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Enhancement of Transient Stability of Multi Machine Systems using FACTS Devices

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Abstract: For the improvement of transient stability limit in two area multimachine power system, an examination has been performed using different FACTS devices. In the MATLAB Simulink domain the simulation of two area multi machine power system including FACTS devices has been carried out. For the improvement of transient stability limit the performance of unified power flow controller (UPFC) has been investigated along with other FACTS devices such as static synchronous compensator (STATCOM) and static synchronous series compensator (SSSC) respectively. This paper brings out the superiority of UPFC over STATCOM & SSSC.
Keywords: Statcom; SSSC; UPFC; Two Area System; Transient Stability

I. INTRODUCTION

Today an increase in interconnections, installation of numerous generators, extra high voltage tie lines, variety of loads and transformers etc is caused by the complex modern electrical power. Inception in power system has led to consider stability as a major concern in power system operations. The capability in the power system to maintain synchronism when it undergoes critical transient disturbances, such as multi-phase short circuit fault, unanticipated change in generation or loss of large loads is called Transient Stability .The non linear power angle relationship governs the resulting system response which involves change in generator rotor angles. The advancement in power electronics technology and its uses in high voltage applications in power system has influenced the power system engineers to use the flexible a.c. transmission system (FACTS) controller. In order to improve steady state stability, voltage stability or transient stability of a complex power systems FACTS controllers is used to rapidly control the power system network parameters .

It avoids the need to construct new transmission lines as it also empowered the increased utilization of existing network closer to its thermal limit, and hence FACTS devices has been classified predominantly into two categories one based on thyristor switched reactor like static var compensator (SVC), while others like STATCOM, SSSC and UPFC employing power electronics based voltage source converters (VSCs).

The STATCOM is a shunt connected device of the FACTS families which regulates the voltage at the point of common coupling by injecting into or absorbing the reactive power from the power system. STATCOM generates reactive power or enforce its controller to work in capacitive region at the time of low voltage conditions in the system. Whereas at high voltage conditions in the system, it absorbs reactive power from the system or enforce controller to work in inductive region.

The SSSC is a series connected device of the FACTS family which injects the compensating voltage in series with the transmission line through coupling transformer irrespective of the line current.By injecting voltage which is in quadrature with the transmission line current SSSC can control the power flow through the transmission line.

In order to achieve optimal performance of power system, among all the devices in FACTS family, the UPFC is most versatile FACTS device which can simultaneously control network impedance, bus voltage magnitude and angle and power flow through the transmission line.

By using different FACTS controllers in the system the paper explore the improvement in transient stability limit of a multi machine two area system. For multimachine system including FACTS controllers such as STATCOM, SSSC and UPFC a Matlab Simulink based model has been developed.

The performance of UPFC is compared with STATCOM and SSSC on transient stability improvement in two area system. The effectiveness of UPFC over STATCOM and SSSC in two area power system is illustrated in the simulation result by enhancing the transient stability. The Section II in the paper explains about multimachine two area power system and section III explains simulation studies on multimachine two area power system including FACTS devices. Section IV includes conclusion.

II. INTER AREA POWER SYSTEM MODEL

In this paper, study has been carried out on two area four machines system. Fig 1 shows the test system used for transient stability studies. Weak transmission line between bus 7 and bus 9 connects The test system comprising of two areas. At each area two generators, each having 900 MVA capacity has been installed. At bus 7 and 9 two constant loads are applied to the system.

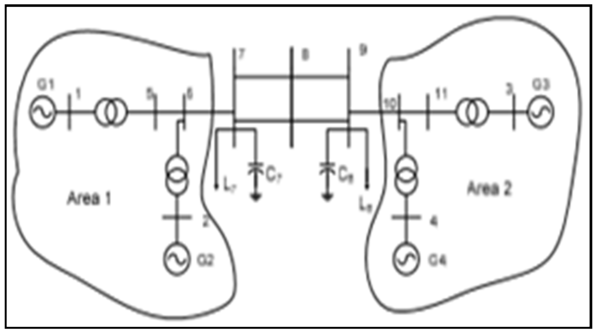

Fig. 1 Four machine two area test system

Appendix I, II and III respectively shows the locations of FACTS devices such as SSSC, STATCOM and UPFC that has been installed at bus 8.

III. SIMULATION RESULTS

A. Inter Area System with SSSC

In modified model of test system, SSSC is located at bus 8, and is in series with tie line [Appendix –I]. The phasor model of typical three levels PWM inverter has been used for SSSC with a rating of ± 100 MVA. A three phase symmetrical short circuit fault of 20 cycle duration has been created at bus 7 to study the test system during disturbances. After initiation of the fault the fault clearing time taken was 4 cycles. Fig. 2 to Fig. 5 shows the variations of different parameters such as terminal voltage of generators, load angle δ and terminal voltages of load 1 and load 2. From the results it can be observed that under steady state conditions the terminal voltage of generators settle down to about 1.03 p. u. for G1 & G4, 1.01 p. u. for G2 and 1.0 p.u. for G3. From Fig. 8 it is evident that inter area oscillations have been damped out and generators G1, G2, G3 and G4 have settled at 43.39°, 42.42°, 43.75°and 42.42° respectively. From Fig. 4 and Fig. 5 it is clear that voltage magnitude at load terminals of area 1 and area 2 have settled at 0.96 p. u., which is practically acceptable.

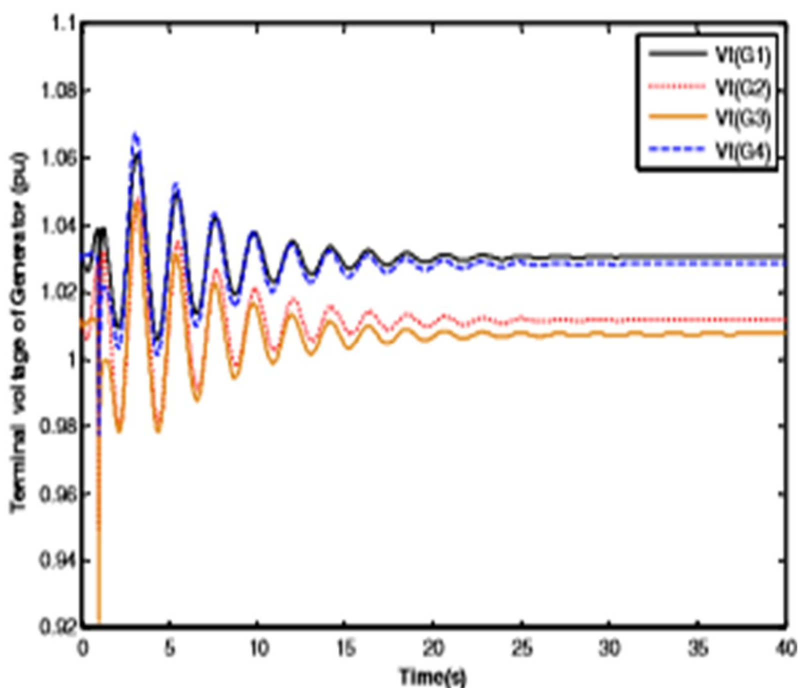

Fig. 2 Variations in terminal voltages of the generators with SSSC

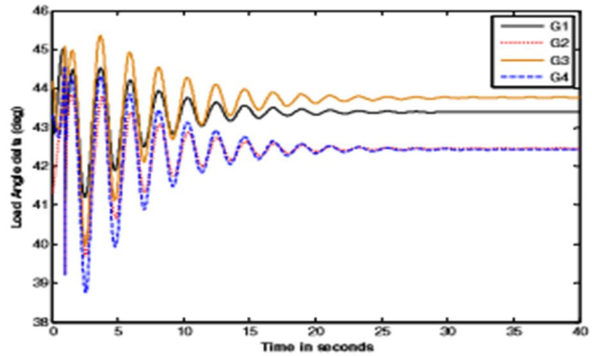

Fig. 3 Variation in load angle of the generator with SSSC

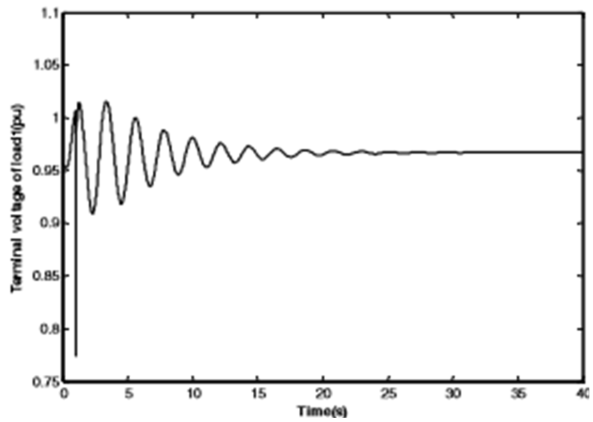

Fig. 4 Variation of terminal voltage at load 1 with SSSC

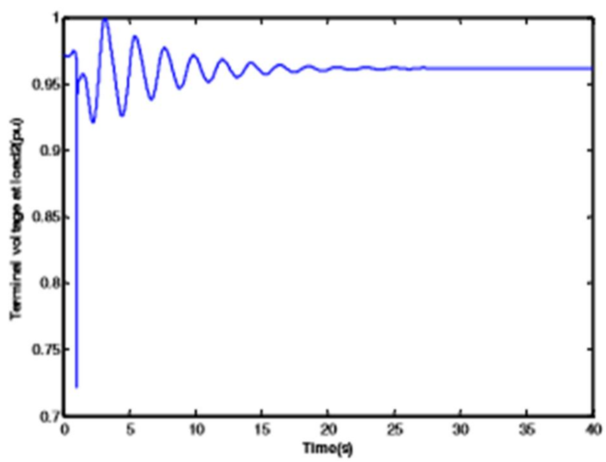

Fig. 5 Variation of terminal voltage at load 2 with SSSC

B. Inter Area System with STATCOM

Appendix II shows the modified model of test system with STATCOM. In modified model, at bus 8 with a rating of ± 250 MVA STATCOM has been placed in shunt position. In test system with STATCOM, a simulink based phasor model of a typical three level PWM has been used. A three phase symmetrical short circuit fault of 20 cycle duration has been created at bus 7, to study the test system during disturbances. After initiation of the fault, the fault clearing time taken was 4 cycles. Fig 6 to Fig 9 shows the variations of parameters such as terminal voltage of generators, load angle δ and terminal voltage of load 1 and load 2. After initial oscillations under steady state conditions the terminal voltages at generator terminals have settled to acceptable values of about 1.03 p. u. for G1 & G4 and 1.0 p. u. for G2 & G3 is clear from Fig 6.

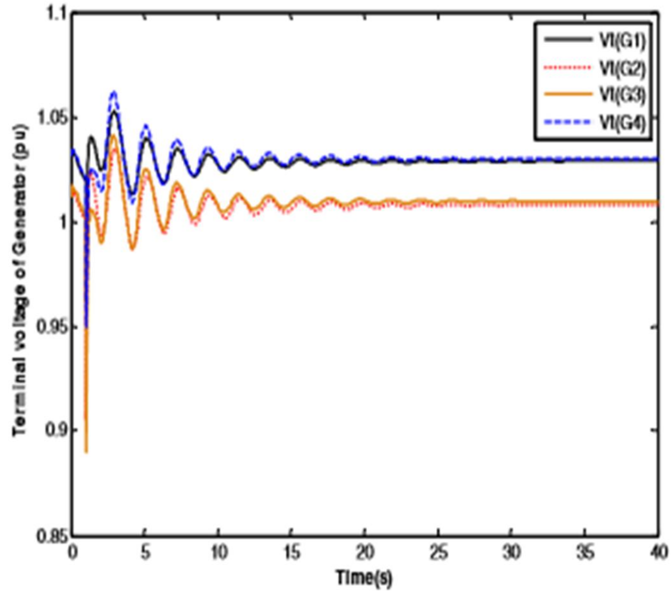

Fig. 6 Terminal Voltage of generators with STATCOM

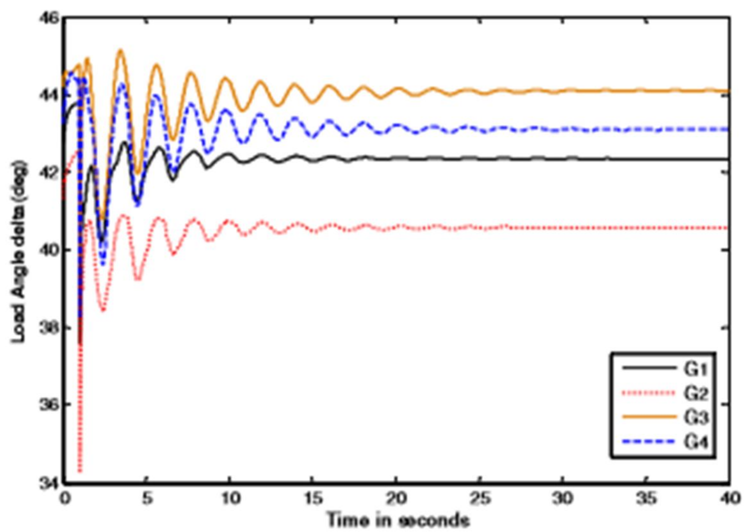

Fig. 7 Variations of load angle δ of generators with STATCOM

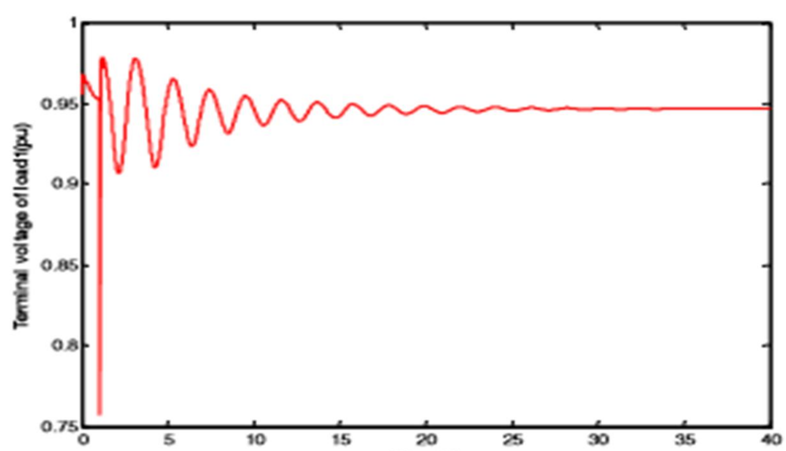

Fig. 8 Variation of terminal voltage at Load 1 with STATCOM

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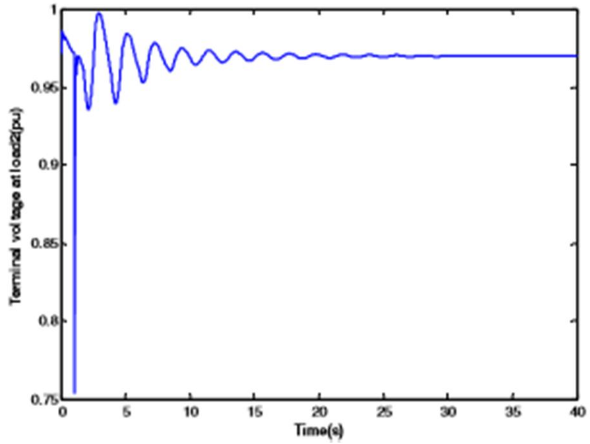

Fig. 9 Variation of terminal voltage at load 2 with STATCOM

From Fig. 7 it is evident that inter area oscillations have been damped out and generators G1, G2, G3 and G4 have settled at 42.43°, 40.58°, 44.08° and 43.09° respectively. It can also be observed from Fig. 8 and Fig. 9 that terminal voltages at load terminals of area 1 and area 2 have settled to acceptable values of 0.95 p. u. and 0.97 p. u. respectively. It can also be observed from Table I that active power transfers from area 1 to area 2 have been increased to 413. 5 MW.

C. Inter Area System with UPFC

In the modified model of two area system, UPFC has been placed at bus 8 and is in series with the tie line [Appendix III]. In the modified model of test system, the simulink based phasor model of UPFC comprising of two IGBT based converters one connected in shunt (±250 MVA) and other connected in series (± 100 MVA) with bus 8 has been used. At bus 7,a three phase symmetrical short circuit fault of 20 cycle duration has been created to study the system during disturbances, similar to SSSC and STATCOM. After the initiation of fault ,the fault clearing time taken was 4 cycles. The simulated results of terminal voltage of generators, load angle δ and terminal voltages of load 1 and load 2 are shown from Fig. 10 to Fig. 13. The variations of terminal voltage at each generator in area 1 and area 2 are shown in Fig. 10.

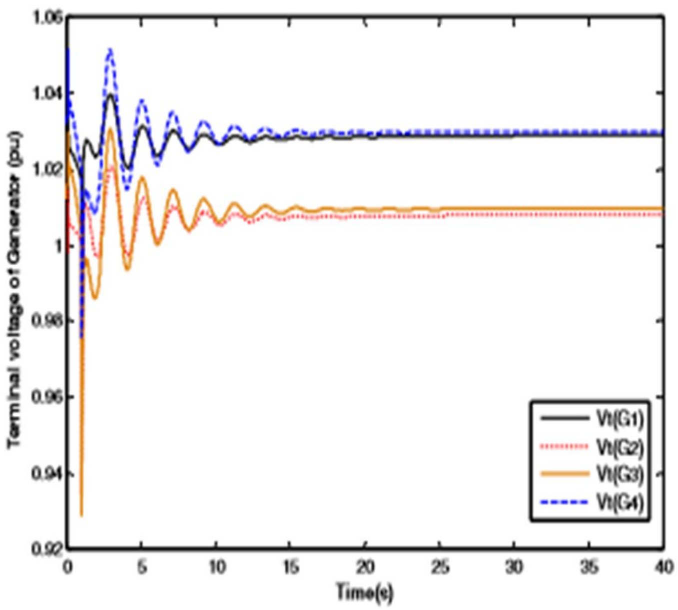

Fig. 10. Terminal voltage of generators with UPFC

From the result it can be observed that terminal voltage of generators settle down to about 1.03 p. u. for G1 & G4 and 1.01 p. u. for G2 & G3 under steady state conditions. From Fig. 11 it is evident that inter area oscillations have been damped out and generators G1, G2, G3 and G4 have settled at 42.44°, 40.7°, 44.18° and 43.23° respectively.

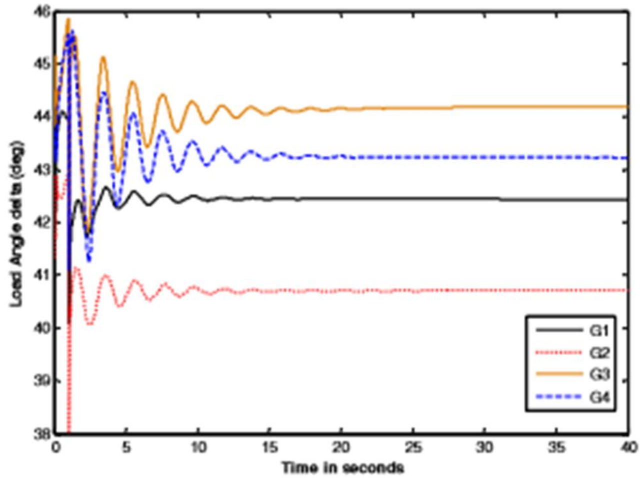

Fig. 11 Variations in load angles of generators with UPFC

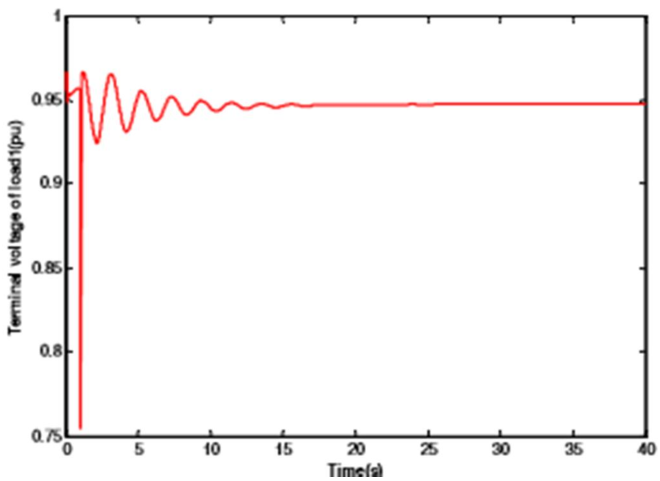

Fig. 12 Variation of terminal voltage at load 1 with UPFC

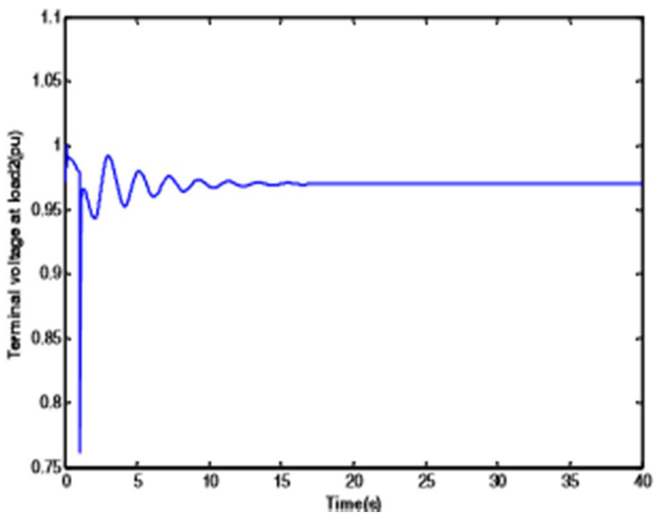

Fig. 13 Variation of terminal voltage at load 2 with UPFC

From Fig. 12 and Fig. 13 it is clear that voltage magnitudes at load terminals of area 1 and area 2 have settled at 0.95p.u. and 0.97 p.u. respectively, which is practically acceptable. From Table I, it can also be observed that active power transfers from area 1 to area 2 have been increased to 415.1 MW. To illustrate the effect of different FACTS devices for stability enhancement of two area multimachine power system, a comparison study has shown in Fig 14 .

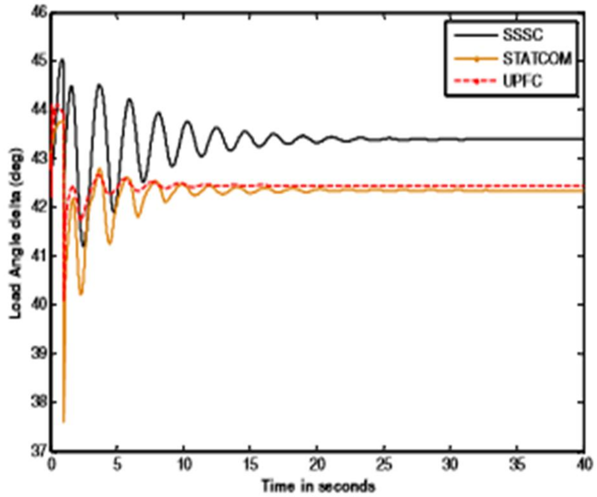

Fig. 14 Variations of load angle of Generator 1 with different FACTS devices

Table 1performance comparisons of different facts devices for inter area system.

FACTS Devices	Voltage Magnitude (p. u.), |V|				Load angle (degree) , δ				Inter Area Power Flow (MW)
	G1	G2	G3	G4	G1	G2	G3	G4	P
SSSC	1.03	1.01	1.0	1.03	43.49	42.42	43.75	42.42	376.7
STATCOM	1.03	1.01	1.0	1.03	43.43	40.48	44.08	43.09	413.5
UPFC	1.03	1.01	1.0	1.03	42.44	40.7	44.18	43.23	415.1

It can be concluded from the Fig. 14, that with the use of UPFC, load angle for generator 1 has settled much earlier as compared to other FACTS devices and it can also be observed from the Table. I, that inter area active power flow have been increased to 415.1 MW with the use of UPFC. Therefore, it can be concluded that UPFC is the most powerful device for transient stability enhancement of two area multimachine test system and hence the paper facilitates the use of UPFC for enhancement of transient stability.

IV. CONCLUSION

In this paper, transient stability enhancement of two area multimachine power system including three different FACTS devices has been compared. The various performance of UPFC in terms of voltage magnitude of generators (G1, G2, G3, and G4) and load (L1, L2) along with load angle (δ) are compared with other FACTS devices such as SSSC and STATCOM. From simulation results it is clear that UPFC is most effective device for transient stability improvement as compared to other FACTS devices.

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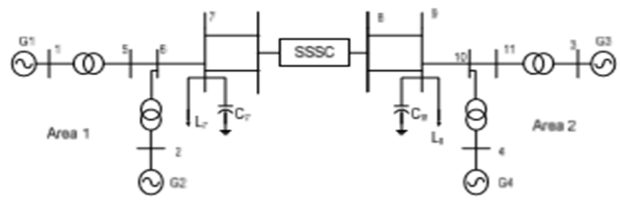
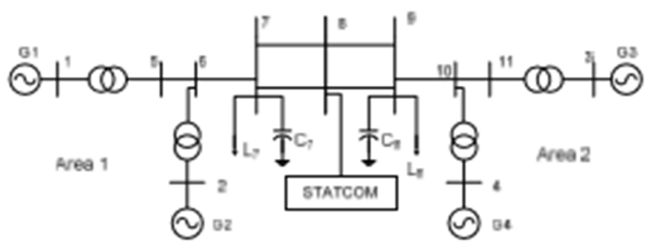
APPENDIX I



APPENDIX II



APPENDIX III