IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

POWER SYSTEM STABILITY ENHANCEMENT USING STATIC SYNCHRONOUS SERIES COMPENSATOR

[1]Kandakatla Prashanth Reddy, [2]Banala Jayanthi, [3]Aluri Rakesh Reddy, [4]Bingi Rahul, [5]Dr. P. Duraipandy
[1]Student, [2]Student, [3]Student, [4]student, [5]Associate Professor.
[1]Electrical and Electronics Engineering,
[1]JB INSTITUTE OF ENGINEERING AND TECHNOLOGY,
(Affiliated to Jawaharlal Nehru Technological University, Hyderabad, Telangana), India.

Abstract:

A power system is becoming more complex and heavily loaded day by day. Earlier electric power systems were small and localized. Thus, real and reactive power compensation in transmission line is essential which will improve the stability of ac system. Flexible alternating current transmission system (FACTS) technology provides new opportunity to control the power and enhancing the capacity of the present as well as new line sit is used to investigate the effect of this device in controlling active and reactive powers as well as damping power system oscillations in transient mode. A transmission line needs regulation. This can be achieved by FACTS controllers. The employed compensators are three phase (IGBT) based, PWM operated converter (VSC). The proposed control employs proportional integral controller to generate a constant error

***Index Terms* – SSSC, POD Controller, Voltage Source Inverter, Transformer, Matlab**

I. INTRODUCTION

Electrical energy transmission and utilization is facing a set of challenges. Numerous changes are introduced continuously in the electrical utility industry due to its ever growing and ongoing expansion. Due to this, transmission systems are pushed closer to their stability and thermal limits. But the quality of power delivered is more important. Also, the transmission systems have many forms of limitations, involving power transfer between areas, also referred as transmission bottlenecks, or within a single area or region. The following are some of the limitations in a transmission lines :

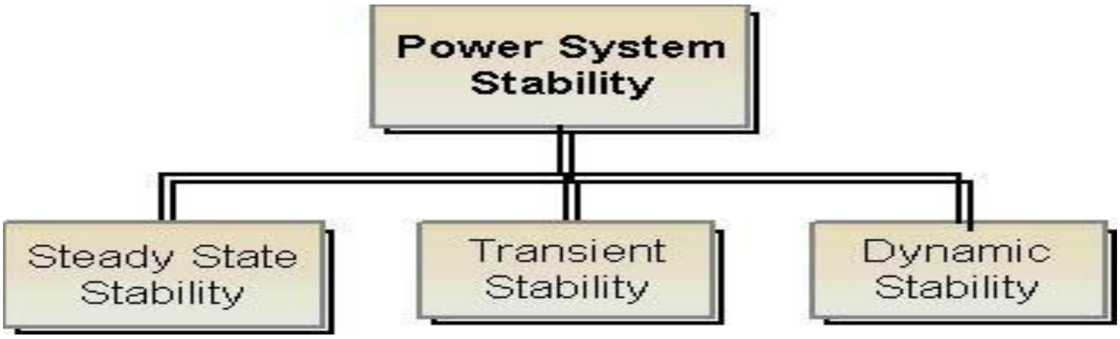
- Steady state power transfer limit
- Voltage stability limit
- Dynamic voltage limit
- Transient stability limit
- Power system oscillation damping limit
- Thermal limit
- Short circuit current limit

The developing countries are experiencing a rapid growth. Hence, the pressure on the transmission networks is higher. We have to transfer as much power as possible on each existing line, delay the installation of new lines and/or controllably transfer power on selected lines to release capacity as well as cut down circulating power freeing up lines for added export out of the region. When addition of new lines is planned, in addition to the cost, environmental considerations and the public concerns delay the securing of new rights-of-way

The first electric power system was a dc system built by Edison in 1882. The subsequent power systems that were constructed in the late 19th century were all dc systems. However despite the initial popularity of dc systems by the turn of the 20th century ac systems started to outnumber them. The ac systems were though to be superior as ac machines were cheaper than their dc counterparts and more importantly ac voltages are easily transformable from one level to other using transformers. The early stability problems of ac systems were experienced in 1920 when insufficient damping caused spontaneous oscillations or hunting. These problems were solved using generator damper winding and the use of turbine-type prime movers.

II. Power system stability

The stability of a system refers to the ability of a system to return back to its steady state when subjected to a disturbance. As mentioned before, power is generated by synchronous generators that operate in synchronism with the rest of the system. A generator is synchronized with a bus when both of them have same frequency, voltage and phase sequence. We can thus define the power system stability as the ability of the power system to return to steady state without losing synchronism. Usually power system stability is categorized into **Steady State**, **Transient** and **Dynamic Stability.**



Stability of the system

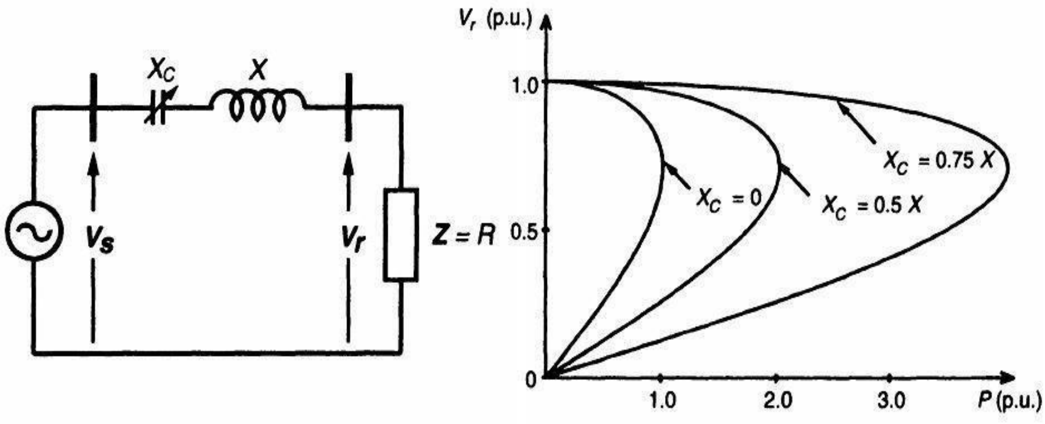
Steady State Stability studies are restricted to small and gradual changes in the system operating conditions. In this we basically concentrate on restricting the bus voltages close to their nominal values. We also ensure that phase angles between two buses are not too large and check for the overloading of the power equipment and transmission lines. These checks are usually done using power flow studies.

Transient Stability involves the study of the power system following a major disturbance. Following a large disturbance the synchronous alternator the machine power (load) angle changes due to sudden acceleration of the rotor shaft. The objective of the transient stability study is to ascertain whether the load angle returns to a steady value following the clearance of the disturbance. The ability of a power system to maintain stability under continuous small disturbances.

III. Voltage stability

Series capacitive compensation reduces the series reactive impedance to minimize the receiving end voltage variation and the possibility of voltage collapse. Figure shows a simple radial system with feeder line reactance X, series compensating reactance Xc and load impedance Z. The corresponding normalized terminal voltage Vr versus power P plots, with unity power factor load and 0, 50, and 75% series capacitive compensation, are shown in Figure .

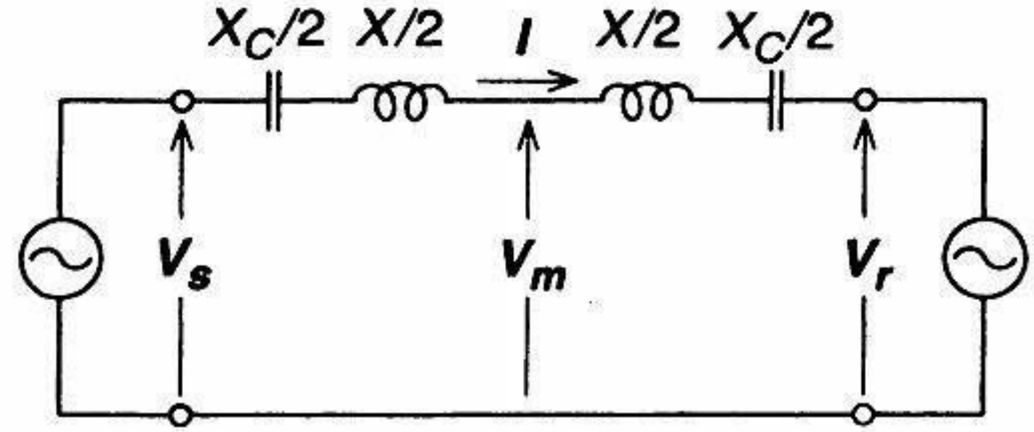
The "nose point" at each plot for a specific compensation level represents the corresponding voltage instability. So by cancelling a portion of the line reactance, a "stiff" voltage source for the load is given by the compensator.



Transmittable power and voltage stability limit of a radial transmission line as a function of series capacitive compensation

IV. Transient stability enhancement

The transient stability limit is increased with series compensation. The equal area criterion is used to investigate the capability of the ideal series compensator to improve the transient stability.



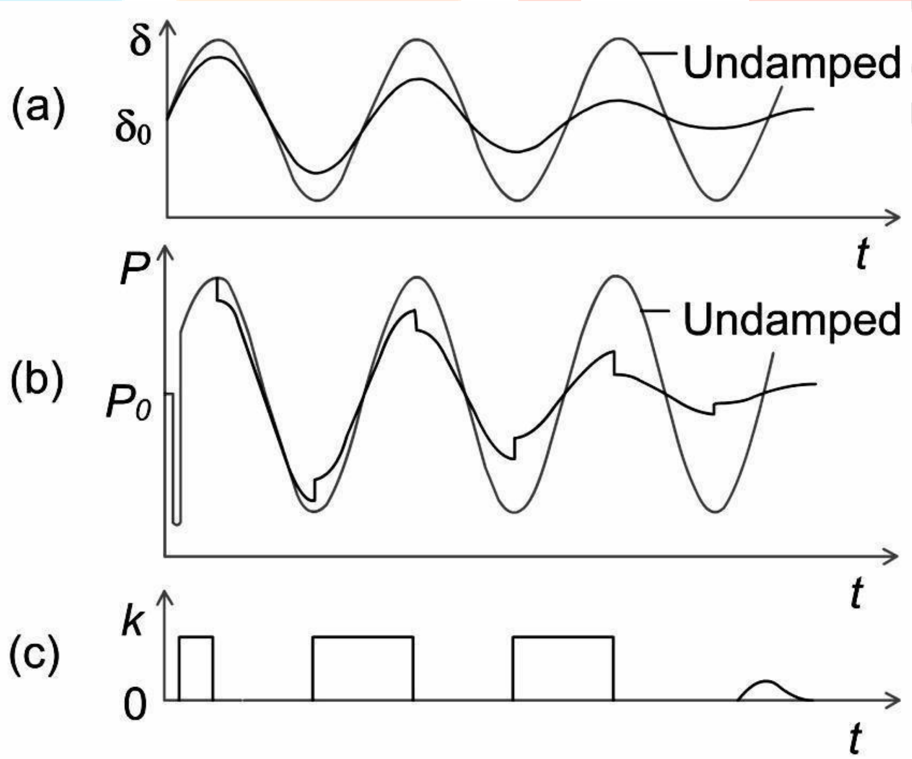
Two machine system with series capacitive compensation

Figure shows the simple system with the series compensated line. Assumptions that are made here are as follows:

- The pre-fault and post-fault systems remain the same for the series compensated system.
- The system, with and without series capacitive compensation, transmits the same power Pm.
- Both the uncompensated and the series compensated systems are subjected to the same fault for the same period of time.

V. Power oscillation damping

Power oscillations are damped out effectively with controlled series compensation. The degree of compensation is varied to counteract the accelerating and decelerating swings of the disturbed machine(s) for damping out power oscillations. When the rotationally oscillating generator accelerates and angle δ increases ($d\delta/dt > 0$), the electric power transmitted must be increased to compensate for the excess mechanical input power and conversely, when the generator decelerates and angle δ decreases ($d\delta/dt < 0$), the electric power must be decreased to balance the insufficient mechanical input power.



Waveforms illustrating power oscillation damping by controllable series compensation (a) generator angle (b) transmitted power and (c) degree of series compensation

Figure shows the waveforms describing the power oscillation damping by controllable series compensation. Waveforms in figure (a) show the undamped and damped oscillations of angle δ around the steady state value δ0. The corresponding undamped and damped oscillations of the electric power P around the steady state value P0, following an assumed fault (sudden drop in P) that initiated the oscillation are shown by the waveforms in figure (b). Waveform (c) shows the applied variation of the degree of series compensation, k applied.

'k' is maximum when $d\delta/dt > 0$, and it is zero when$d\delta/dt < 0$.

VI. DEFINITION OF FACTS AND ITS TYPES

According to IEEE, FACTS, is defined as "alternating current transmission systems which incorporate power electronics based and other static controllers to enhance controllability and power transfer capability" (Hingorani and Gyugyi 2000). High power electronic devices play an important role in improving grid reliability with the use of energy storage systems, FACTS, distributed energy, and HVDC. The challenge facing the power system engineer today is the usage of existing transmission facilities to a greater effect and efficiency which is very effectively obtained through FACTS technology. FACTS provide proven technical solutions to address new operating challenges which are presented today. The applications of FACTS devices in power systems are in the areas of power flow control, system stability and security enhancement, improving efficiency, power quality and protection. Figure 1.4 (a) shows the general symbol of FACTS controller. In general, FACTS devices can be divided into four categories:

- Series FACTS devices
- Shunt FACTS devices
- Combined Series-Series FACTS devices
- Combined Series-Shunt FACTS devices.

SERIES FACTS DEVICES

Series FACTS devices could be variable impedance, such as capacitor, reactor, etc., or power electronics based variable source of main frequency, subsynchronous and harmonic frequencies (or a combination) to serve the desired need. In principle, all series FACTS devices inject voltage in series with the transmission line. Figure 1.4 (b) shows the symbol of series FACTS devices.

SHUNT FACTS DEVICES

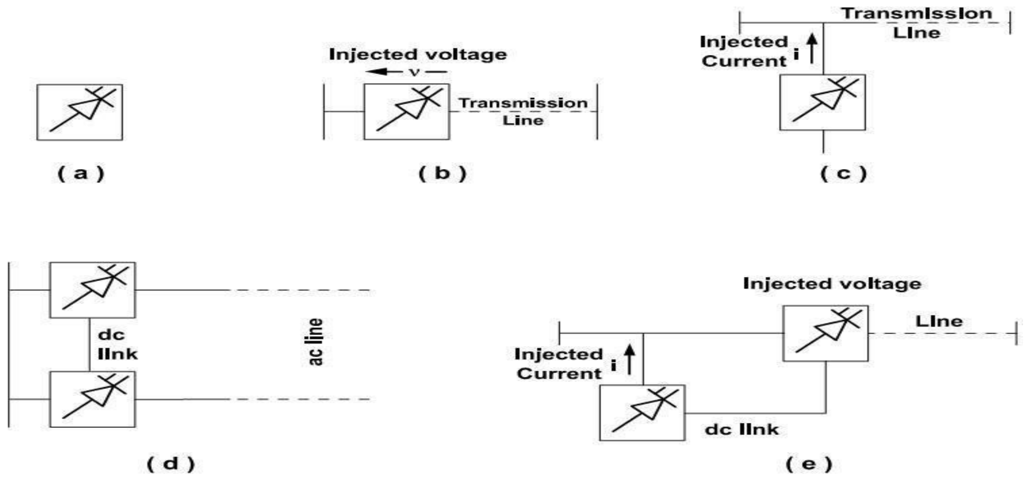
Shunt FACTS devices may be variable impedance, variable source, or a combination of these. They inject current into the system at the point of connection.

COMBINED SERIES-SERIES FACTS DEVICES

Combined series-series FACTS device is a combination of separate series FACTS devices, which are controlled in a coordinated manner in a multi-line transmission system. Figure 1.4 (d) shows the symbol of series series FACTS devices. The interline power flow controller (IPFC) is an example for this type. It balances both the real and reactive power flow in the lines and maximizes the utilization of transmission system (Hingorani and Gyugyi, 2000).

COMBINED SERIES-SHUNT FACTS DEVICES

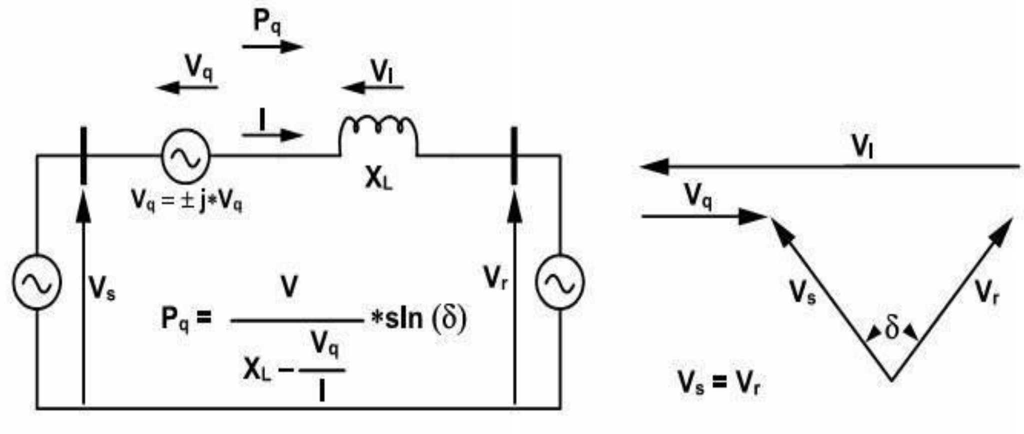
Combined series-shunt FACTS device is a combination of separate shunt and series devices, which are controlled in a coordinated manner or one device with series and shunt elements. Figure 1.4 (e) shows the symbol of series-shunt FACTS device - the Unified power flow controller (UPFC) (Hingorani and Gyugyi, 2000).



Basic types of FACT controllers
(a) General symbol of fact controller (b) Series Controller (c) Shunt Controller (d) Series-Series Controller (e) Series-Shunt Controller.

VII. STATIC SYNCHRONOUS SERIES COMPENSATOR(SSSC)

The Voltage Sourced Converter (VSC) based series compensators -Static Synchronous Series Compensator (SSSC) was proposed by Gyugyi in 1989. The single line diagram of a two machine system with SSSC is shown in Figure . The SSSC injects a compensating voltage in series with the line irrespective of the line current.

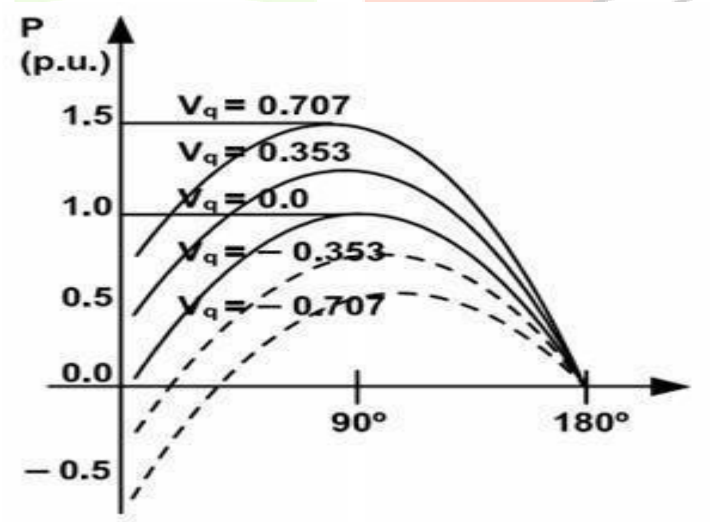


Simplified diagram of series compensation with the phasor diagram.

From the phasor diagram, it can be stated that at a given line current, the voltage injected by the SSSC forces the opposite polarity voltage across the series line reactance. It works by increasing the voltage across the transmission line and thus increases the corresponding line current and transmitted power.

The compensating reactance is defined to be negative when the SSSC is operated in an inductive mode and positive when operated in capacitive mode. The voltage source converter can be controlled in such a way that the output voltage can either lead or lag the line current by 90o. During normal capacitive compensation, the output voltage lags the line current by 90o. The SSSC can increase or decrease the power flow to the same degree in either direction simply by changing the polarity of the injected ac voltage. The reversed (180o) phase shifted voltage adds directly to the reactive voltage drop of the line. The reactive line impedance appears as if it were increased. If the amplitude of the reversed polarity voltage is large enough, the power flow will be reversed. The transmitted power verses transmitted phase angle relationship is shown in Equation and the transmitted power verses transmitted angle as a function of the degree of series compensation is shown in Figure

$$P = \frac{V^2}{X}\sin\delta + \frac{V}{X}V_q\cos\frac{\delta}{2}$$



Transmitted power verses transmitted angle as a function of series compensation

VIII. POWER OSCILLATION DAMPING CONTROLLER

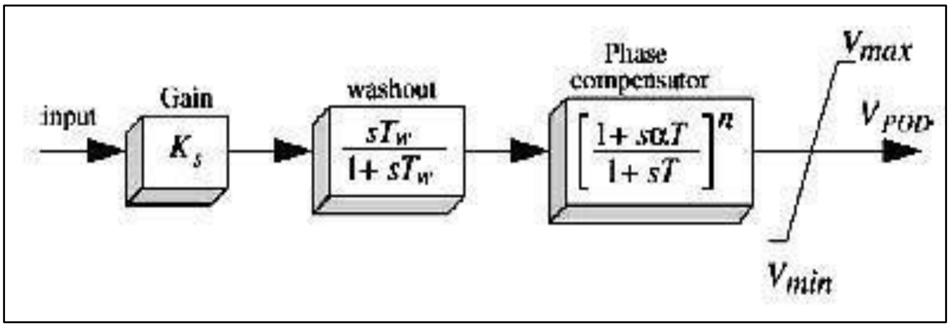


Figure 4.1 POD controller

SSSC can be used forping power oscillation and so enhance the overall dynamic performance of the system. POD consists of the three blocks.

1)wash out filter blocks. 2)phase compensator block 3) gain block.

The washout filter block is used to avoid a POD response to the steady-state changes of the input signal. Phase compensator block provides the appropriate phase lag/lead characteristics and stabilizer gain Ks determine the amount of damping introduced by POD.

The selection of an appropriate input signal is a fundamental issue in the design of an effective and robust POD controller. Locally measurable signals are always preferred as input signal.

Signal such line active power, line reactive power, line current magnitude, bus voltage magnitude and angles are considered in the selection of input signals for the POD controller in this paper bus voltage and bus current are considered for input sign.

A number of design methods may be used for POD parameter tuning The most popular ones are based on frequency response eigenvalue sensitivities as well as a combination of these methodologies.

The phase parameters of the phase compensator block are computed as

$$T = \frac{1}{\omega_n \sqrt{\alpha}}$$

$$\alpha = \frac{1 - \sin(\varphi/n)}{1 + \sin(\varphi/n)}$$

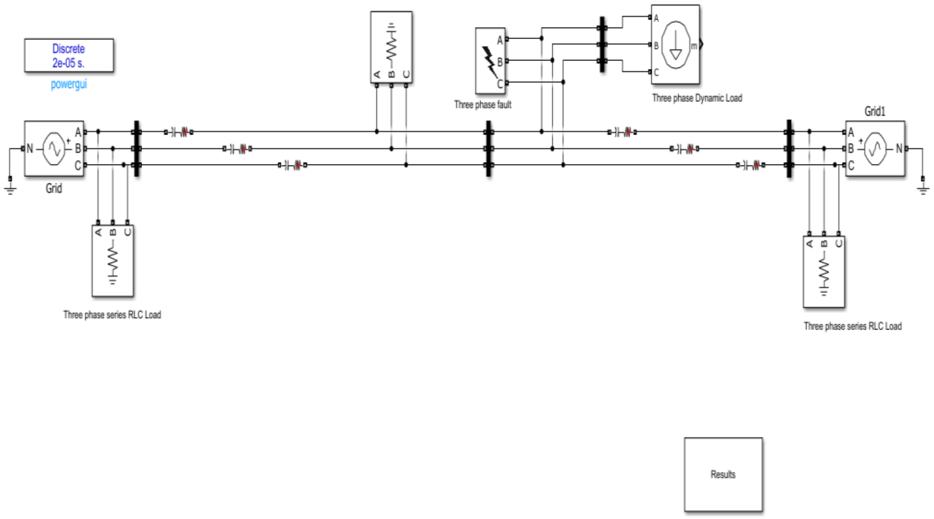
Where φ the phase to be compensated, ωn is the frequency of the mode to damp and *n* the number of lead-lag networks usually 10% damping ratio is considered to be enough.

IX. MATLAB

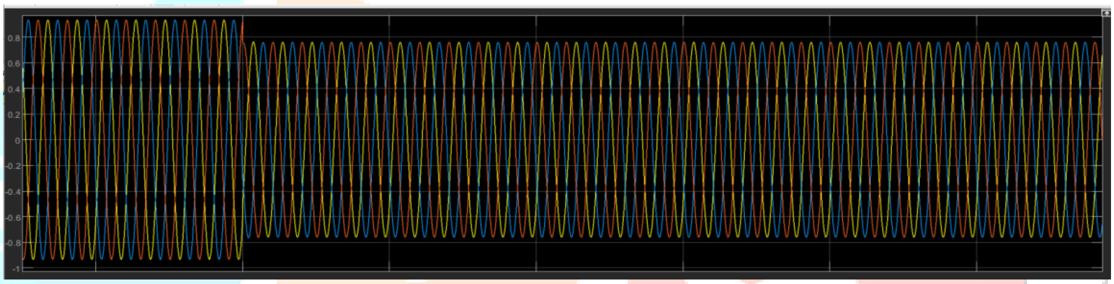
Matlab is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical uses include Math and computation Algorithm development Data acquisition Modeling, simulation, and prototyping Data analysis, exploration, and visualization Scientific and engineering graphics Application development, including graphical user interface building. Matlab is an interactive system whose basic data element is an array that does not require dimensioning. This allows you to solve many technical computing problems, especially those with matrix and vector formulations, in a fraction of the time it would take to write a program in a scalar no interactive language such as C or Fortran.

X. SIMULATION

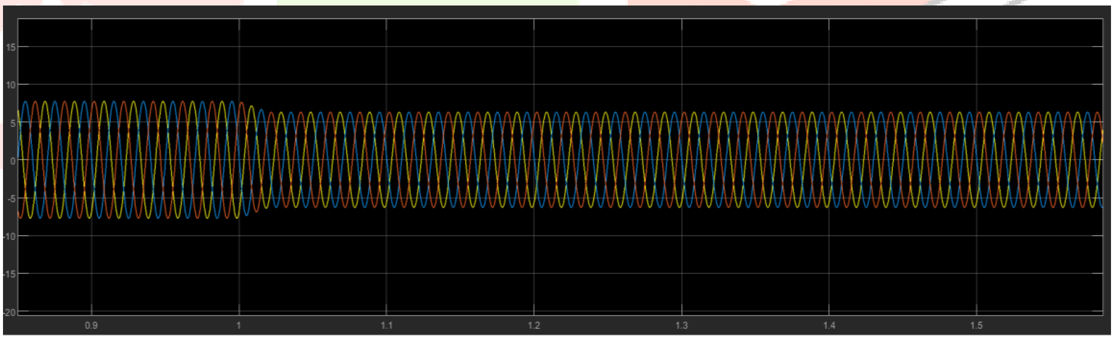
10.1. SIMULATION DIAGRAM OF SINGLE AREA SYSTEM WITHOUT SSSC



Block diagram with out SSSC



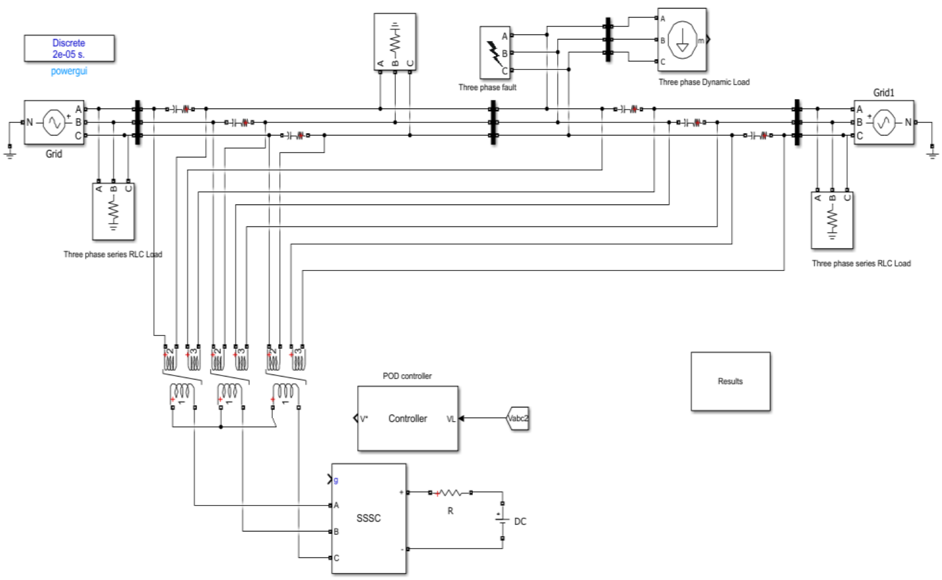
voltage waveform without the installation of SSSC

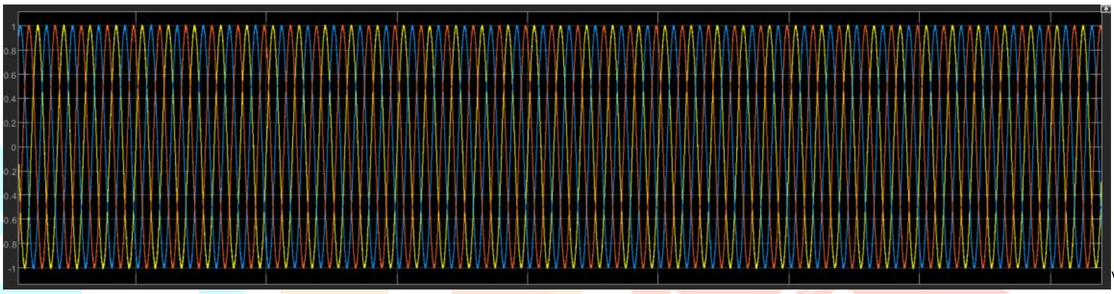


current waveforms without the installation of SSSC

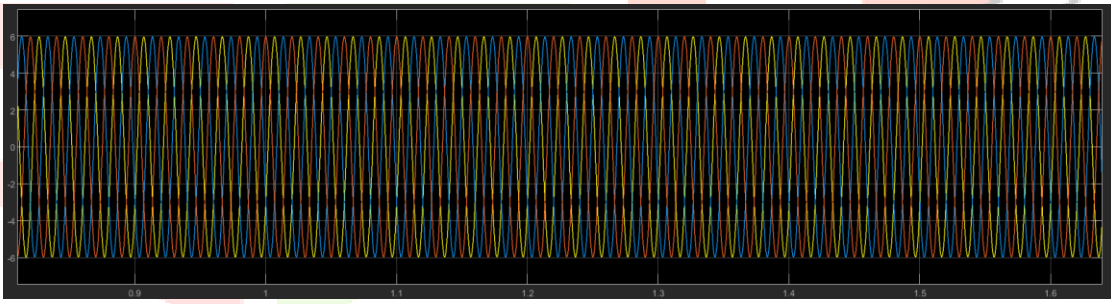
active and reactive powers without the installation of SSSC

10.2. BLOCK DIAGRAM OF SINGLE AREA SYSTEM WITH SSSC

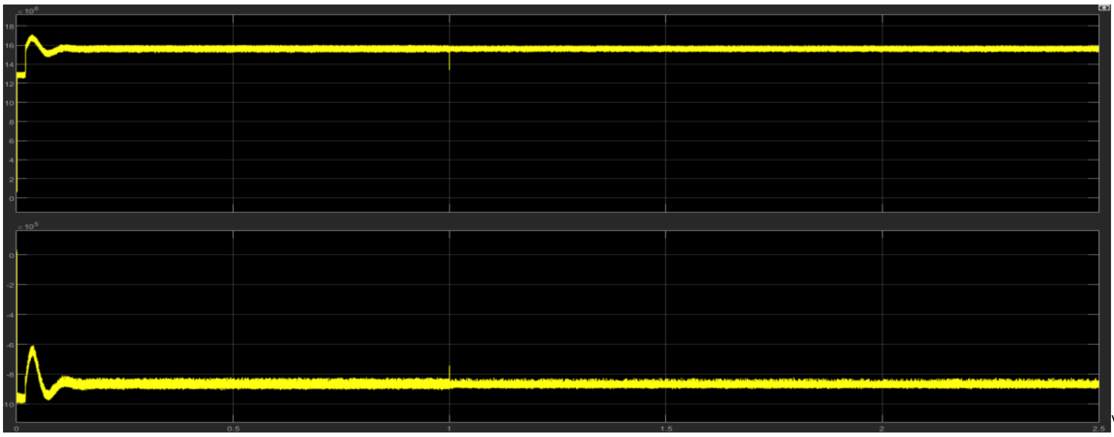




voltage waveform with the installation of SSSC and POD Controller



current waveform with the installation of SSSC and POD Controller



Active and reactive powers with the installation of SSSC and POD Controller

10.3 OBSERVATION

S.NO	TYPE OF FAULT	WITHOUT SSSC				WITH SSSC			
		V (pu)	I (pu)	P (pu)	Q (pu)	V (pu)	I (pu)	P (pu)	Q (pu)
1	LG	0.38	12.7	4.5	8.2	1	6.8	10	-1.8
2	LL	0.39	12.8	4.8	9.1	1	6.8	10	-1.8

XI. Simulation

The onset of series connected FACTS controller like SSSC has made it possible not only to regulate power flow in critical lines. SSSC has reactive voltage control which can inject controllable reactive voltage in quadrant with the line current, emulating either inductive or capacitive reactance in series with transmission line. The operation of SSSC model is verified by connecting it in series with the transmission line SSSC has been studied on two machine power system and connected at bus-2. Thus SSSC can be effectively used to damp oscillations on power transmission system with and without fault .It can also able to control power flow at particular or desired point. It has been found that the SSSC is capable of controlling the flow of power at desired point on transmission line. It 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.

XII. Simulation

Based on obtained simulation results the performance of the SSSC has been examined in a two machine system simply on the selected bus-2,and applications of the SSSC will be exteneded in future to a complex and multimachine system to investigate the problems related to the various modes of power oscillation in the power systems.

XIII. Reference

- Sen, K.K. (1998). “SSSC-static ynchronous series compensator ,theory,modelling and publications.” IEEE Trans. Power Delivery.Vol.13,No.1,PP.241-246.
- B.N.Singh, A.Chandra, K.Al-Haddad and B.Singh, “Performance of slidingmode and fuzzy controllers for a static synchronous series compensator, “IEE Proceedings onhe no. 19990072, IEE, 1999.
- F. Wang, “Design of SSSC Damping Controller to Improve Power System Oscillation Stability, “0-7803-5546-6/99/$10.00 © 1999 IEEE.
- Muhammad Harunur Rashid, “Power Electronics – Circuits, Devices, and Applications, “PRENTICE HALL, Englewood Cliffs, New Jersey.07632, 1988.
- L. Gyugyi, 1994, “Dynamic Compensation of AC Transmission Line by Solid State Synchronous Voltage Sources,” IEEE Transactions on Power Delivery, 9(22), pp. 904-911.