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Comparison of SVC and TCSC for Transient Stability Enhancement of Multi-machine System

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ABSTRACT: This paper presents the effectiveness of shunt and series FACTS controllers in multi machine power system for the enhancement of voltage stability, power systems oscillation damping and total power transfer capability. The simulation of IEEE 3 machine 9 buses system is carried out with Static VarCompensator (SVC) and ThyristorControlled Series Capacitor (TCSC) using Simulink/MATLAB. The comparison of SVC and TCSC is also presented .The simulation results show the improvement of voltage profile & damping of oscillations of power systems by SVC and enhancement of power transfer by TCSC.

KEYWORDS:FACTS Controller, Static Var Compensator (SVC), Thyristor Controlled Series Compensator(TCSC), transient stability, damping .

I.INTRODUCTION

Every year the electrical power systems are becoming more & more complicated. With the increased interconnections & loading, the transmission system become weak & unstable, so there is intense need to improve transient stability. For this purpose various FACTS devices are used. The basic SVC compensator with PSS in improving synchronizing & damping powers of a single machine infinite bus system is used. Series compensator like TCSC & shunt compensator like SVC with proper controller used to improve voltage stability.
An estimation of TSA has been used to study the effects of series & shunt FACTS devices on the transient stability. The modeling and optimal tuning of various FACTS devices for a dynamic stability enhancement of multi machine power systems is studied. The efficacy of SVC and TCSC controller in improving voltage stability and total transfer capacity using multi-objective GA was investigated. Modeling and interfacing techniques for SVC and TCSC for a long term dynamic simulation was studied. This paper presents the placement of SVC and TCSC controller at their optimal position in IEEE 3 machine 9 bus power system. The paper also investigates the comparison of both controllers in improving transient stability enhancement.

II.STATIC VAR COMPENSATOR (SVC)

SVC is a shunt connected FACTS controller whose main function is to regulate the voltage at a given bus by controlling its equivalent reactance. Basically it consists of a fixed capacitor (FC) and a thyristor controlled reactor (TCR). The basic model of SVC is shown in Figure 1.

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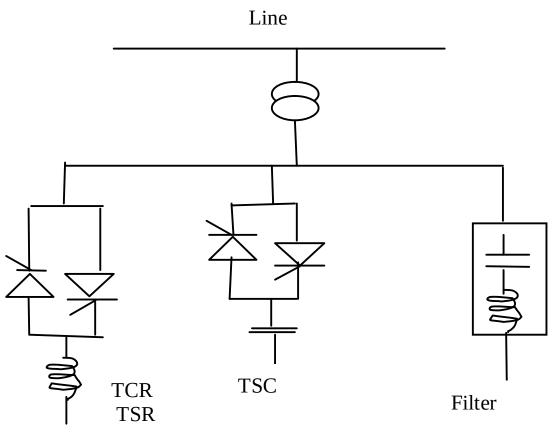

Figure 1. SVC basic model

Figure 2, shows steady state and dynamic voltage-current characteristic of SVC. In active control range, current/ susceptance and reactive power are varied in order to regulate voltage according to a slope characteristic . The value of slope depends on voltage regulation, which is desired by sharing of reactive power production between various sources & other needs of the system. The slope lies in range of 1-5%. At the capacitive & inductive limits SVC becomes a shunt capacitor & shunt reactor respectively.

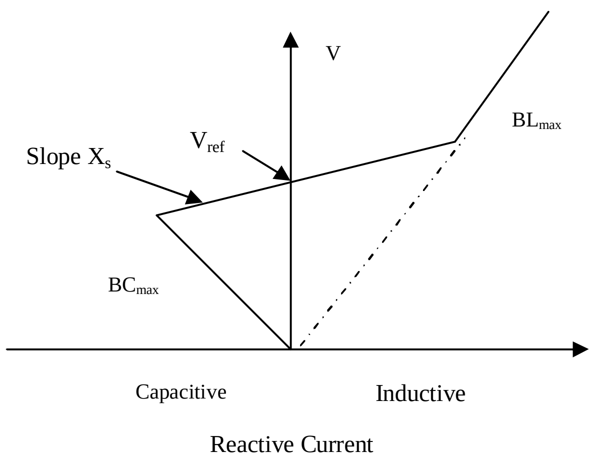

Figure 2. Steady-state and dynamic voltage/current characteristics of the SVC

III.THYRISTOR -CONTROLLED SERIES CAPACITOR (TCSC)

TCSC is a series connected FACTS controller. TCSC provides powerful means of controlling and increasing power transfer level of a system by varying apparent impedance of a specific transmission line. With the use of TCSC, the system will operate stably at power levels well beyond those for which system was originally made without losing the stability. The TCSC also mitigate SSR.TCSC basically consists of the series compensating capacitor shunted by a thyristor –controlled reactor as shown in Figure 3. However, the basic idea behind the TCSC scheme is to provide a continuously variable capacitor by means of partially cancelling the effective compensating capacitance by the TCR. The TCR at the fundamental system frequency is a continuously variablereactive impedance,controllable by delay angle α, the steady –state impedance of the TCSC is that of a parallel LC circuit, consisting of a fixed capacitive impedance, $X_L(\alpha), that\ is,$

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$$X_{TCSC}(\alpha) = \frac{X_C X_L(\alpha)}{X_L(\alpha) - X_C}$$

Where $X_L = \omega L$, and α is the delay angle measured from the crest of the capacitor voltage.

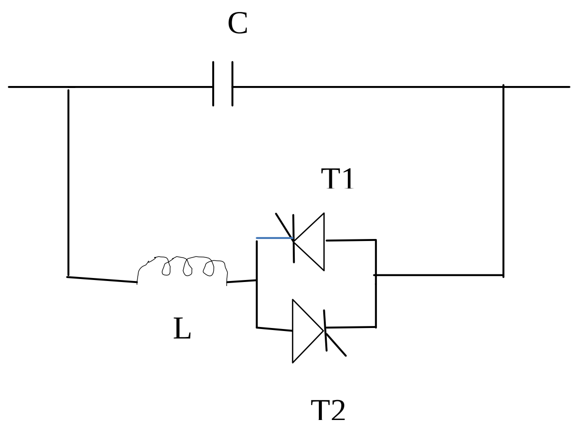

Figure 3. TCSC basic model

IV.SIMULATION MODEL AND RESULTS WITH SVC

The test system considered for transient stability investigation is standard IEEE 3 machine 9 buses system. The 3 machine test system is operating with load at bus 5 carrying 125 MW, bus 6 carrying 90 MW and bus 8 carrying 100 MW. The real power generations are 247.5 MW, 192 MW and 128 MW in generators 1, 2 and 3 respectively. SVC which is a shunt FACTS device is connected at bus 8 since it is a load bus and TCSC which is a series FACTS device is connected between buses 8-9. The base MVA is 100 MVA and the system frequency is 60 HZ. All time constants are in seconds.

The complete system of IEEE 3 machine 9 bus system with all the required components has been model by using MATLAB/Simulink blocks. The simulation is done with the single line to ground fault occurred at 5.2 sec at bus 8 and the simulation model is shown in figure 4. The fault is cleared at 5.6 sec which means the fault clearing time is 0.4 sec.

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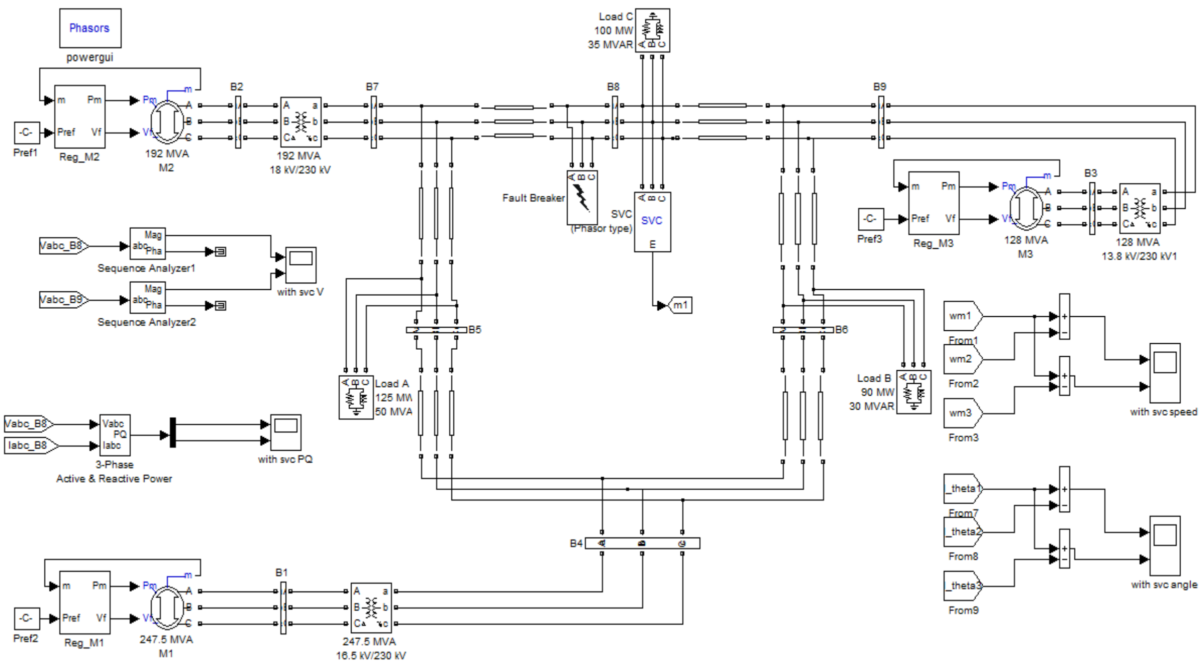

Figure 4. Simulink model of IEEE 3 machine 9 bus system with SVC

4.1 OUTPUT WAVEFORMS

The simulation results show that the system have more fluctuations in speed, voltage, & power without SVC controller than with SVC. The results show that the speed variations in the system damp in10s without SVC & in 9s with SVC. Also the magnitude of machine oscillations is reduced with the use of SVC. It is also seen that the SVC is placed at the mid of transmission line as it provide better results when placed at the centre rather than at the end of line.

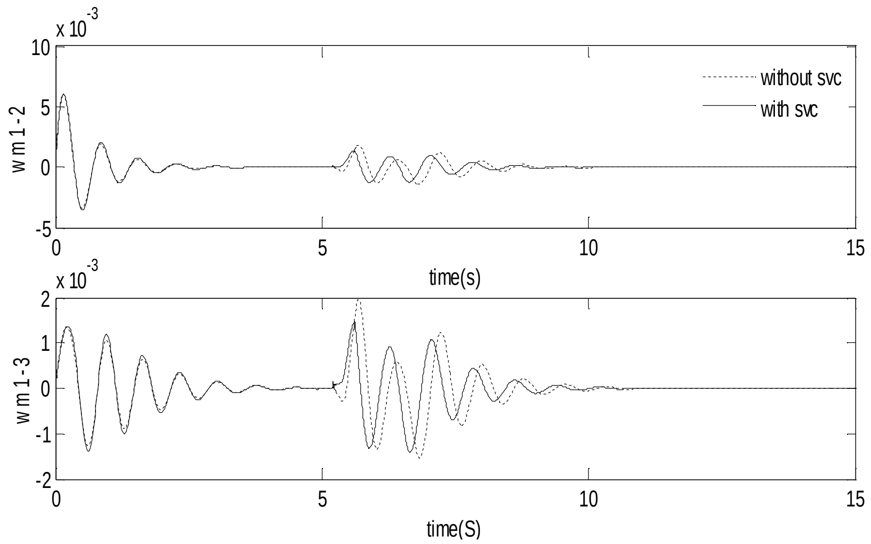

Figure 5. Comparison of difference of speed variation of machines without and with SVC

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The result below shows that therotor angle variations of machines without SVC have higher magnitude and also take longer time to damp than with SVC which shows that system is more stable with Facts controller.

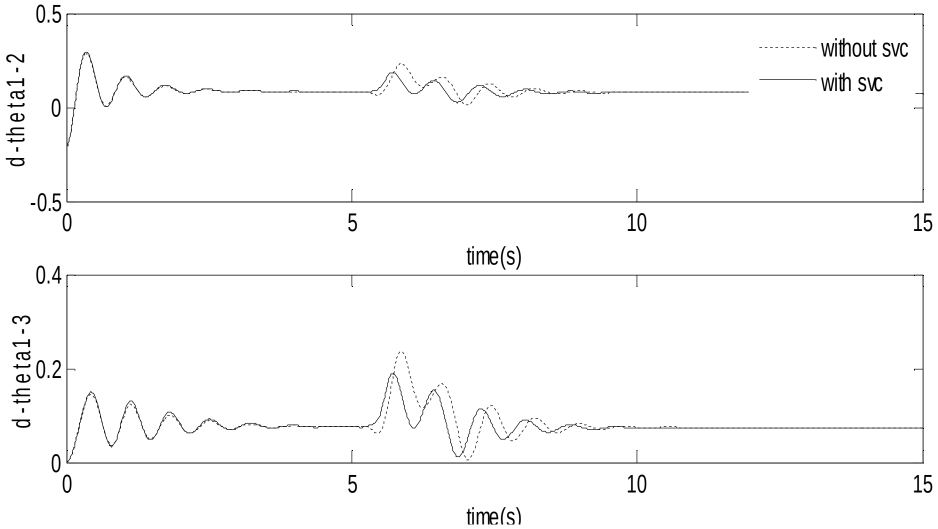

Figure 6. Comparison of rotor angle variation of machines without and with SVC

The result below shows that the system voltage fluctuations without SVC damp in 7s and in 6.3s with SVC which is placed at the bus 8.

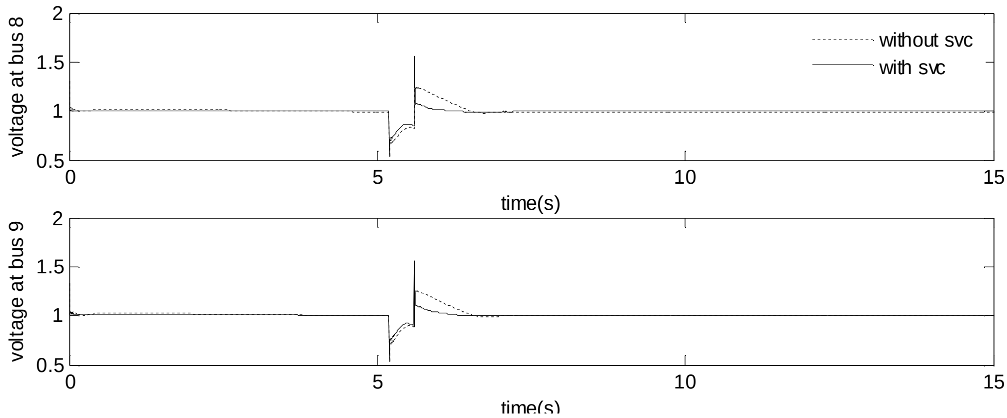

Figure 7. Comparison of voltages at bus 8 and bus 9 without and with SVC

The simulation result below shows that the system power variations damp in 7.5s without SVC and in 7s with SVC which is placed at bus 8. All the parameters are in per unit.

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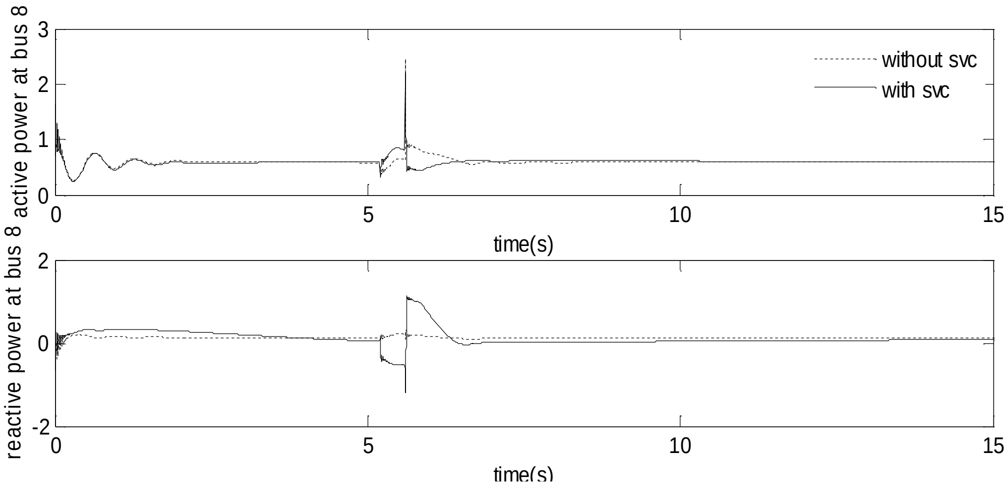

Figure 8. Comparison of active and reactive power at bus 8 without and with SVC

V. SIMULATION MODEL AND RESULTS WITH TCSC

The figure below shows simulation model of test system with TCSC controller . The TCSC is placed in series at the mid of transmission line between bus 8 and bus 9 as it provide better results when placed at the centre than at the end of line.

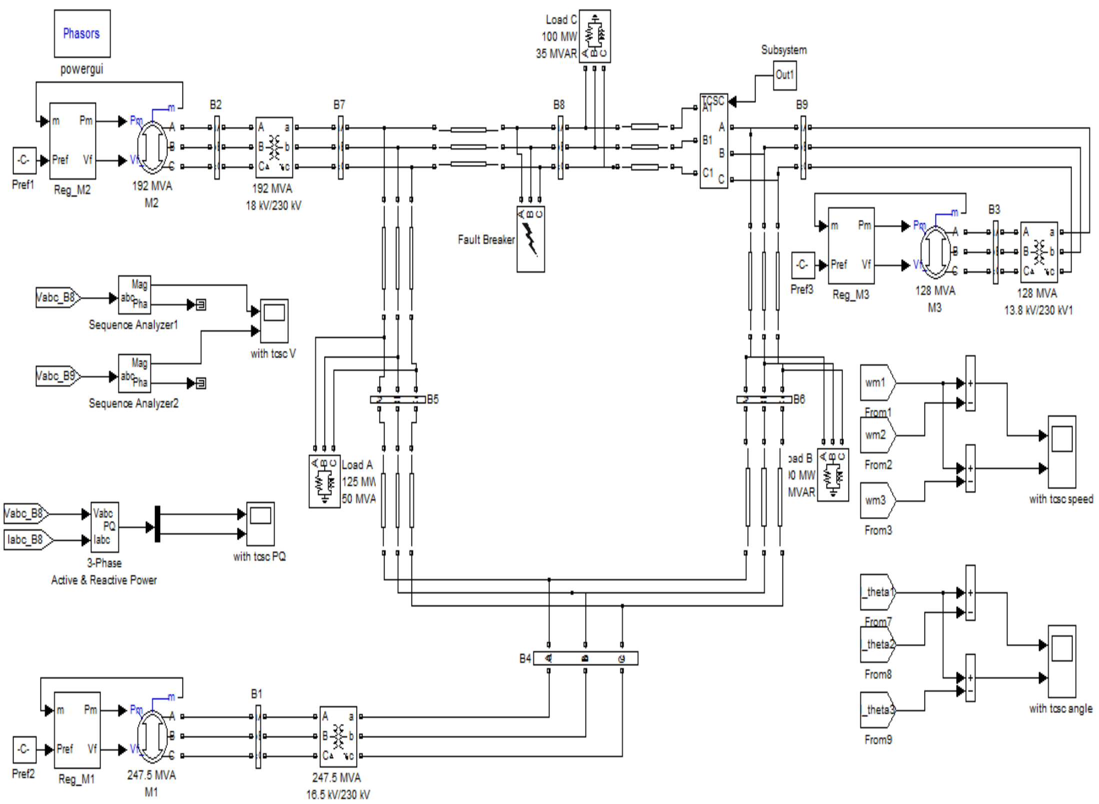

Figure 9. Simulink of IEEE 3 machine 9 bus system with TCSC

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5.1 OUTPUT WAVEFORMS

The simulation results of the system without and with TCSC controller connected in the line between buses 8-9 show that the voltage variation becomes stable in 6.7s and 6.6 s respectively. Also the magnitude of voltage variation with TCSC is lesser than without it.

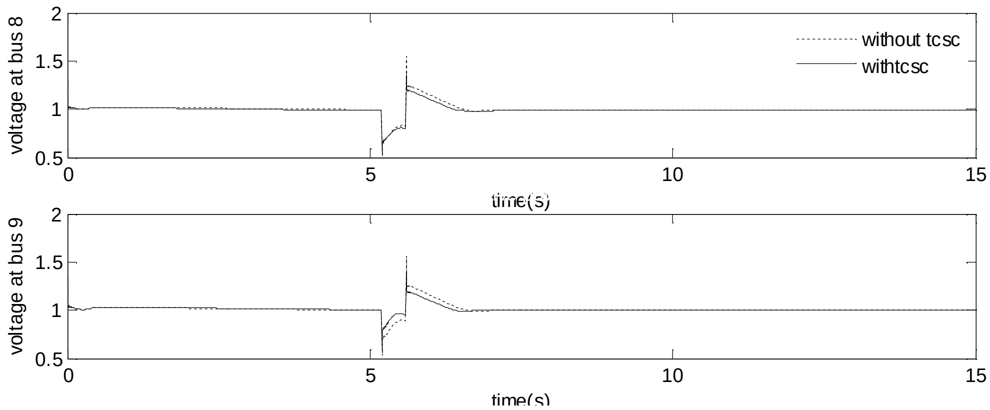

Figure 10. Comparison of voltages at bus 8 and bus 9 without and with TCSC

The result below shows that the active and reactive power of the system are increased with the use of TCSC controller.

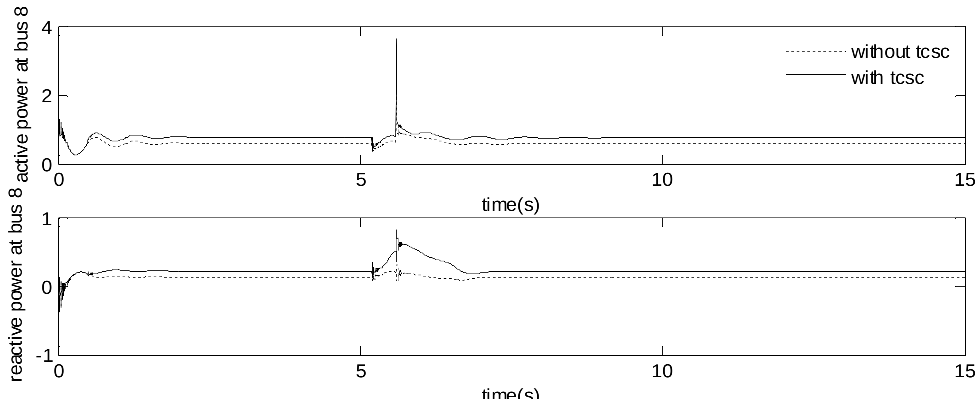

Figure 11. Comparison of active and reactive power at bus 8 without and with TCSC

VI.COMPARISON OF OUTPUT WAVEFORM OF SVC AND TCSC

When the results of both SVC and TCSC are compared with each other than the SVC provide better damping of machine oscillations and also with the use of SVC the bus voltage become stable rapidly that is voltage profile is improved , whereas TCSC increases the active and reactive power of the system.

The results below shows that the oscillations in the speed of machines is lesser with the use of SVC than with TCSC.

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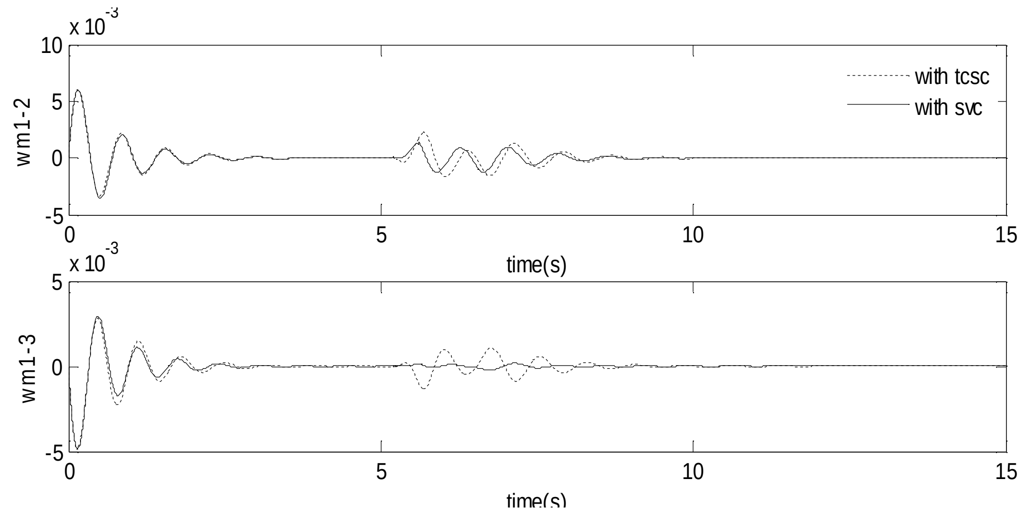

Figure 12. Comparison of speed variation of machines when fault occur with SVC and TCSC

The simulation result below shows that the rotor angle variations of machines becomes stable in 6.5s and in 7.5s with the use of SVC and TCSC respectively. So the stability of the system is more with the use of SVC than TCSC.

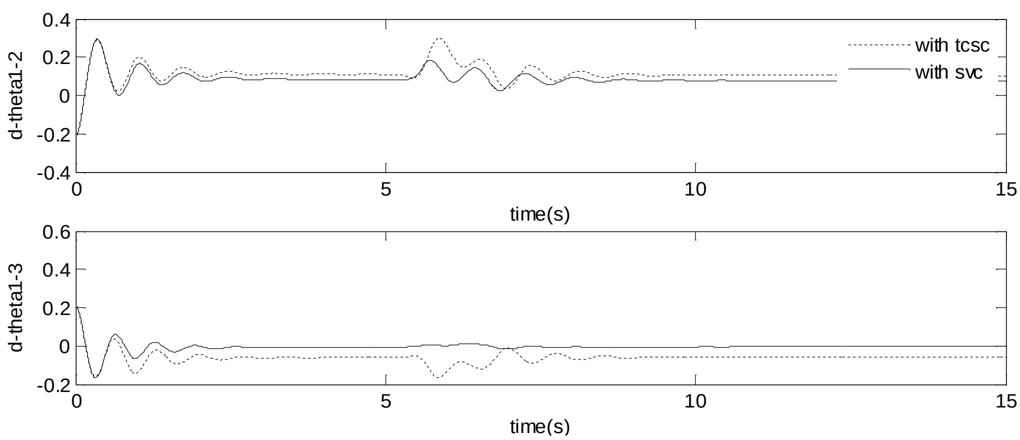

Figure 13. Comparison of rotor angle variation of machines when fault occur with SVC and TCSC

The result below shows that the magnitude of fluctuations in voltage of the system with the use of SVC is lesser than with the TCSC. The system voltage becomes stable in 5.8s and 5.9s with the use of SVC and TCSC respectively.

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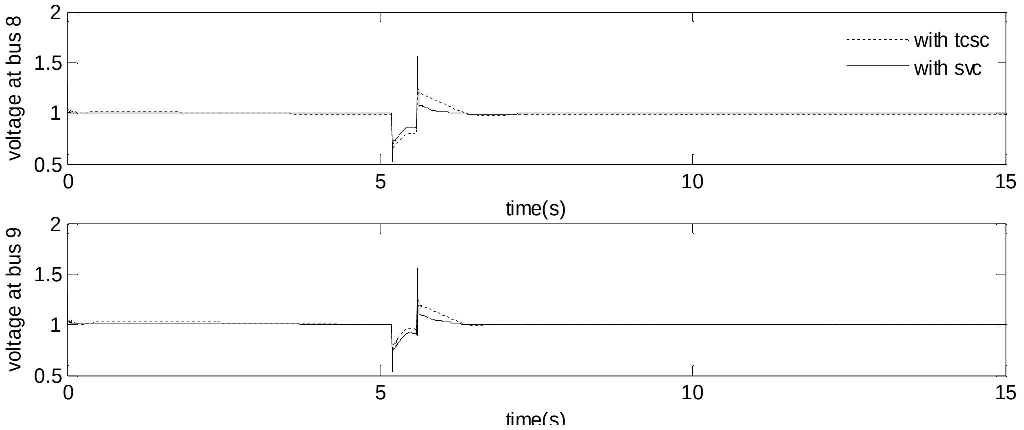

Figure 14. Comparison of voltages at bus 8 and bus 9 when fault occur with SVC and TCSC

The simulation result below shows that the active and reactive power of the system ncreases more with the use of TCSC than with SVC .

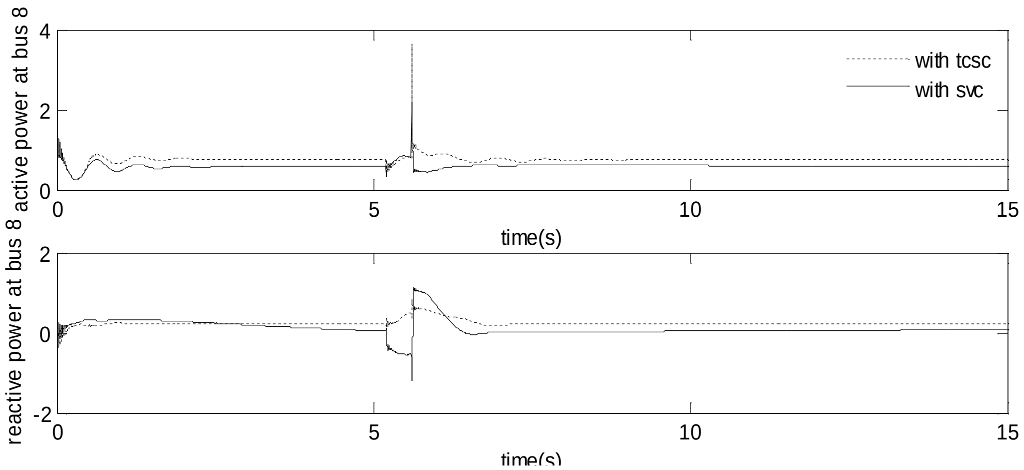

Figure 15. Comparison of active and reactive power at bus 8 when fault occur with SVC and TCSC

VII. CONCLUSION

FACTS devices are a powerful tool to improve the transient stability of power system. In this paper two FACTS devices, SVC and TCSC are used to improve the transient stability of nine bus system MATLAB/SIMULINK. Results show that SVC is better as compared to TCSC in enhancing the transient stability of power system while TCSC controls the active and reactive power flow much better than SVC.

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