Scientific Journal Impact Factor (SJIF): 1.711
International Journal of Modern Trends in Engineering and Research
IJMTER
ISSN (ONLINE) : 2349 - 9745
ISSN (PRINT) : 2393 - 8161

Mitigation of power oscillation to enhance power system stability using SSSC

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Abstract— In the modern power system the fault in the system is predestined which leads to power oscillation and cause instability in the system. Therefore satisfactory damping of power oscillation is an important issue concern when dealing with the stability of power systems. The main objective of this paper is to mitigate power system oscillations, which has been considered as one of the major disquiets in power system operation. Simulations have been done for 4 bus two area power system in MATLAB/SIMULINK environment. Simulation results obtained for selected bus-2 power for 1-phase, 2-phase and 3-phase fault with and without SSSC. Results show that the SSSC damp the power oscillation and control power flow.

Keywords—*static synchronous series compensator (SSSC), oscillation, FACTS, damping, two area model, stability.*

I. INTRODUCTION

The modern power system is a highly nonlinear system that operates in a constantly changing environment. The large power system has many interconnections and bulk power transmission over long distances. Due to this there is low frequency inter area oscillations which may leads to system instability [1]. The system must be able to operate satisfactorily under abnormal conditions and successfully meet the load demand. It must also be able to survive numerous disturbances of a severe nature, such as short-circuit on a transmission line or loss of a large generator. The power flow through transmission line is a function of line impedance, magnitude and phase angle. If these parameters can be controlled, the power flow through the transmission line can be controlled. [3] It is important to damp these oscillations as quickly as possible because they cause mechanical wear in power plants and many power quality problems. The introduction of flexible ac transmission system (FACTS) devices has led to a fast and more versatile approach to control the power system stability in a desired way. FACTS controllers provide a set of interesting capabilities such as power flow control, reactive power compensation, voltage regulation, damping of oscillations [4-5]. In this work SSSC is used to enhance the stability. 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 behavior of a series inductor or capacitor. 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 [6]. SSSC with a suitably designed external damping controller can be used to improve the damping of the low frequency power oscillations in a power network. These features make the SSSC an attractive FACTS device for power flow control, power oscillation damping and improving transient stability.

Volume 02, Issue 04, [April– 2015] ISSN (Online):2349–9745 ; ISSN (Print):2393-8161

II. FACTS DEVICES AND POWER SYSTEM STABILITY

2.1. FACTS Devices

Flexible AC Transmission System (FACTS) is a new integrated concept based on power electronic switching converters and dynamic controllers to enhance the system utilization and power transfer capacity as well as the stability, security, reliability and power quality of AC system interconnections. Basic types of facts controllers are shown in figure1. For a given MVA size, the series controller is several times more powerful than the shunt controller in application of controlling the power/current flow. Drawing from or injecting current into the line, the shunt controller is a good way to control voltage at and around the point of connection. The shunt controller serves the bus node independently of the individual lines connected to the bus. Series connected controllers have to be designed to ride through contingency and dynamic overloads, and ride through or bypass short circuit currents. A combination of series and shunt controllers can provide the best of effective power/current flow and line voltage. FACTS controllers may be based on thyristor devices with no gate turn-off or with power devices with gate turn-off capability. The principle controllers are based on the dc to ac converters with bidirectional power flow capability. Energy storage systems are needed when active power is involved in the power flow.

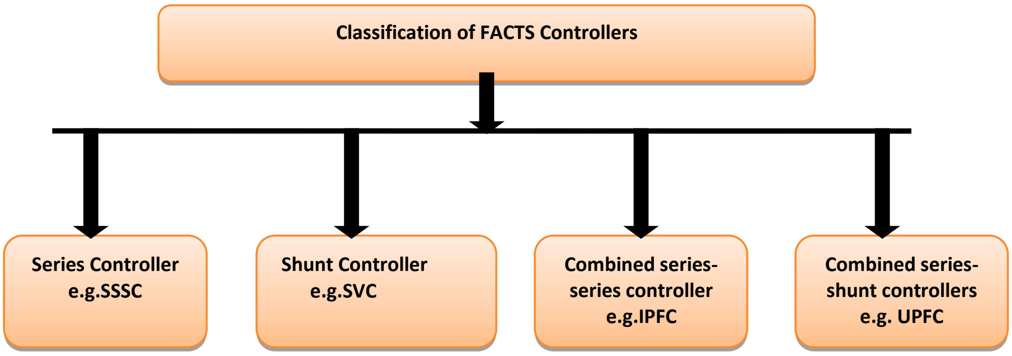

Figure 1.Classification of FACTS Devices

2.2. Power System Stability

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 [7]. The adequate level of system security must be maintained to minimize the risk of blackout. The various form of stability is shown in figure2.

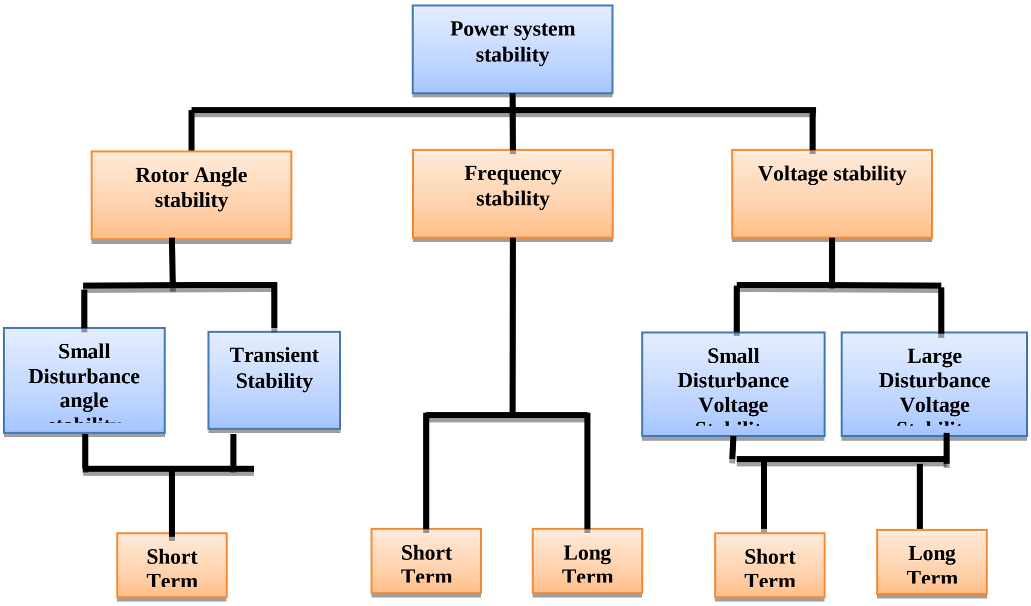

Figure 2.Classification of Stability

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[8].

III. STATIC SYNCHRONOUS SERIES COMPENSATOR

3.1. SSSC Configration

The basic scheme of the SSSC is shown in Fig3. The compensator is equipped with a source of energy, which helps in supplying or absorbing active power to or from the transmission line along with the control of reactive power flow. As the name suggests, SSSC is a series compensator. It is connected in series with the transmission line. Three phase series transformers are used to connect the compensator in series with the power system. A SSSC 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

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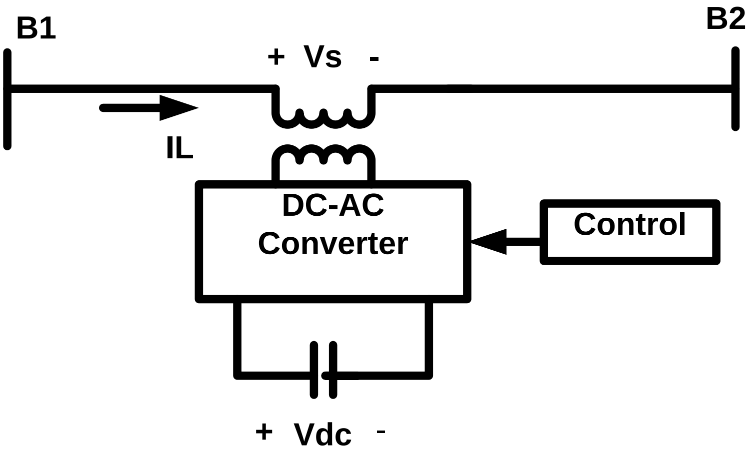


Figure 3.Simplified Diagram of SSSC

has a net effect of reducing the line inductance. SSSC injects a quadrature voltage, ***V_s*.,** in proportion to the line current but is lagging in phase [1]

$$V_s = -jkXI_L \quad \ldots\ldots\ldots\ldots\ldots(1)$$

3.2. Controller of SSSC

The control system consists of a phase-locked loop (PLL) which synchronizes on the positive-sequence component of the current I. The output of the PLL (angle T=w t) is used to compute the direct-axis and quadrature-axis components of the AC three-phase voltages and currents (labeled as Vd, Vq or Id, Iq on the diagram).Measurement systems measuring the q components of AC positive-sequence of voltages V1 and V2 (V1q and V2q) as well as the DC voltage Vdc .

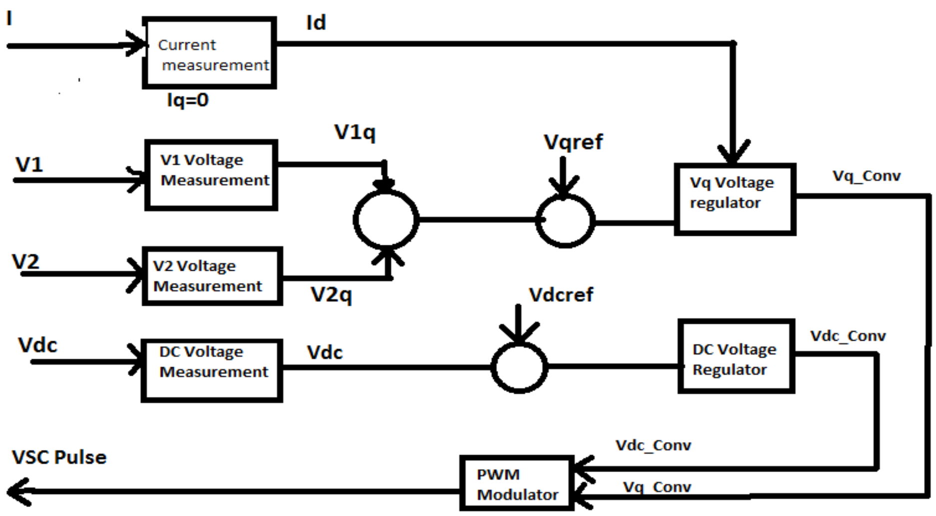


Figure 4 .Simplified Diagram of SSSC Controller

AC and DC voltage regulators which compute the two components of the converter voltage (Vd_conv and Vq_conv) required to obtain the desired DC voltage (Vdcref) and the injected voltage (Vqref). Fig.4 represents that control concept[8]. The Vq voltage regulator is assisted by a feed forward type regulator which predicts the V_conv voltage from the Id current measurement.

IV. TEST SYSTEM DESCRIPSION

The power grid shown in figure 5 consists of two power generation substations and one major load center at bus B3. The first power generation substation (M1) has a rating of 2100 MVA, representing 6 machines of 350 MVA and the other one (M2) has a rating of 1400 MVA, representing 4 machines of 350 MVA. The load center of approximately 2200 MW is modeled using a dynamic load model where the active & reactive power absorbed by the load is a function of the system voltage. The generation substation M1 is connected to this load by two transmission lines L1 and L2. L1 is 280-km long and L2 is split in two segments of 150 km in order to simulate a three-phase fault at the midpoint of the line. The generation substation M2 is also connected to the load by 50-km line (L3) When the SSSC is bypass, the power flow towards this major load is as follows: 664 MW flow on L1, 563 MW flow on L2 and 990 MW flow on L3. The SSSC, located at bus B2, is in series with line L1. It has a rating of 100MVA and is capable of injecting up to 10% of the nominal system voltage.

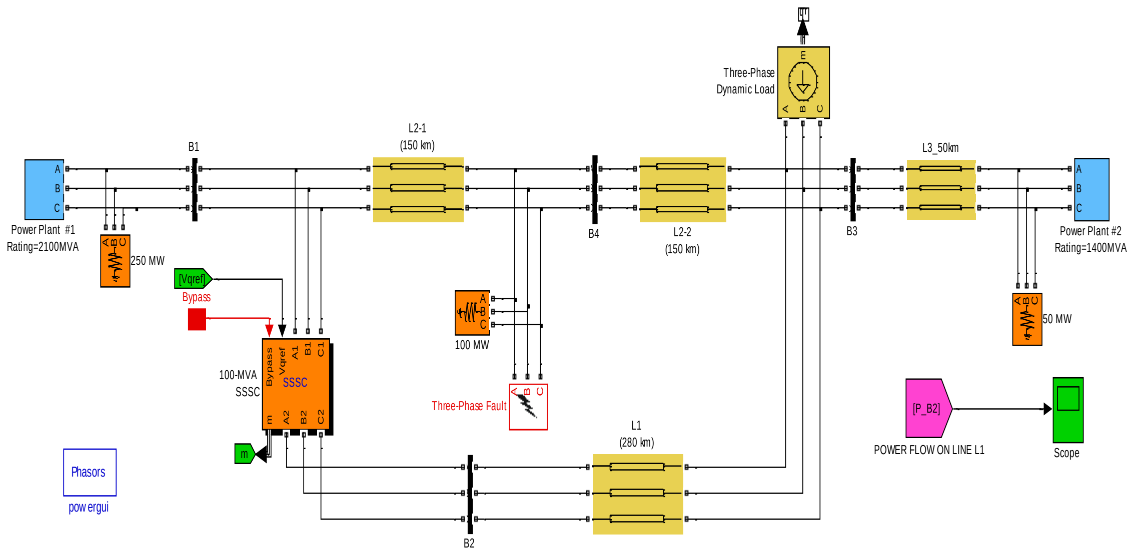


Figure5.Simulink model of two area power system

V. SIMULATION RESULTS

Simulation results obtained for selected bus-2 power for 1-phase, 2-phase and 3-phase fault with and without SSSC in a two area power system model showen in figure[6-11].

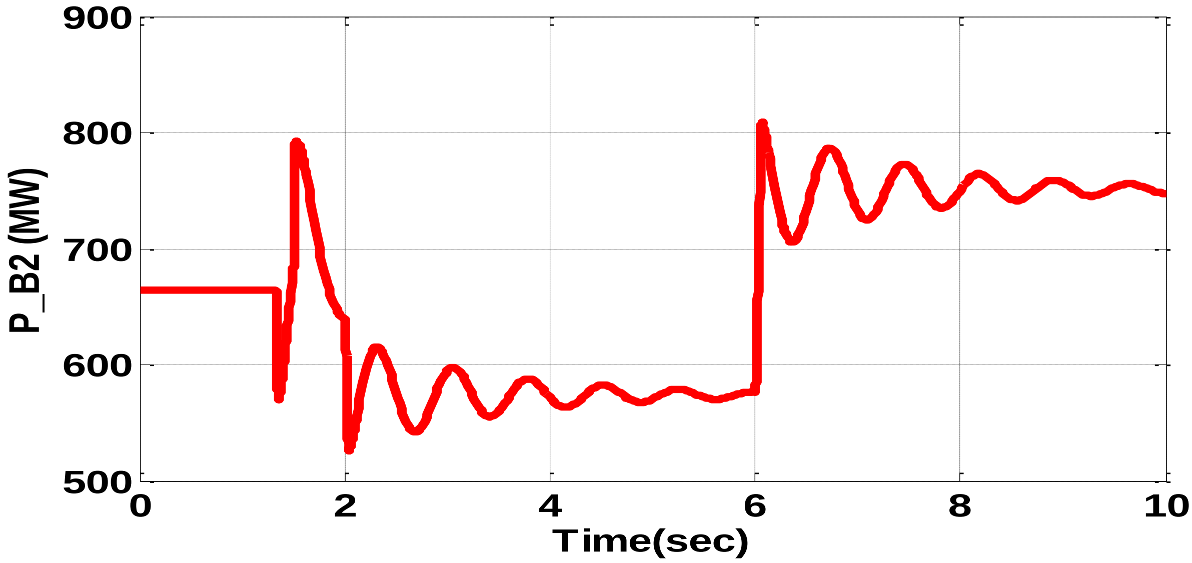


Figure 6. 1-Phase Fault Without SSSC

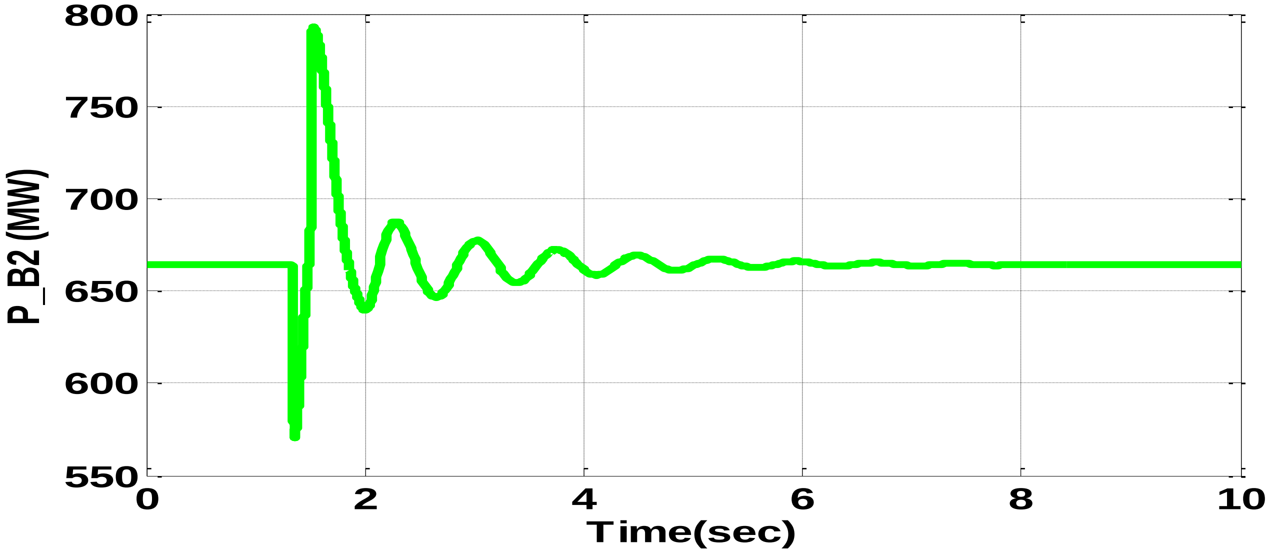


Figure 7. 1-Phase Fault With SSSC

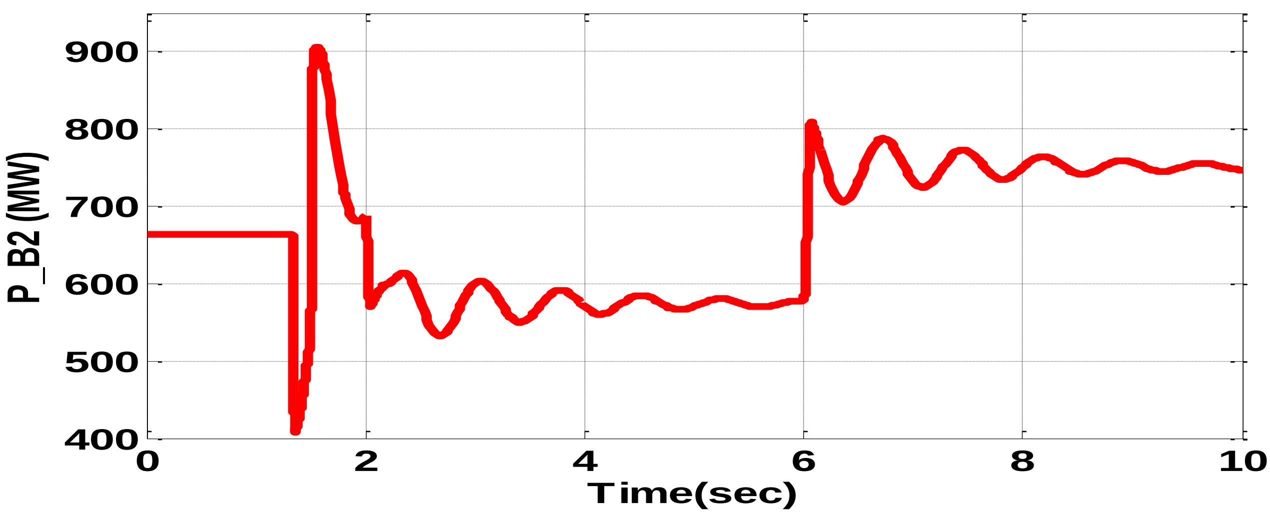


Figure 8. 2-Phase Fault Without SSSC

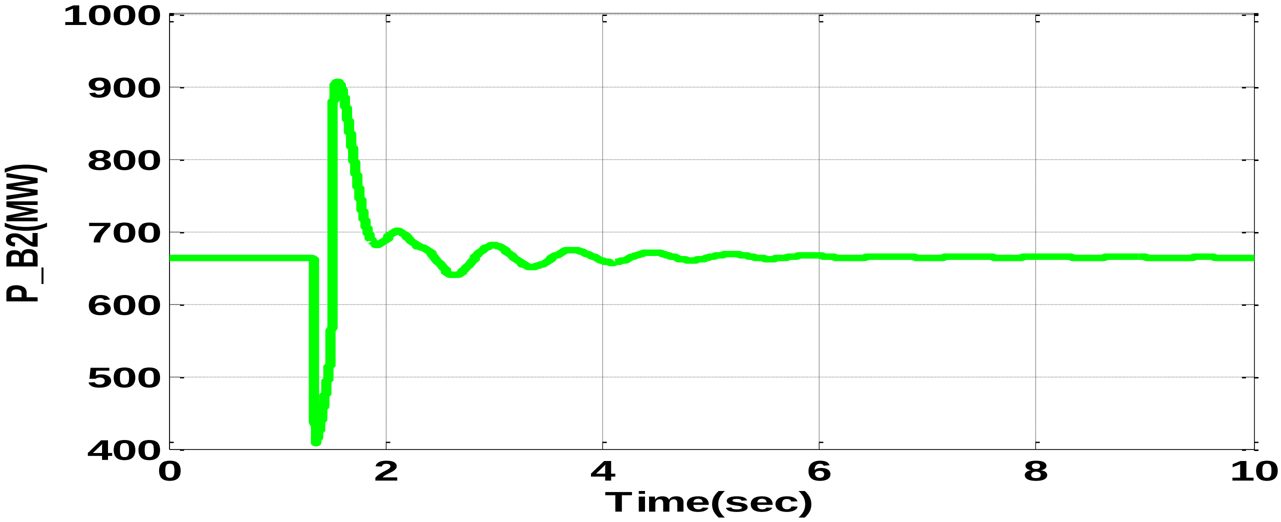


Figure 9. 2-Phase Fault With SSSC

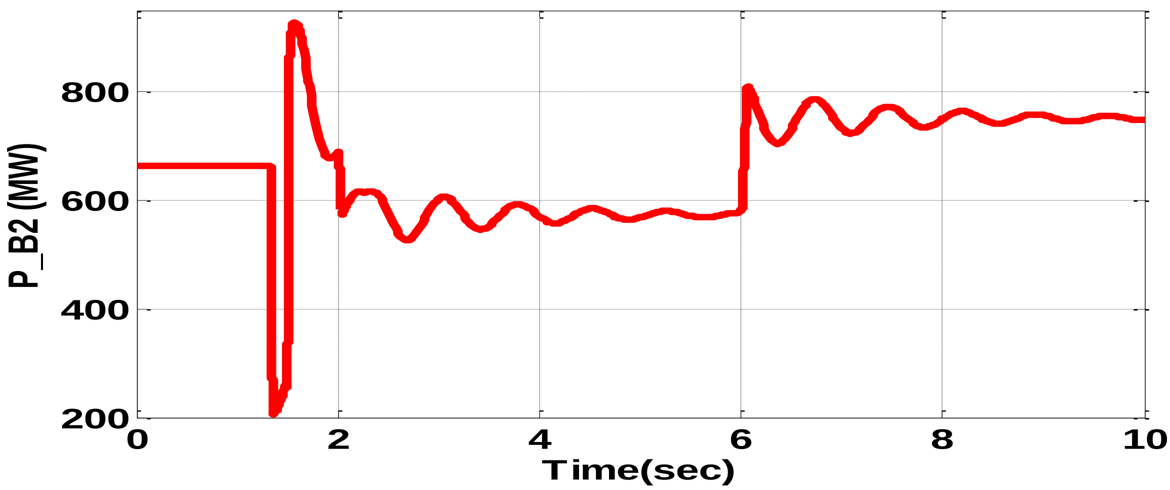
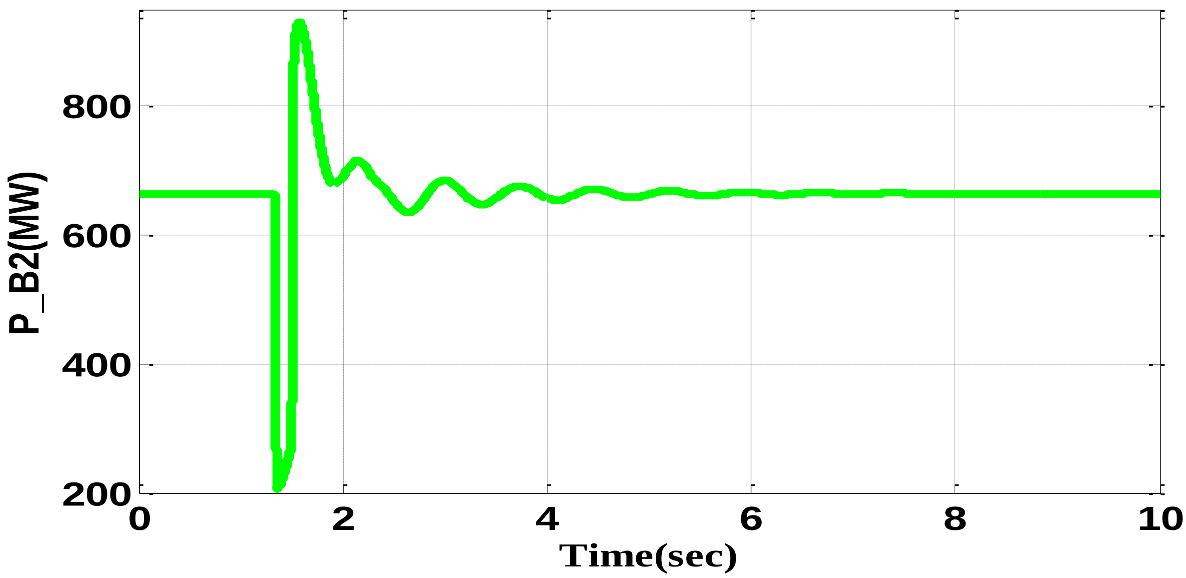


Figure10. 3-Phase Fault Without SSSC



Figur10. 3-Phase Fault With SSSC

VI.CONCLUSION

The result shows that the power system oscillations are damped out very quickly with the help of SSSC in few seconds. SSSC improve dynamic response and at the same time faster then other conventional controllers 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, the SSSC is used to damp power oscillation on a power grid following a single-phase,two phase and three-phase fault.

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