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Transient Stability Improvement using Shunt and Series Compensators

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Abstract

Background/Objectives: To study the improvement of transient stability using FACTS devices (TCSC and STATCOM). **Methods/Statistical Analysis:** The objectives are met by varying the value of capacitance value of constant capacitor by fluctuating the firing angle of TCR. STATCOM is realized by linking the system with voltage source via transformer. **Findings:** In the transmission line of 8 bus system FACTS device is used and both ends power transfer is controlled. Major transient parameter are stimulated individually and analysed. **Applications/Improvements:** The single phase and three phase systems are modeled with and without FACTS device and the results are simulated using MATLAB.

Keywords: Injection of Voltage, STATCOM, TCSC, Transient Stability Improvement

1. Introduction

Increase in the utilization of power tends to operate the power system closer to their limits of stability conventional methods give a solution to operate within the limits. Advent of semiconductor based equipment namely the FACTS devices, enables overcome the present operating[1].

Extending the capacity of the system with incorporation of FACTS devices is proven to be profitable. Series and/or shunt compensation may be provide based on the type and capacity of the system .the effects of TCSC, STATCOM over the system varies with optimal location and rating of the devices comparison of the compensating devices with respect to reactive power flow is indispensable.

1.1 Power Transfer Limit

One or more of the following network characteristics limits power flow over a transmission system.

a. Stability limit
b. Thermal limit
c. Voltage limit
d. Loop flow

When referred in technical aspects, limitation exerted on power transfer is neglected by extending the capacity of generator or transmission line. Addition of new element does not reflect on operating limits due to proper FACTS design.

1.2 Controllability of Power System

Considering the common notation of the power-angle curve, it is certain that the power system performance is dependent on the three main variables, namely Voltage (V), Angle (δ) and Impedance (Z). FACTS devices are implemented mainly for steady state as well as dynamic quantities. The Figure 1 represents the variables to be controlled, but the method of control is left to the user or the

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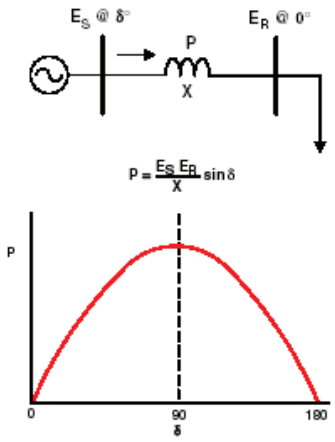


Figure 1. Controllability of power system.

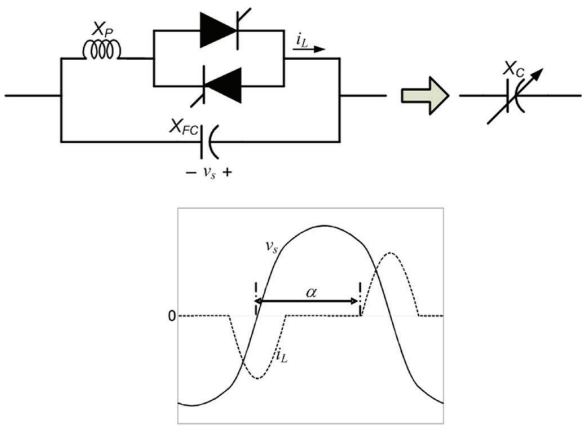


Figure 2. TCSC model and Dynamic Parameters.

operator. This method can be employ conventional control equipment or FACTS devices.

2. Thyristor Controlled Series Compensator

TCSC is a main type of series compensating FACTS device, which is represented below in Figure 2. The relationship between Vc and I_L is exposed in the Figure 2, of which VC zero crossing is fixed as reference.

2.1 TCSC- Operating Principle

To control the ac power over a broad range of values, a controlled capacitive reactance is added in cascade to the transmission line, which is termed as TCSC. The firing angle (α) is varied to increment the fundamental frequency voltage across the fixe capacitor which in turn varies the series reactance value. Figure 2 exposes the TCSC model and dynamic behavior of voltage and current and visualize relationship of firing angle with fundamental frequency.

Xc of the TCSC is specified in terms of the firing angle[2].
where,

$$Xc = \beta1[Xfc+ \beta2]- \beta4\ \beta5\text{-}Xfc$$
$$\beta1 = [2(\pi- \alpha)+\sin2(\pi- \alpha)] / \pi$$
$$\beta2 = (XfcXp) / (Xfc\text{-}Xp)$$
$$\beta3 = \sqrt{(Xfc/Xp)}$$
$$\beta4 = \beta3\tan[\beta3(\pi- \alpha)] - \tan(\pi- \alpha)$$
$$\beta5 = [4\ \beta22\cos2(\pi- \alpha)] / [\pi Xp]$$

2.2 Effect of Compensation with TCSC

At a time among different lines of the system only one TCSC can be employed, for capacitive mode firing angle should be in the range of 140^0 – 180^{03}. Capacitance fluctuate with different firing angle and positions at 145^0 system observed to close to resonance and operation is stable at 160^0. The TCSC is connected between the lines 3-4, the reactive power of certain buses were improved[4]. Table 1 exposes the comparison of reactive power in different buses and it clearly visualize improvement in all buses after adding TCSC.

Figure 3 demonstrated the MATLAB simulation model of TCSC in which P4 and P5 are the signal generators providing the gate pulse for SCR which connected anti parallel to each other, by doing the necessary changes in P4 and P5.

3. STATCOM-Modelling

STATCOM is a main type of shunt compensating FACTS device, has the capability of absorbing and/or generating

Table 1. Comparison of reactive power in different buses

BUS	(MVAR) without TCSC	(MVAR) with TCSC
7	0.174	0.198
1	0.133	0.148
3	0.836	1.090
4	0.663	0.456

reactive power. STATCOM provides immediate control of power thereby improving the capacity of transmission voltage[5].

In Figure 4, a STATCOM is designed as a power converter fed from an energy source, which absorbs or generates controllable power[6]. STATCOM model is realized as a voltage source converter which establishes exchange of reactive power alone within the system. STATCOM is modeled to increase the reliability of the system.

3.1 Effect of Compensation with STATCOM

In an 8 bus system 3 phase fault in one of the bus is considered and STATCOM is positioned in the line 4-8.

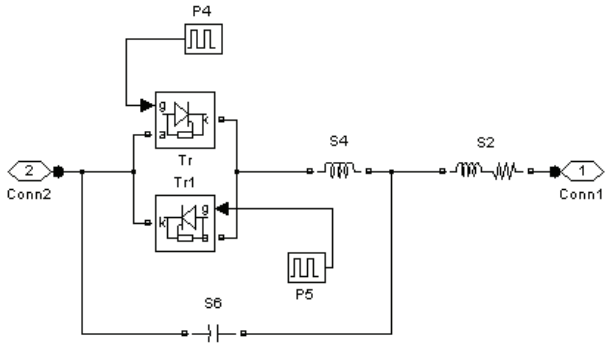


Figure 3. TCSC Model.

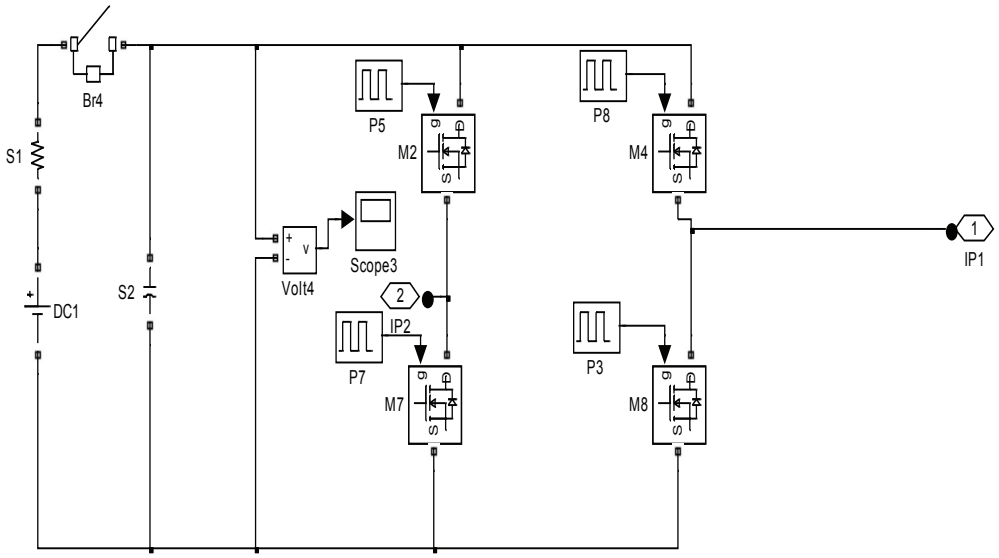


Figure 4. VSC used as STATCOM.

simulation output with and without STATCOM devices is exposed in Figure 5[7,8].

The midpoint voltage is taken as source voltage phase angle, so that only reactive power is exchanged among STATCOM and AC system.

4. Simulation Output of with and without TCSC

Figure 6 exposes the Simulink model of eight bus system without TCSC and it is simulated using MATLAB[9] and their result are discussed below.

Figure 7 indicates the bus-3 Real and reactive power. In the Figure 7 it is observed that the real and reactive power in the bus 3 is taken for study, simulated wave form visualizes the real time magnitude and time span.

In the Figure 8, simulated current and voltage waveforms of bus 3 is presented, magnitude of voltage and current pictured clearly which have to compared with the values of voltage and current simulated using TCSC.

Figure 9 exposes the Simulink model of eight bus system with TCSC and it is simulated using MATLAB and their result are discussed below.

In the Figure 10, real and reactive power in the bus 3 considered, simulated wave form envisage that there is improvement in the real power reactive power compared to the system without TCSC.

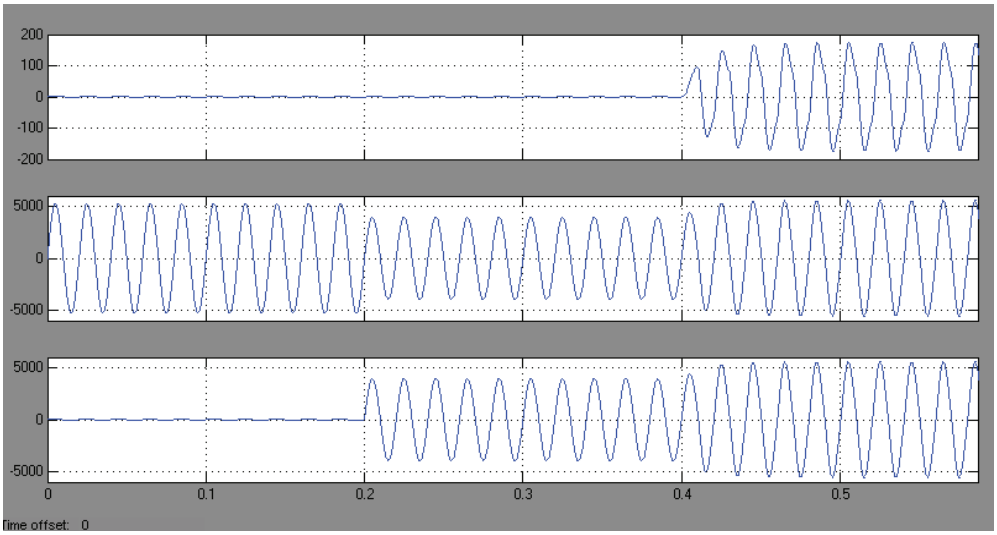


Figure 5. Voltage across external, load-1 and load-2 waveforms.

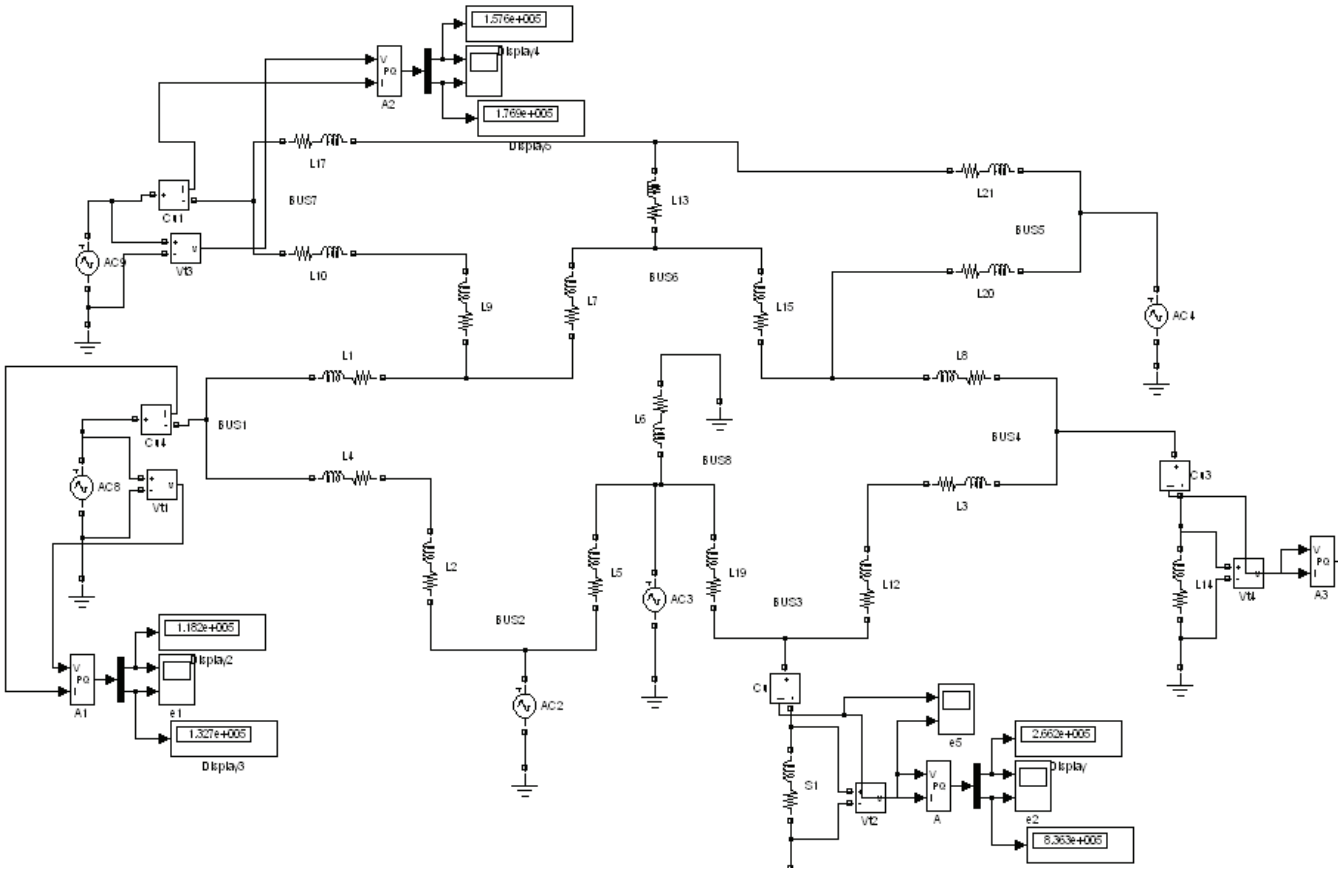


Figure 6. TCSC lacking system.

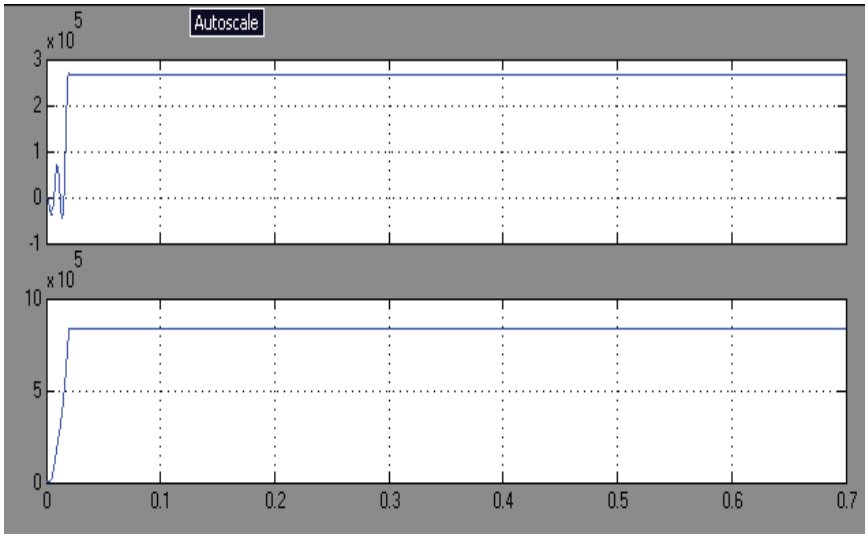


Figure 7. Bus-3 Real and reactive power.

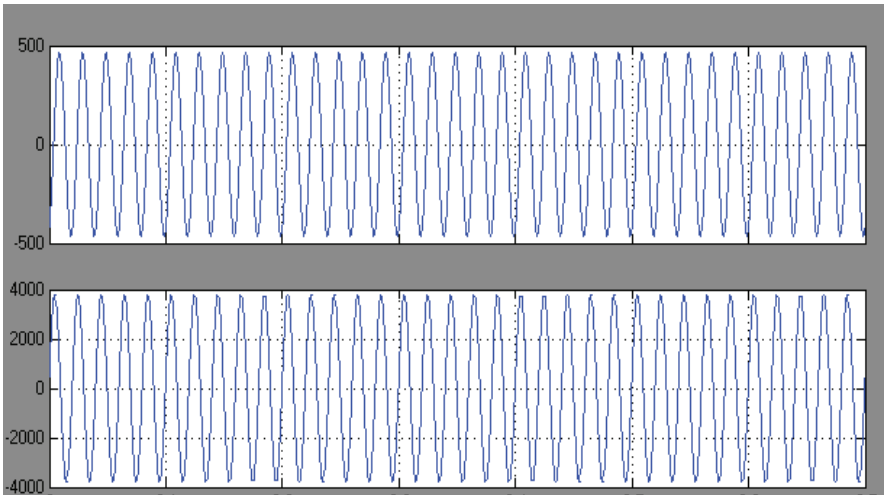


Figure 8. Bus-3 Current and voltage.

In the Figure 11 simulated current and voltage waveforms of bus 3 is presented, it clearly reveals that there is an considerable increment in value of current and voltage after incorporating TCSC[10].

5. Simulation Output of STATCOM

Figure 12 exposes the Simulink model of eight bus system without STATCOM and it is simulated using MATLAB and their result are discussed.

In the Figure 13, real and reactive power in the load 1 is taken for study, simulated wave form visualize the real time magnitude and time span.

In the Figure 14, simulated voltage waveforms across the load 1 is presented, magnitude of voltage pictured clearly which have to compared with the values of voltage simulated using STATCOM.

Figure 15 exposes the Simulink model of eight bus system with STATCOM and it is simulated using MATLAB and their result are discussed below.

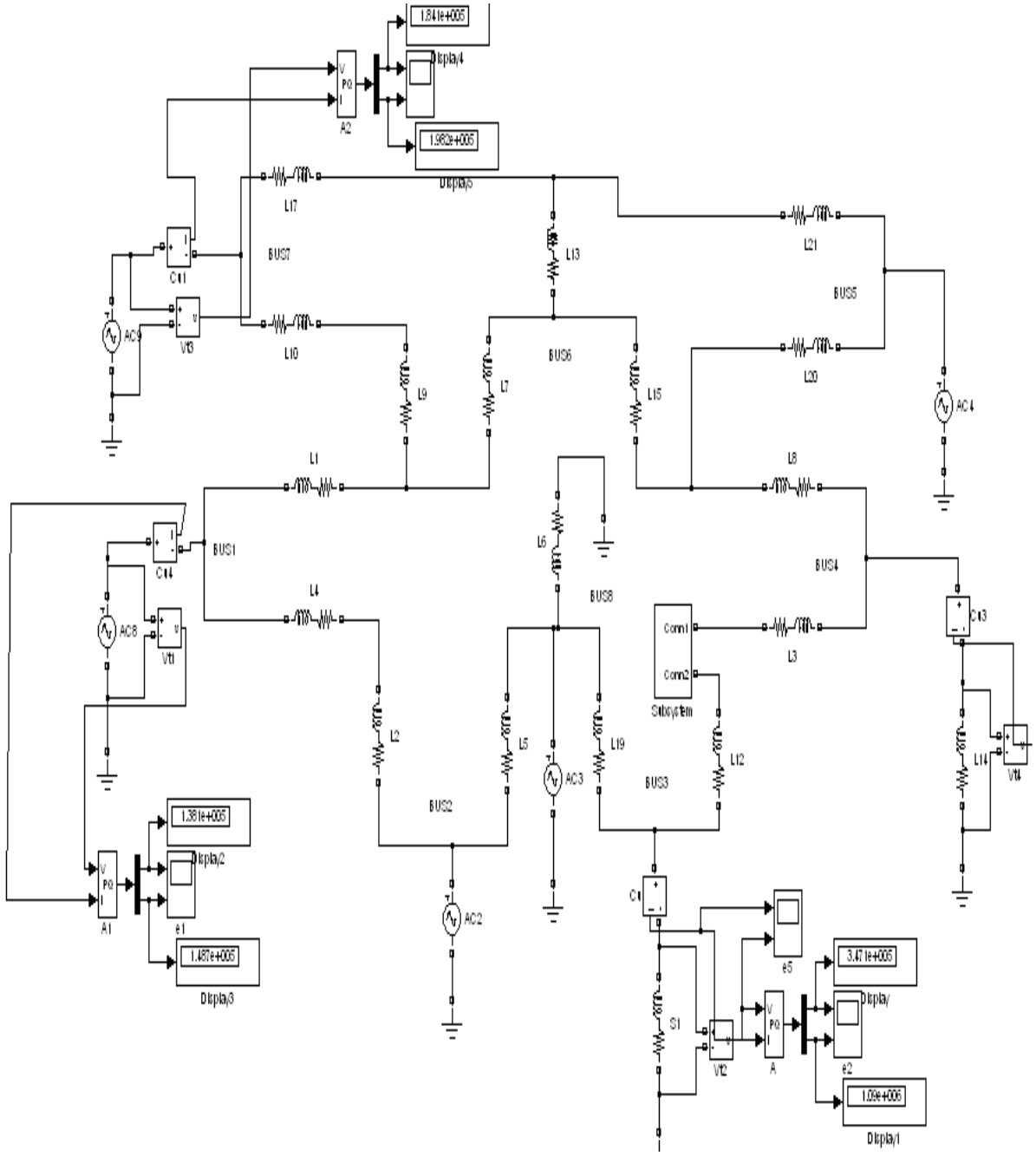


Figure 9. System using TCSC.

In the Figure 16 real and reactive power cross load 1 is considered, simulated wave form envisage that there is improvement in the real power reactive power compared to the system without STATCOM.

In the Figure 17, voltage waveforms across the load 1 is presented, it clearly reveals that there is a considerable increment in value of voltage after incorporating STATCOM.

Table 2 expose Comparison of reactive power in different buses and it clearly visualize improvement in all buses after adding STATCOM.

6. Conclusion

Standard 8- bus system without any shunt or series compensation is considered as the base system. Separate

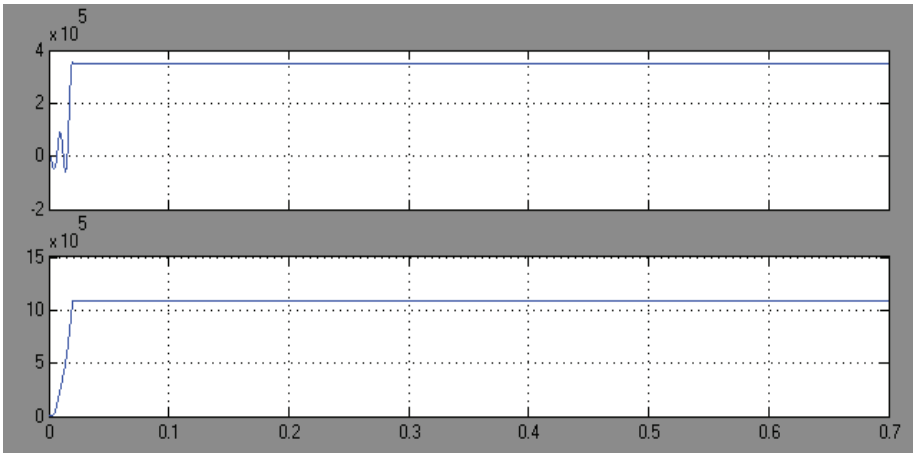


Figure 10. Bus3 Real and reactive power.

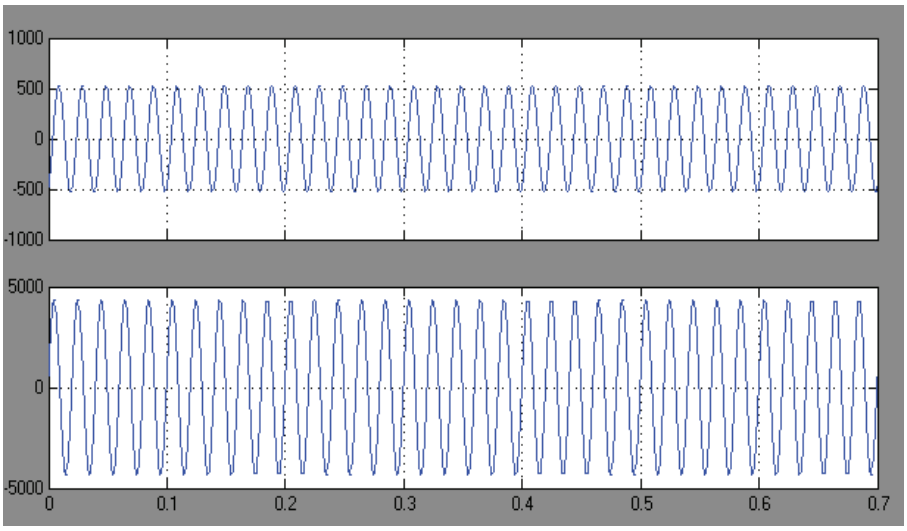


Figure 11. Bus-3 Current and voltage.

analysis for series and shunt compensation was carried out by using TCSC & STATCOM respectively. Based on values of the reactive power in uncompensated system, bus-3 was chosen to be the best among the possible locations. The system performances for the base system and compensated conditions have been observed through simulation. The optimal placement of FACTS device (TCSC & STATCOM) has improved the reactive power at the load buses. Compared to TCSC, STATCOM proves to provide better stability to the system in terms of improvement in the reactive power flow.

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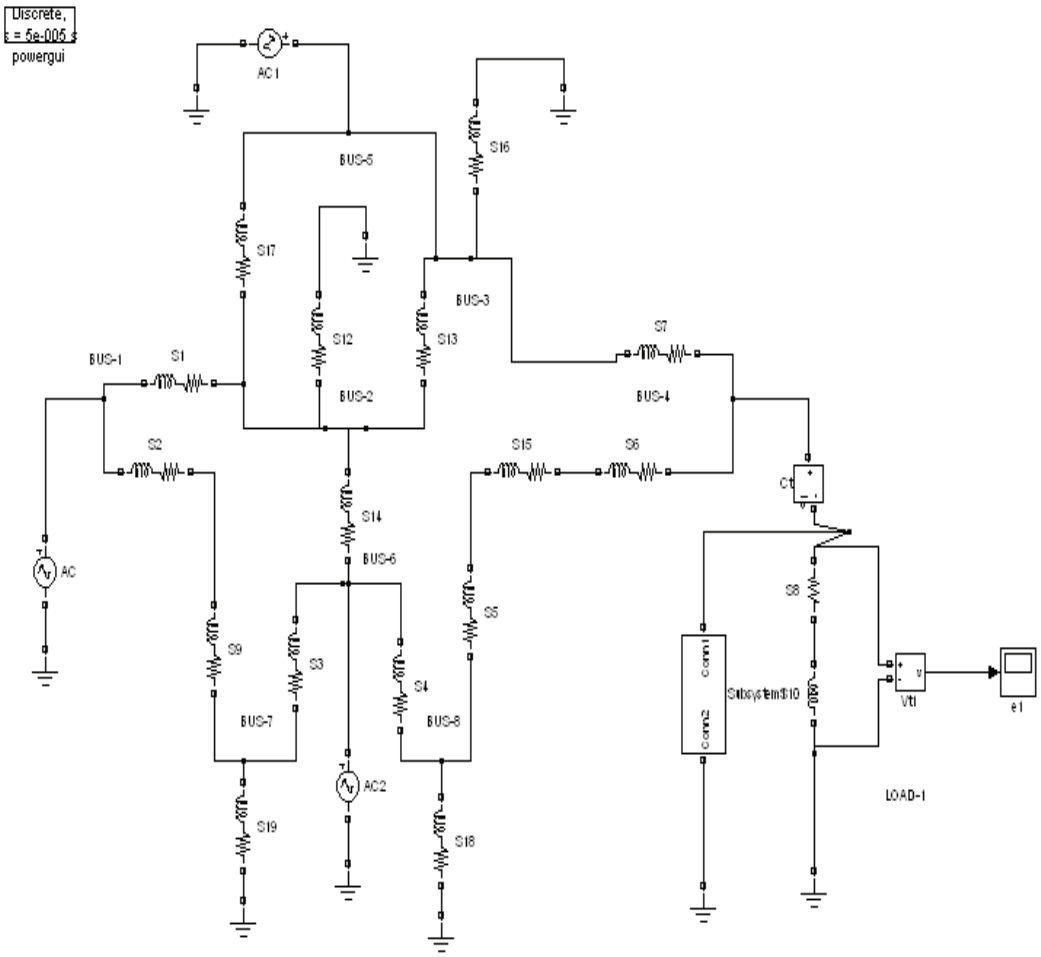


Figure 12. Eight Bus system without STATCOM model.

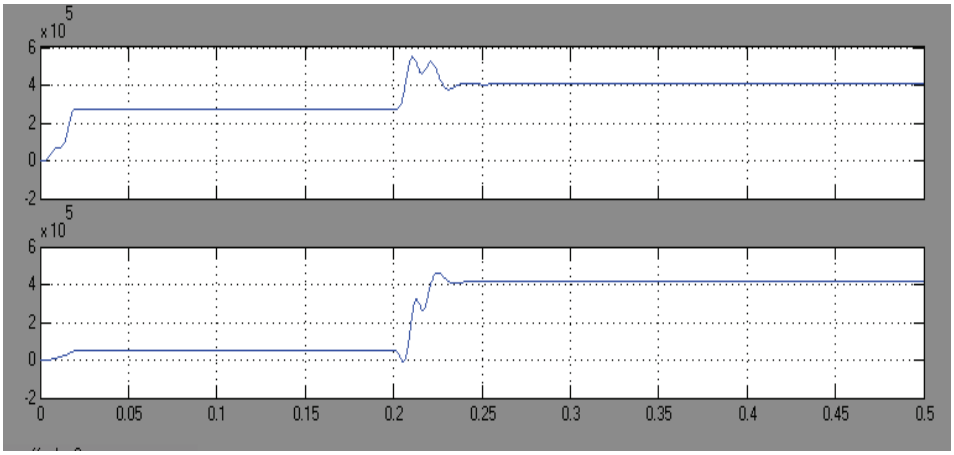


Figure 13. Real and reactive power across load-1.

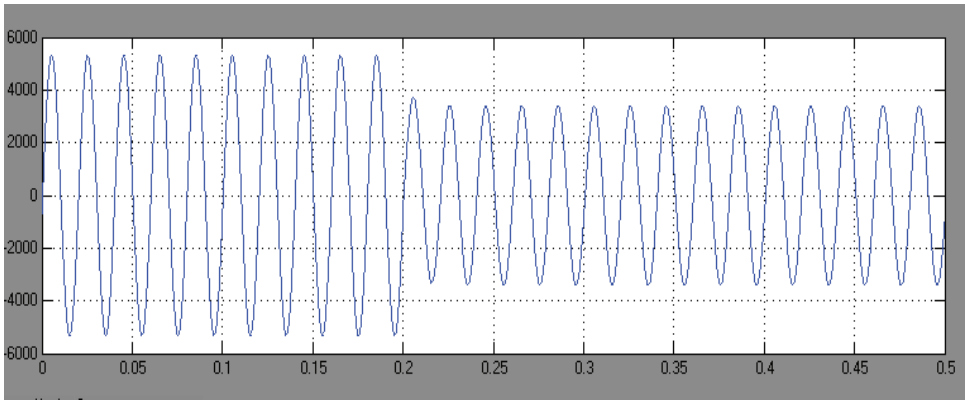


Figure 14. Voltage across load-1.

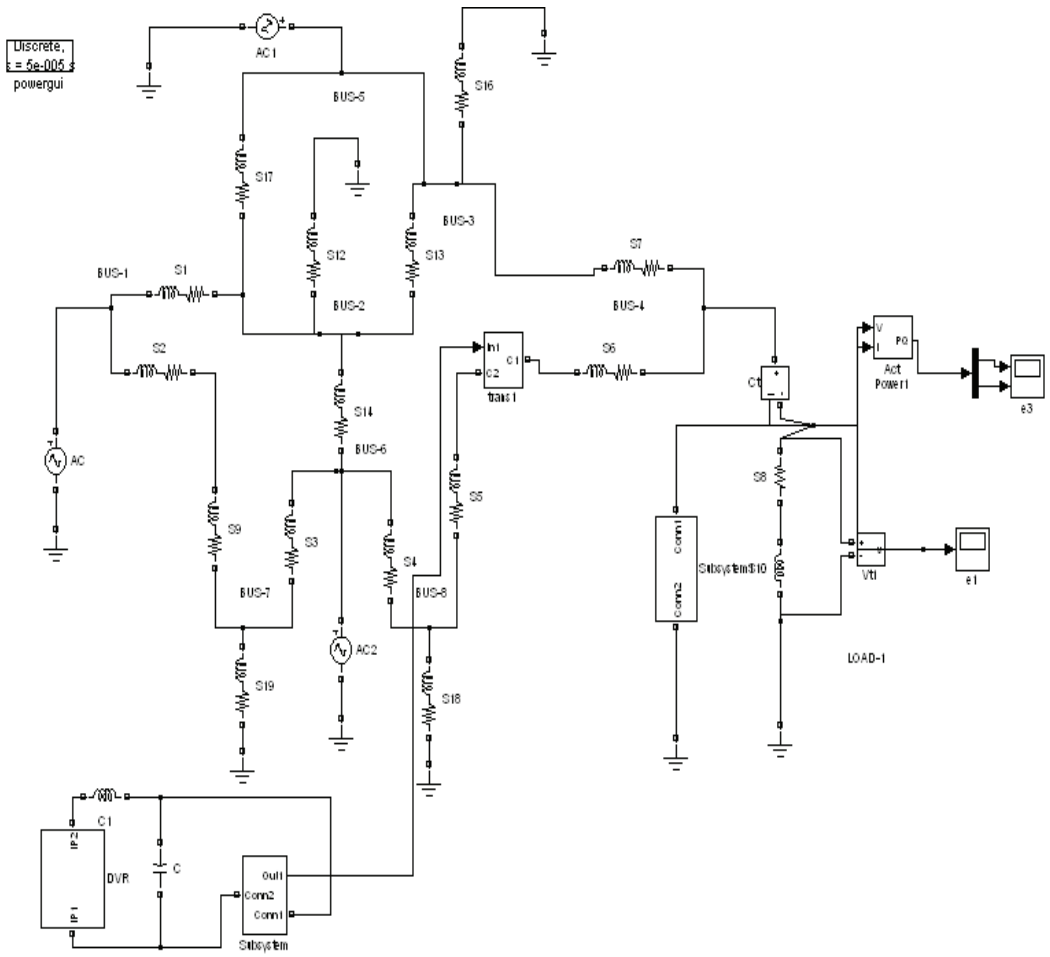


Figure 15. Bus system with STATCOM model.

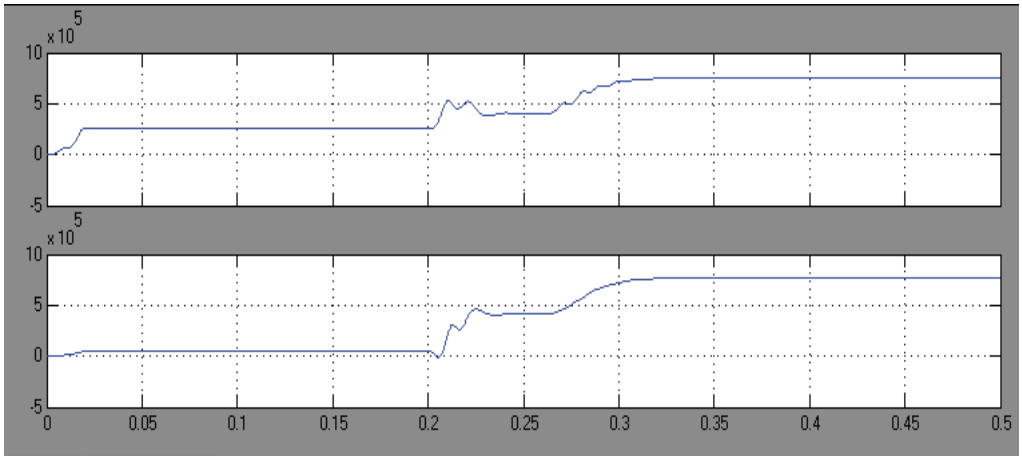


Figure 16. Real and reactive power across load-1.

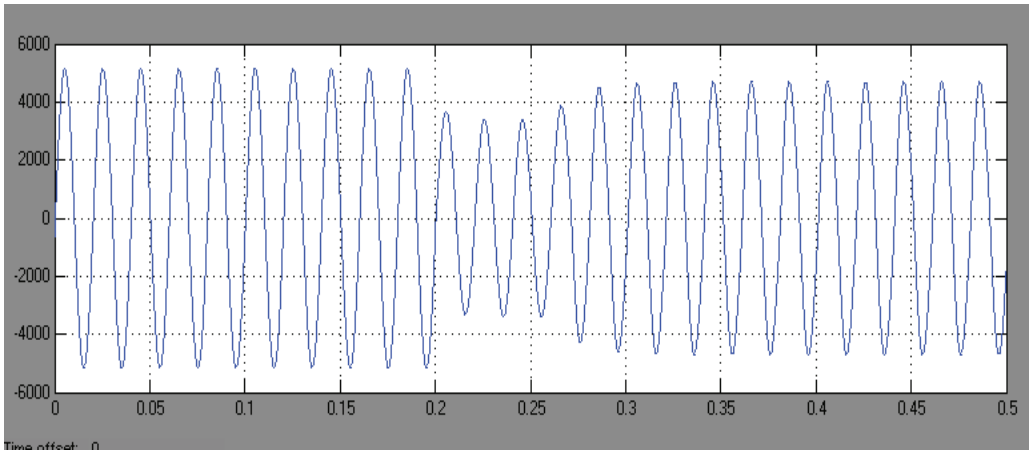


Figure 17. Voltage across load-1.

Table 2. Comparison of reactive power in different buses

Bus	(MVAR)Without STATCOM	(MVAR) With STATCOM
7	0.174	0.238
1	0.133	0.163
3	0.836	1.105
4	0.663	0.592

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