the magnitude and phase of the line current. In this paper, Fuzzy controller as one of the most useful controller was utilized in SSSC control system. By using fuzzy controller can achieve their goals i.e; oscillation damping, fast response and finally stabilizing power system.

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