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The Study of Voltage Profile and Power Quality with SVC in Transmission System at Different Loads

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Abstract

This paper illustrates the effect of different static load models on the optimal location of Static Var Compensator (SVC). Six static load types in which active and reactive powers vary with the voltage as an exponential form. In case our study, each load is modeled as a stair-case dynamic load (SCDLM), in which active and reactive powers are varied at a chosen time around the base value with desired step size and realized by simultaneous switching of static loads Modeling and simulation of the system are performed using MATLAB Sim Power Systems Block sets. PI controllers are used to control SVC firing angles. The studied power system is a simple five-bus system.

Keywords: SVC, load models, location of SVCs, voltage control.

I. Introduction

Most of the world electric power systems are widely interconnected to reduce cost of the electricity and to improve the reliability of power supply. It is ideal to locate the generators at load centers. Because of economical and environmental reasons, the generating stations are usually located at remote locations. The Inter connection of generating stations and utilities improve the reliability with minimum generation resources. If the transmission capability is less, then more generation would be required to serve the same load with same reliability. Hence the cost of electricity would be higher.

The power system is a complex network consisting of synchronous generations, transmission lines, loads, etc. As the power system grows it becomes more complex to operate the system and can become less secure for riding through the major outages. The power that can be transmitted over a line depends on series reactance of the line, bus voltages and transmission angle (δ). The voltage profile along the line can be controlled by reactive shunt compensation [1]. The series line inductive reactance can be controlled by series capacitive compensation.

SVC is modeled as a fixed shunt capacitor and connected to different load buses in a five bus system to show the effect of different location of this device on system voltage profile for different static load types. Six static load types in which active and reactive powers vary with the voltage as an exponential form are used to show the effect of voltage dependent load models on voltage profile and location of the SVC in power systems [7]. In case our study, each load is modeled as a stair-case dynamic load (SCDLM), in which active and reactive powers are varied at a chosen time around the base value with desired step size and realized by simultaneous switching of static loads. To keep the bus voltages at the desired level and to show the capability of the SVC on voltage control, the load voltages are controlled by using SVC controller. From the simulation results, it is obtained that bus voltages for different load models have approximately the same variation with the different location of the SVC for different static load models and the optimal location of the SVC doesn’t depend on the load models.

The area of voltage stability and control for power systems has yielded an extensive and diverse array of analytical contributions [3]. It is now well-accepted that the basic problem is under influence of static and dynamic aspects of system equipments. The voltage stability and control are dynamic phenomenon. Accordingly, these lead to dynamic modeling and formulation of the system. Consequently one of the most important issue states itself as the modeling requirement, and adequacy of the various system components.

The SVCs are generally used as load balancing and power factor correcting devices by adjusting the susceptance in each phase by controlling the conducting angles of the TCR. SVC is basically a shunt connected static var generator/load whose output is adjusted to exchange capacitive or inductive current. So the SVC maintains or controls the specific power system variables typically, the controlled variable is the bus voltage.

FACTS technology opens up new opportunities for controlling power and enhances the usable capacity of the present transmission system for transmission planners. The opportunities arise through the ability of FACTS controllers to control the inter – related parameters that govern the operation of transmission systems including series impedance, shunt, impedance, current, phase angle and damping of oscillations at various frequencies below the rated frequency. These constraints cannot be overcome otherwise, while maintaining the required system stability, by mechanical means without lowering the useable transmission capacity. By providing added flexibility, FACTS controllers can enable a line to carry power close to its thermal rating. Mechanical switching needs to be supplemented by rapid power electronic devices.

Static var compensators control only one of the three important parameters (voltage, impedance, phase angle) that determine the power flow in the AC power system [3-7]. It has been realized that static var compensator, which is true equivalent of ideal synchronous condenser, is technically feasible with the use of gate turn – off (GTO) thyristor. The UPFC is a recently introduced FACTS controller which has the capability to control all the three transmission parameters (voltage, impedance, phase angle) [1]. The UPFC not only performs the functions of the STATCON, TCSC, and the phase angle regulator but also provides additional flexibility by combining some of the functions of the controllers.

Simplified expression for power flow in a loss less transmission line is given by

$$P = \frac{V_s V_r}{X} Sin\,(\delta + \Phi) \quad \text{---------} \ (1)$$

δ - Difference in bus angles

Φ - Phase angle shift introduced by phase shifting transformer.

The power expression shows that the control of voltage, series reactance and phase angle Φ has effect on the power flow.

Possibilities of power flow

$$P = \frac{V_s V_r}{X} \sin\delta \quad \text{---------------} \ (2)$$

Control of the line impedance X (e.g. with a thyristor controlled series capacitor) can provide a powerful means of current control.

II. Voltage control

The power / current can also be controlled by regulating the magnitude of voltage of sending end or receiving end. But the regulation of the magnitude of the voltage of sending end or receiving end is much more influenced over the reactive power flow than the active power flow. It was observed that varying the amplitude of the injected voltage in series, both the active and reactive current flow can be influenced. Voltage injection methods form the most important portfolio of voltage controllers.

TABLE 1: FACTS controllers by its function and type

NAME	TYPE	MAIN FUNCTION	CONTROLLER USED	COMMENT
SVC	Shunt	Voltage control	Thyristor	Variable impedance device
STATCOM	Shunt	Voltage control	GTO,IGBT or MCT	Variable voltage source
TCSC	Series	Power flow control	Thyristor	Variable impedance device
TCPAR	Series and shunt	Power flow control	Thyristor	Phase control using series (quadrature) voltage injection
SSSC	Series	Power flow control	GTO,IGBT or MCT	Variable voltage source
UPFC	Shunt and series	Voltage and power flow control	GTO,IGBT or MCT	Variable voltage source
IPFC	Series and series	Power flow controller	GTO,IGBT or MCT	Variable voltage source

2.2. Impedance control

FACTS controllers modify the series and parallel impedances of transmission lines. The way a FACTS controller is connected to the ac power system has a direct effect on the transfer of active and reactive power within the system. Series connected controllers are usually employed in active power control and to improve the transient stability of power systems. Shunt connected controllers govern reactive power and improve the dynamic stability

2.3. Transmission angle control

Control of transmission angle, which in turn controls the driving voltage, provides a powerful means of controlling the current flow and hence active power flow when the angle is not large. For relatively small angular adjustments, the resultant angular change is approximately proportional to the injected voltage, while the voltage magnitude remains almost constant.

2.4. Real power control

In many ways real power can be controlled. Control of line impedance X can provide a powerful means of current control which in turn gives active power control. Control of transmission angle ä, which in turn controls the driving voltage, provides a powerful means of controlling the current flow and hence active power flow when the angle is not large.

2.5. Reactive power control

Injecting voltage in series with the line and with any phase angle with respect to the driving voltage can control the magnitude and phase of the line current. This means injecting a voltage phasor with variable phase angle can provide a powerful means of precisely controlling the reactive power(as well as active power) flow. Combination of the line impedance control with a series controller and voltage regulation with a shunt controller provides a cost effective means to control both the active and reactive power flow between the two systems.

III. SVC USING A TCR AND TSC

This compensator overcomes two major shortcomings of the earlier compensators by reducing losses under operating conditions and better performance under large system disturbances. In view of the smaller rating of each capacitor bank, the rating of the reactor bank will be 1/n times the maximum output of the SVC, thus reducing the harmonics generated by the reactor. In those situations where harmonics have to be reduced further, a small amount of FCs tuned as filters may be connected in parallel with the TCR.

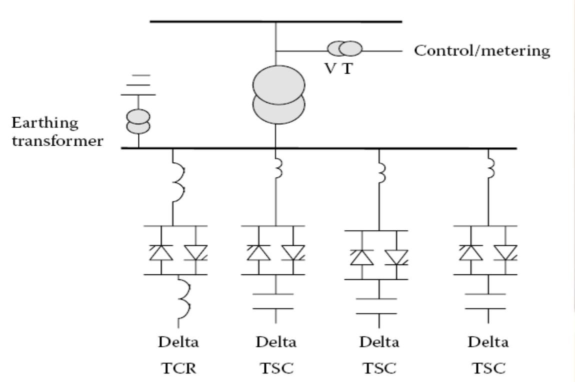

Fig.3.1. SVC using a TCR and TSC

3.2. SVC of combined TSC and TCR type

When large disturbances occur in a power system due to load rejection, there is a possibility for large voltage transients because of oscillatory interaction between system and the SVC capacitor bank or the parallel. The LC circuit of the SVC in the FC compensator.

In the TSC–TCR scheme, due to the flexibility of rapid switching of capacitor banks without appreciable disturbance to the power system, oscillations can be avoided, and hence the transients in the system can also be avoided. The capital cost of this SVC is higher than that of the earlier one due to the increased number of capacitor switches and increased control complexity [7].

SVC installations consist of a number of building blocks. The most important is the Thyristor valve, i.e. stack assemblies of series connected anti-parallel Thyristors to provide controllability. Air core reactors and high voltage AC capacitors are the reactive power elements used together with the Thyristor valves. The step up connection of this equipment to the transmission voltage is achieved through a power transformer.

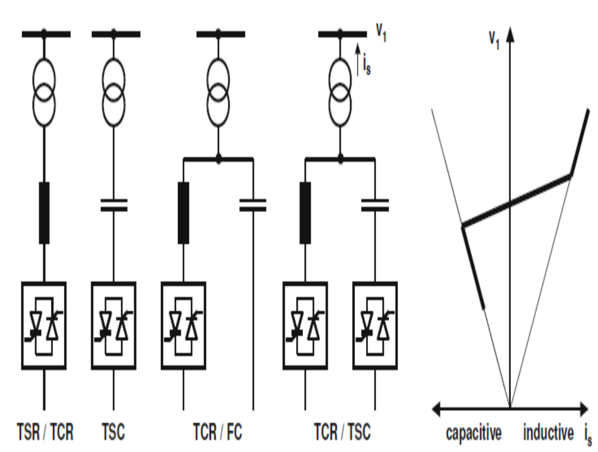

Fig.3.2. SVC of combined TSC and TCR type and voltage/current characteristics

3.3. SVC building blocks and voltage / current characteristic

In principle the SVC consists of Thyristor Switched Capacitors (TSC) and Thyristor Switched or Controlled Reactors (TSR /TCR). The coordinated control of a combination of these branches varies the reactive power as shown. The first commercial SVC was installed in 1972 for an electric arc furnace. On transmission level the first SVC was used in 1979. Since then it is widely used and the most accepted FACTS-device.

3.4. Modelling of SVC and Power system

A single-phase SVC is modelled using MATLAB Sim Power Systems Block set as shown in Figure 3.3 and three SVC blocks are connected in Delta configuration in the three-phase system[8]. The device is represented by a fixed capacitor in parallel with a Thyristor controlled reactor (TCR). The TCR consists of a fixed reactor of inductance L and a bidirectional thyristor. When thyristors are fired, the equivalent reactance of TCR is given By where is the inductor reactance and is the firing angle of the SVC. The thyristors are fired symmetrically in an angle control range of *90* to 180 with respect to the capacitor voltage. Total equivalent reactance E of SVC may be defined by

$$X_E = X_C \frac{/r_x}{\sin 2 \ -2 \ + \ (2-1/r_x)} \quad \text{-----(3)}$$

Where rx = C/L and c is the fixed capacitor. If the firing angle is bigger than the resonance angle res, SVC operates in capacitive region; on the other hand, it operates in inductive region.

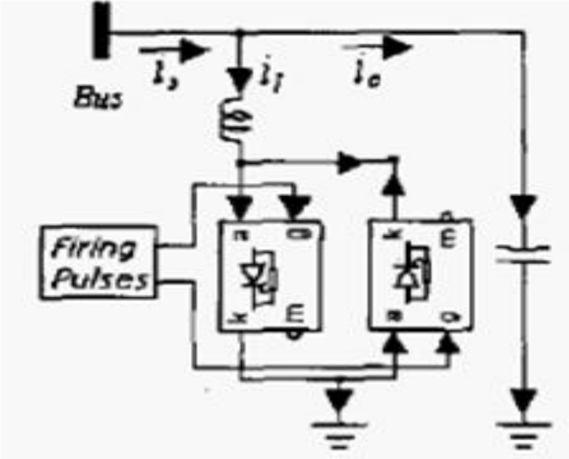

Fig.3.3. A single phase SVC MATLAB model

The control structure of the SVC consists of Regulator Circuit Model (RCM) and Switching Circuit Model (SCM). In the RCM as shown in Fig. 4.1. RMS voltage measured at the load bus is compared with a reference voltage and the difference between them is used as the input of a PI controller. The resulting output is then transferred in angle values and added constant firing angle**,** and then limited by a saturation block. The SCM shown in Fig. 4.1. provides firing pulses to thyristors converting the angle signal that comes from the regulator circuit model. The thyristor 2 receives the pulse delayed of 180 for each phase.

For the static load models, it is generally assumed that voltage dependency of active and reactive power could be represented by exponential load models given by

$$P = P_e \frac{V^n}{V_0} \quad \text{-----------------(4)}$$

$$Q = Q_e \frac{V^n}{V_0} \quad \text{-----------------(5)}$$

IV. SIMULATION MODELS

1. Case study I: SVC at nearby load

The effect of different locations of the SVC on the voltage magnitude for different static load models are analysed on a generic five-bus power system as shown in Figure 4.1. The system data is taken For the static load[8], six load models given **are** used to show the effect of different load models on the location of the shunt compensators for system voltage profile. For this purpose SVC is treated as a *20* MVar shunt capacitor and after installing of the shunt capacitor at different buses, variations of bus voltage magnitudes and Real and Reactive power at bus 5 are given in Figure 4.2, 4.3

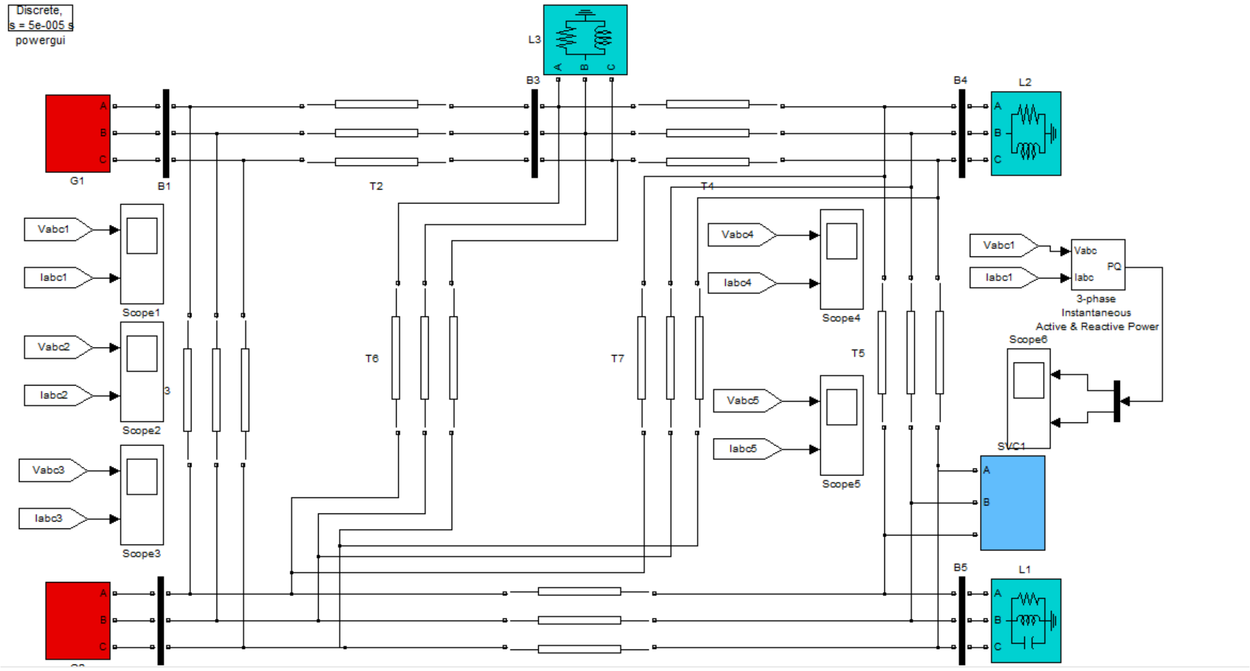

Fig: 4.1.Simulink model of proposed system for case study-1

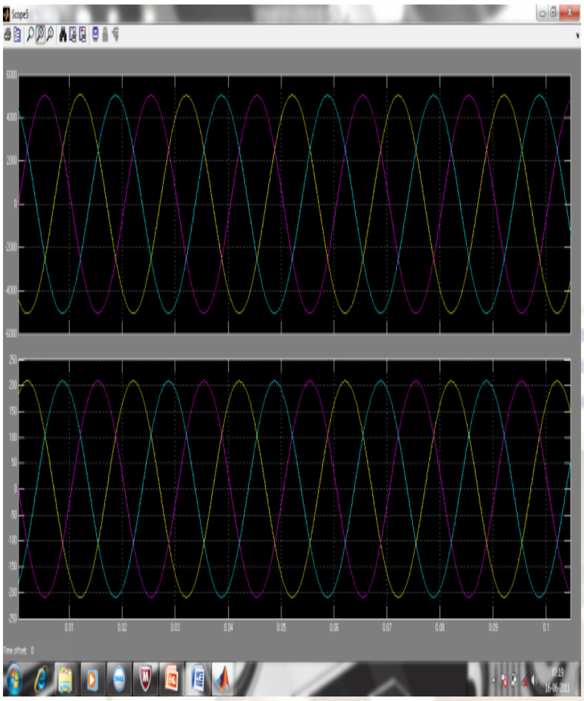

Fig:4.2.Voltage and currents at bus-5

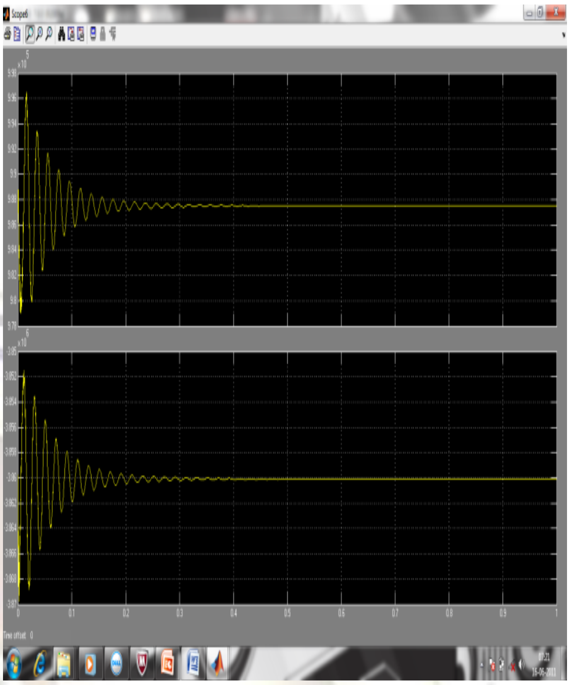

Fig: 4.3. Real and Reactive power.

2. Case study- II: SVC at nearby generator

The SVCs on voltage control for variable load conditions is investigated. All loads of the system are changed as a stair-case load.

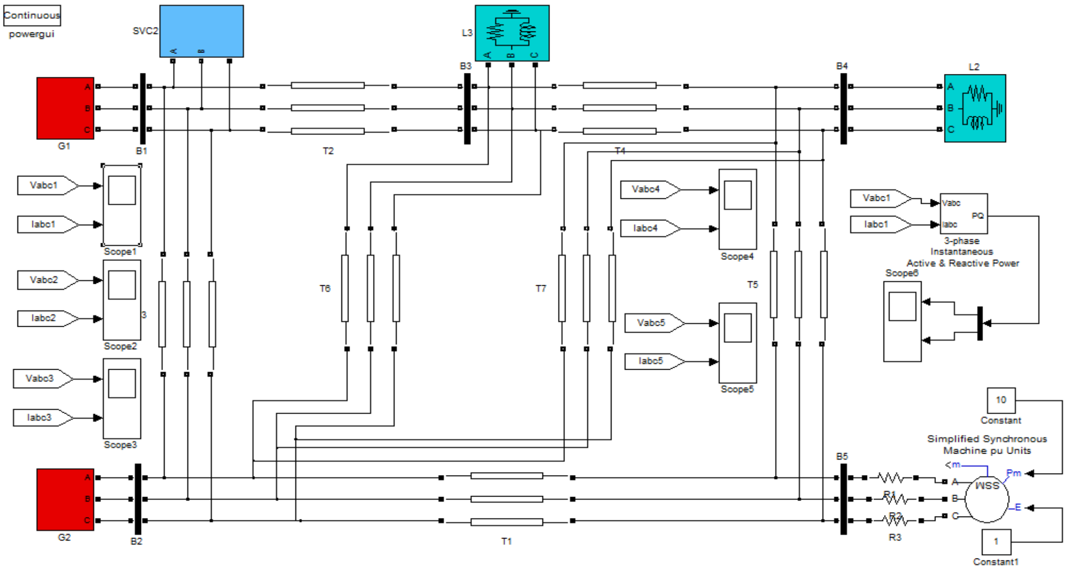

Fig: 4.4 .Simulink model of the proposed system for case study-2

From Fig, bus *5* is targeted as the location for the SVC, because it has the lowest voltage level with the load variations. To keep the bus *5* voltage at 1.015 pu**,** parameters of the SVC are chosen as C= 170 F and L=25mH**.** The firing angle limits of the SVC are defined as 100 degree SVC and the PI controller parameters are chosen as KP=10and KI=300**.** Variation of bus voltages after the location of the first SVC.After locating of the SVC at the bus *5*, the bus voltage is kept at 1.015 pu for each load level, but this is not enough to keep the other load voltages at desired level.the variation of bus voltages and real and reactive power at bus-5 are shown in fig 4.5 and 4.6

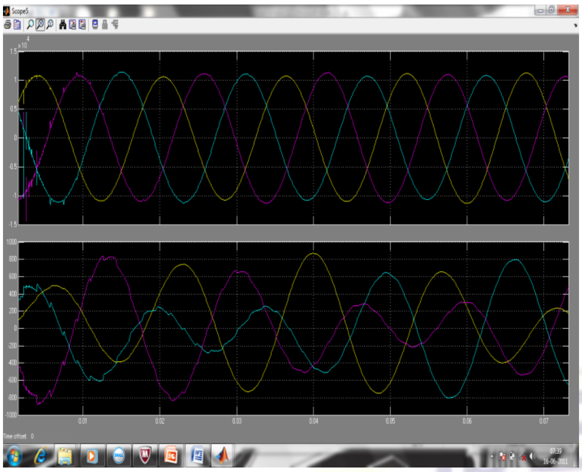

Fig:4.5.voltage and currents at bus-5

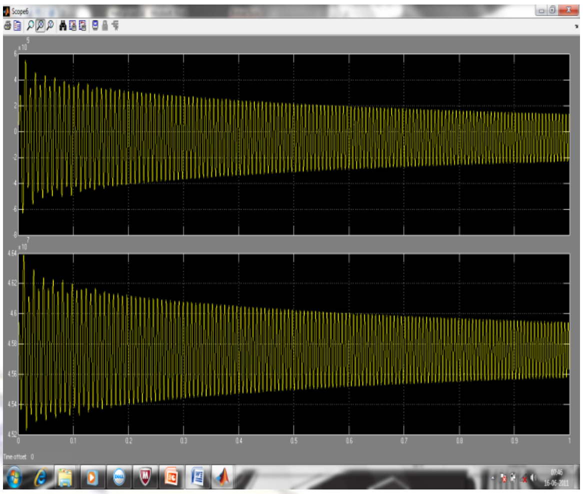

Fig:4.6. Real and reactive power

Case Study-III: SVC at inbetween transmission line

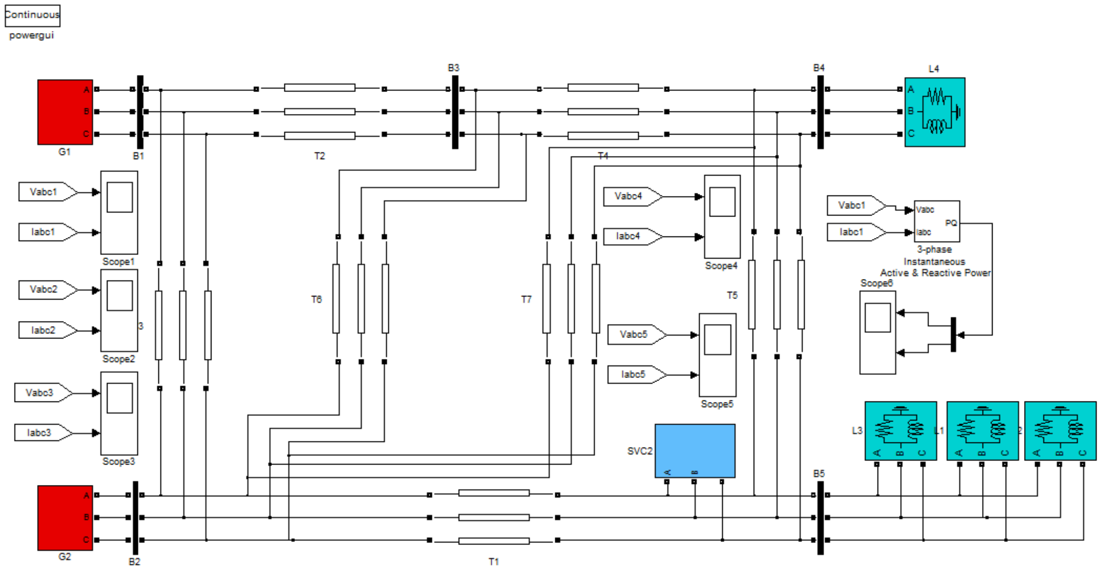

Fig: 4.7. Simulink model of the proposed system for case study -3

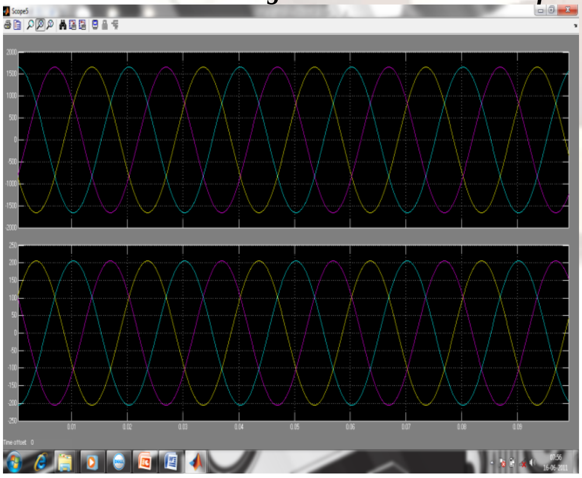

Fig: 4.8.voltages and currents at bus-5

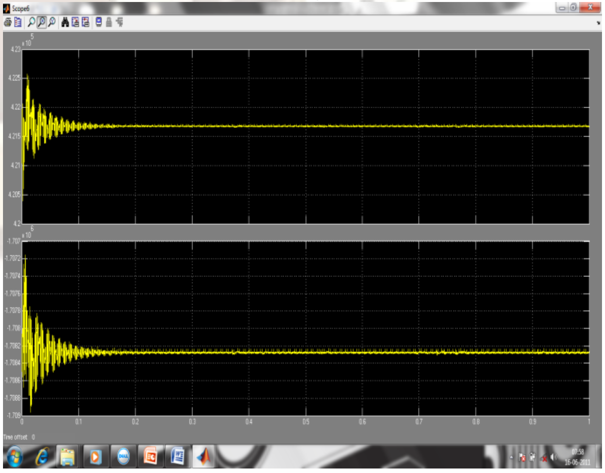

Fig: 4.9. Real and reactive power

V. Conclusion

This Project concludes that the location of SVC at different places to maintain power quality and power factor as unity. The project focuses on location of SVC at three different places which are nearer to the load, nearer to the generating station and between the

Transmission lines and it gives the best location of SVC with good voltage regulation by connecting the filters in the feeder. By choosing the SVC at nearer to load side is the best reduction of losses, maintain good voltage regulation and power factor without any recovery of time for compensating the voltage levels.

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