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Transient Stability Enhancement of Multi-Machine System Using FACTS Controllers

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Abstract*—With increasing complexity in power system it becomes a concern to power system stability and especially to aspects of transient stability and small signal stability. Transient stability plays a significant role in stable operation of power system during fault and large disturbance. This paper studies the comparative performance of SVC (Static Var Compensator) and UPFC (Unified Power Flow Controller) for the improvement of transient stability of multi-machine system. The UPFC is more effective FACTS(Flexible AC Transmission System) device for controlling active and reactive power flow in a transmission line and power oscillation damping by controlling its series and shunt parameters. Simulations are carried out in MATLAB/Simulink environment for multi-machine system to analyses effects of SVC and UPFC on transient stability performance of the system. The performance of UPFC is compared with SVC. The simulation results demonstrate the effective and robustness of the proposed UPFC for transient stability improvement of the system.

***Index Terms*—FACTS, MATLAB/Simulink, SVC, UPFC, Transient stability, Multi-machine system**

I. INTRODUCTION

World's most of the electric power supply systems are widely interconnected. These interconnections are needed because, apart from delivery, the purpose of transmission network is pool power plants and load centers in order to minimize the total power generation capacity and fuel cost. As the power transfers grow, the power system becomes increasingly more and more complex to operate and the system can become less secure for riding through the major outages. It may lead to large power flows with inadequate control, excessive reactive power in various parts of the system, large dynamic swings between different parts of the system, and thus the full potential of transmission interconnections cannot be utilized. With the increased loading of long transmission lines, the problem of transient stability after a major fault can become a transmission power-limiting factor [1]. Similarly other stability problems may be there due to momentary system conditions [2]. The power system should adapt to momentary system conditions i.e. power system should be flexible. Stability depends upon both the initial operating conditions of the system and the severity of the disturbance. Recent development of power electronics introduces the use of Flexible AC Transmission System (FACTS) controllers in power systems. FACTS controllers are capable of controlling the network condition in a very fast manner and this feature of FACTS can be exploited to improve the voltage stability, and steady state and transient stabilities of a complex power system [3]-[5]. This allows increased utilization of existing network closer to its thermal loading capacity, and thus avoiding the need to construct new transmission lines.

Static VAR Compensator (SVC) is a first generation FACTS device that can control voltage at the required bus thereby improving the voltage profile of the system. The primary task of an SVC is to maintain the voltage at a particular bus by means of reactive power compensation (obtained by varying the firing angle of the thyristors). SVCs have been used for high performance steady state and transient voltage control compared with classical shunt compensation. SVCs are also used to dampen power swings, improve transient stability, and reduce system losses by optimized reactive power control [6]-[7].

Among the available FACTS devices, the Unified Power Flow Controller (UPFC) is the most versatile one that can be used to improve steady state stability, dynamic stability and transient stability. The UPFC can independently control many parameters since it is the combination of Static Synchronous Compensator (STATCOM) and SSSC. These devices offer an alternative mean to mitigate power system oscillations. It has been reported in many papers that UPFC can improve stability of single machine infinite bus (SMIB) system and multi-machine system [8]. The inter-area power system has special characteristic of stability behavior [9]. This paper investigates the improvement of transient stability of a two-area power system with a UPFC. A MATLAB/Simulink model is developed for a two-area power system with a UPFC. The performance of UPFC is compared with SVC. From the Simulation results, it is inferred that UPFC is an effective FACTS device for transient stability improvement.

II. FACTS CONTROLLERS

FACTS controllers may be based on thyristor devices with no gate turn-off or power devices with gate turn-off capability. FACTS controllers are used for the dynamic control of voltage, impedance and phase angle of high voltage AC transmission lines. The basic principles of the following FACTS controllers, which are used in the two-area power system under study, are discussed briefly.

A. Static Var Compensator (SVC)

Static Var compensator are used by utilities in transmission system or several purpose the main purpose of svc is usually for rapid control of voltage at weak point in a network mainly svc may be installed at the midpoint of the transmission interconnection or at the line ends .static var compensator are shunt connected fact device whose output are varied to control the voltage of the electric power system by generating or absorbing reactive power. Generally SVC is connected as fixed capacitor thyristor control reactor (FC-TCR) as shown in figure 1[7]. The SVC is connected to a coupling transformer that is connected to the bus whose voltage to be improved the reactance of FC-TCR is a varied by firing angle control of antiparallel thyristor firing angle can be controlled through a pi controller in such a way that the voltage of the bus where the svc is connected is maintained as a reference value.

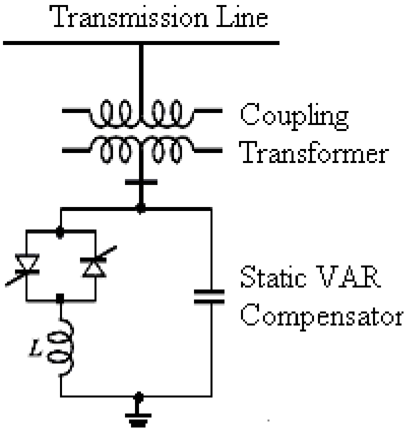


Fig. 1 Configuration of SVC

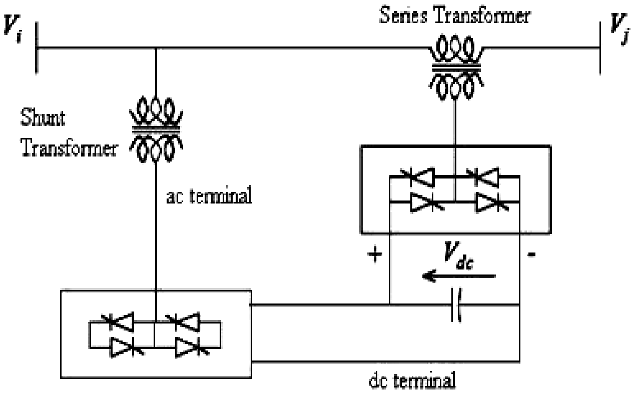


Fig. 2 Configuration of UPFC

B. Unified Power Flow Controller (UPFC)

Among the available FACTS devices, the Unified Power Flow Controller (UPFC) is the most versatile one that can be used to enhance steady state stability, dynamic stability and transient stability. The basic configuration of a UPFC is shown in Fig. 2[8]. The UPFC is capable of both supplying and absorbing real and reactive power and it consists of two ac/dc converters. One of the two converters is connected in series with the transmission line through a series transformer and the other in parallel with the line through a shunt transformer. The dc side of the two converters is connected through a common capacitor, which provides dc voltage for the converter operation. The power balance between the series and shunt converters is a prerequisite to maintain a constant voltage across the dc capacitor. As the series branch of the UPFC injects a voltage of variable magnitude and phase angle, it can exchange real power with the transmission line and thus improves the power flow capability of the line as well as its transient stability limit. The shunt converter exchanges a current of controllable magnitude and power factor angle with the power system. It is normally controlled to balance the real power absorbed from or injected into the power system by the series converter plus the losses by value.

III. MULTI-MACHINE POWER SYSTEM MODEL

Consider a two-area power system (Area-1 & Area-2) with series and shunt FACTS devices, connected by a double circuit long Transmission line as shown in fig.3 and fig.4. Here, the series FACT devices such as UPFC are equipped between bus-2 and bus-3 and the shunt FACT device such as SVC is equipped at bus-2. The direction of real power flow is from Area-1 to Area-2. In the two-area power system model, the Area-1 consists of Generator 1 (G1) and Generator 2 (G2) and the Area-2 consists of Generator 3 (G3) and Generator 4 (G4). The system data are given in [10].

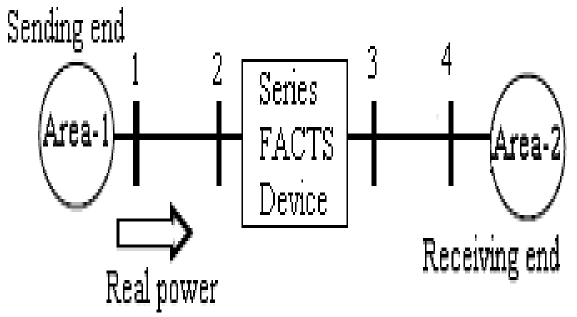


Fig. 3 Two-area power system with series FACTS device

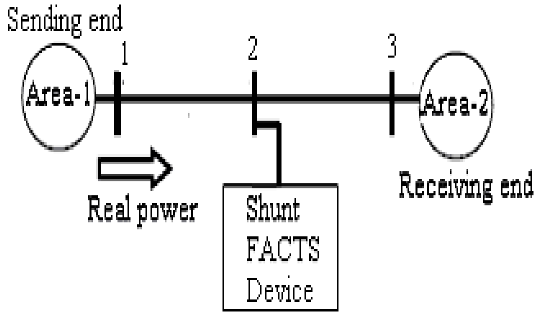
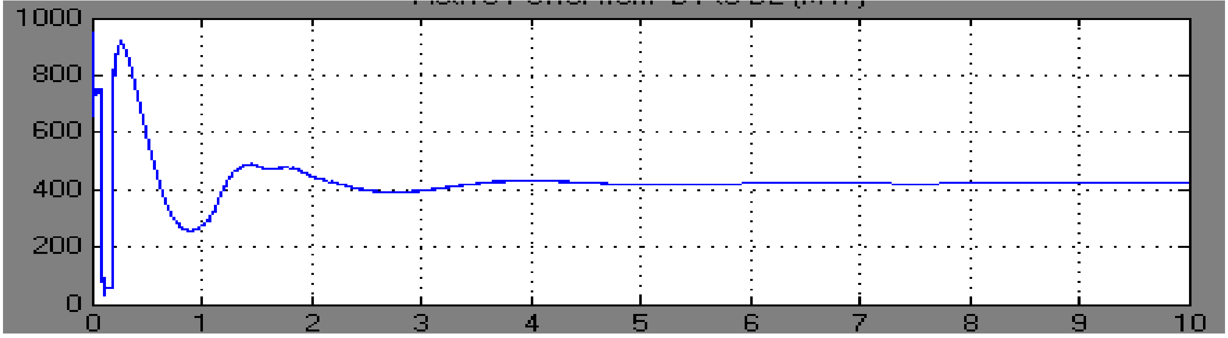


Fig. 4 Two-area power system with shunt FACTS device

IV. SIMULATION RESULTS AND DISCUSSION

Fig-3 and Fig-4 show multi-machine system for series and shunt FACTS controller. It is considered that a 3-phase symmetrical short circuit fault of 100 milli-seconds duration occurs at bus-3 in case of UPFC and 3-phase symmetrical short circuit fault of 100 milli-seconds duration occurs at bus-2 in case of SVC. The system is simulated in MATLAB/Simulink environment and the corresponding results without FACTS controller of line power flow, terminal voltage of area-1 and area-2, rotor angle oscillation (delta1-delta2) and (delta1-delta4), and speed oscillation (ω3-ω4) and (ω1-ω4) are shown in Fig.5 (a-f). Fig.5 there is oscillation in line power, terminal voltage, rotor angle and rotor speed. Fig.6(a-f) shows the response curves of line power flow, terminal voltage of area1 and area2, rotor angle oscillation (delta1-delta2) and (delta1-delta4), and speed oscillation (ω3-ω4) and (ω1-ω4) with UPFC. It is seen that with UPFC oscillations are damps out. Fig.7(a-f) shows the response curves of line power flow, terminal voltage of area1 and area2, rotor angle oscillation (delta1-delta2) and (delta1-delta4), and speed oscillation (ω3-ω4) and (ω1-ω4) with SVC. It is seen that oscillation are damps out and transient stability of the system is improved.



Time in seconds
Fig-5(a)

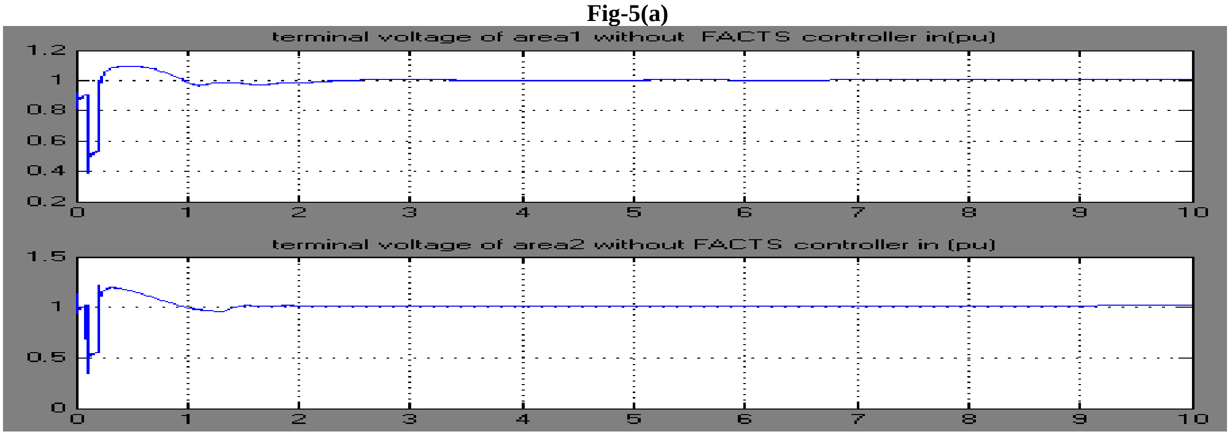


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Fig-5(b)

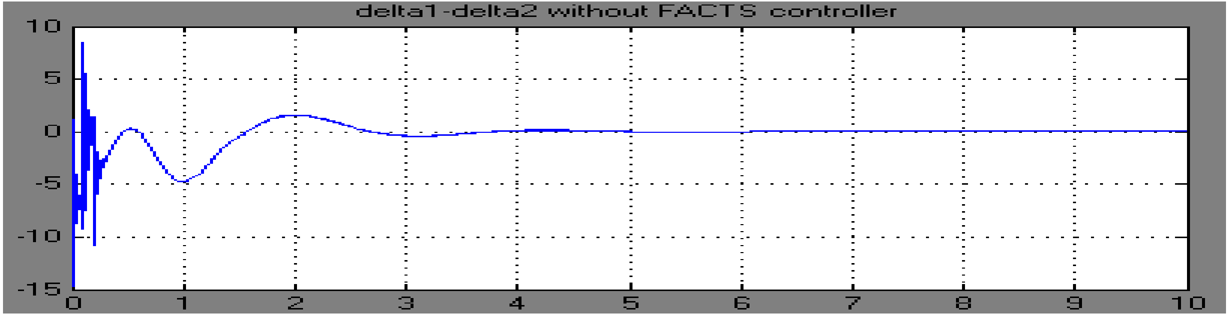

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Fig-5(c)

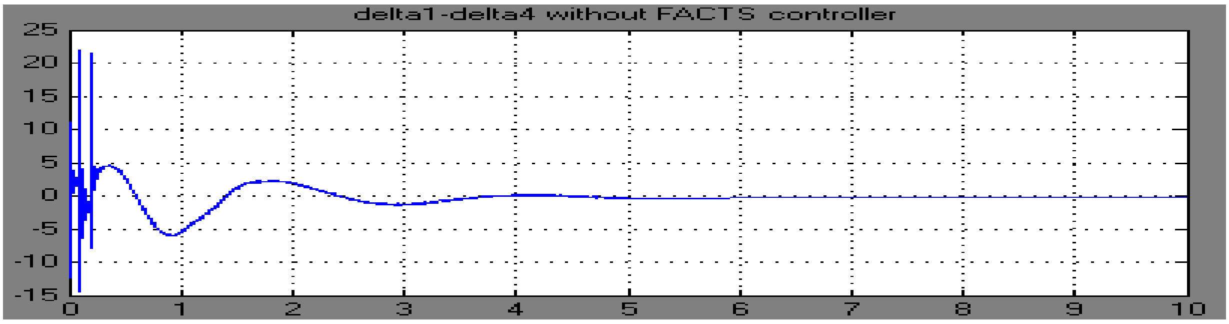

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Fig-5(d)

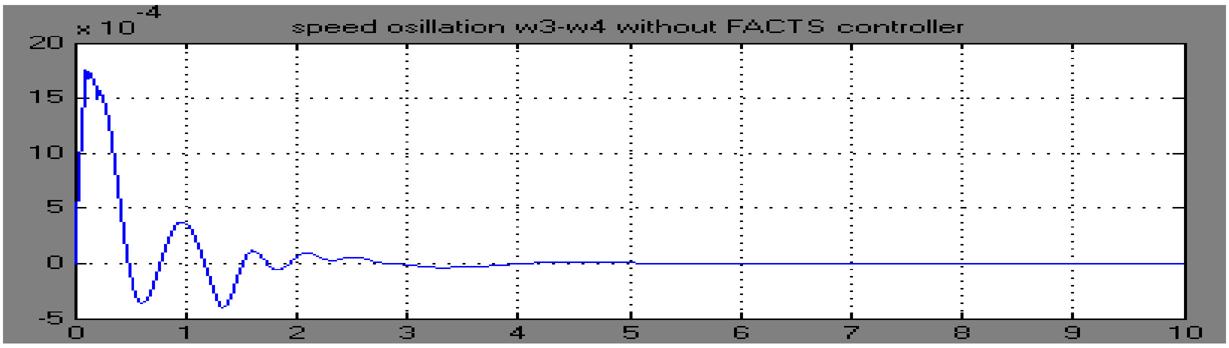

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Fig-5(e)

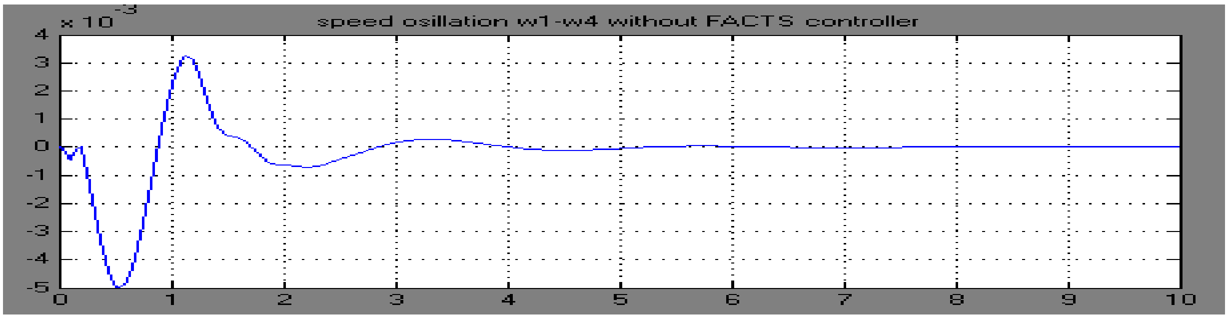

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Fig-5(f)
Fig-5-(a-f) Response curves without FACTS controller

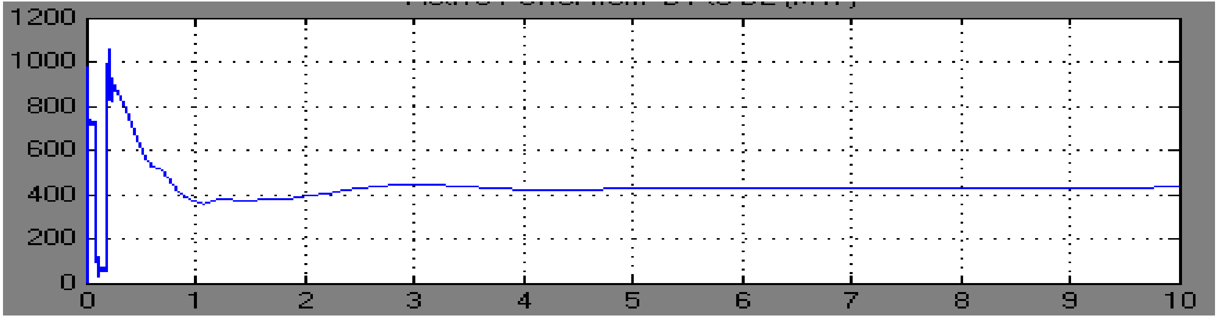

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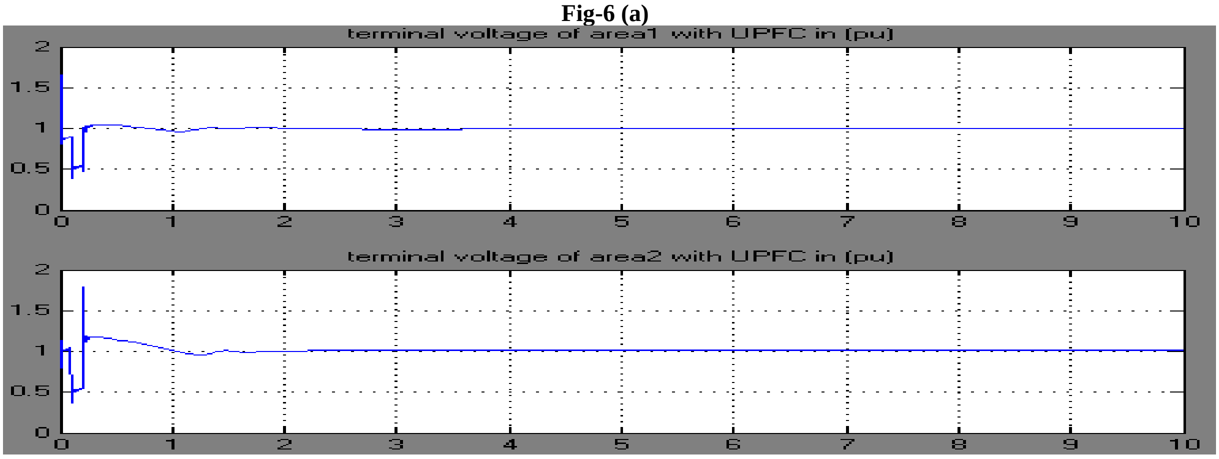
Fig-6 (a)



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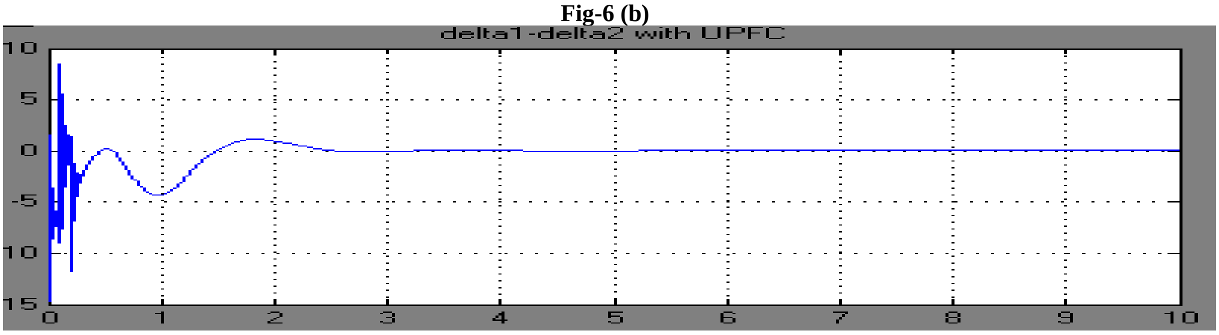

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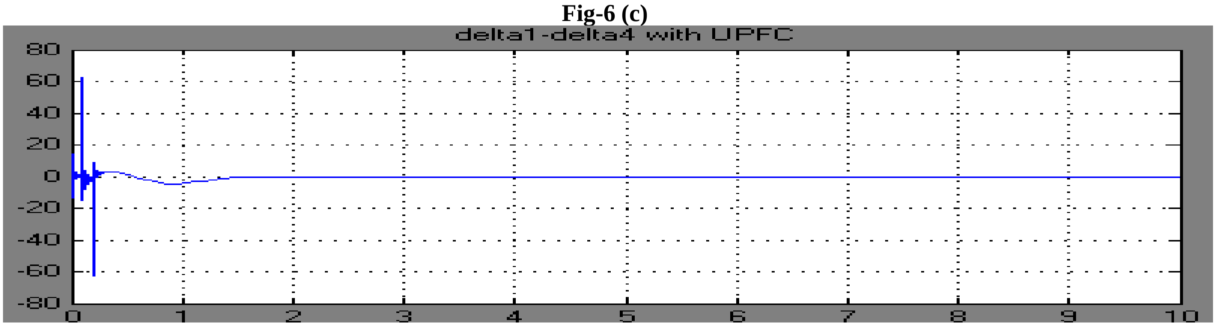

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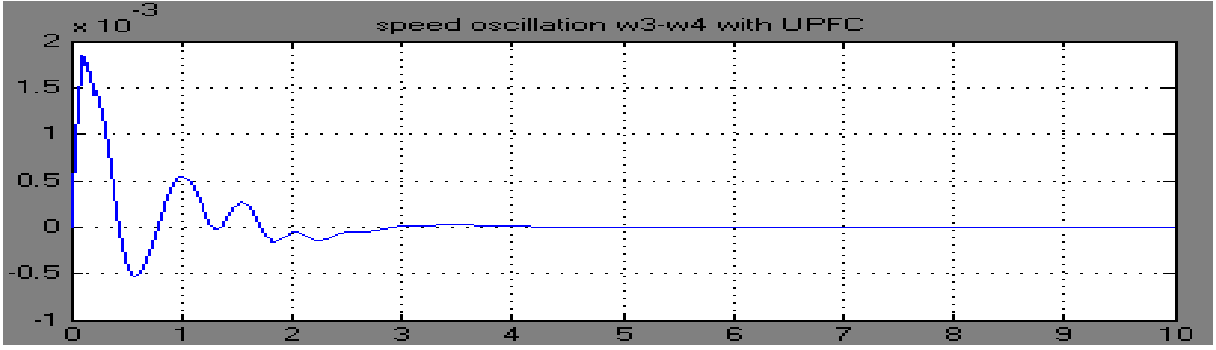

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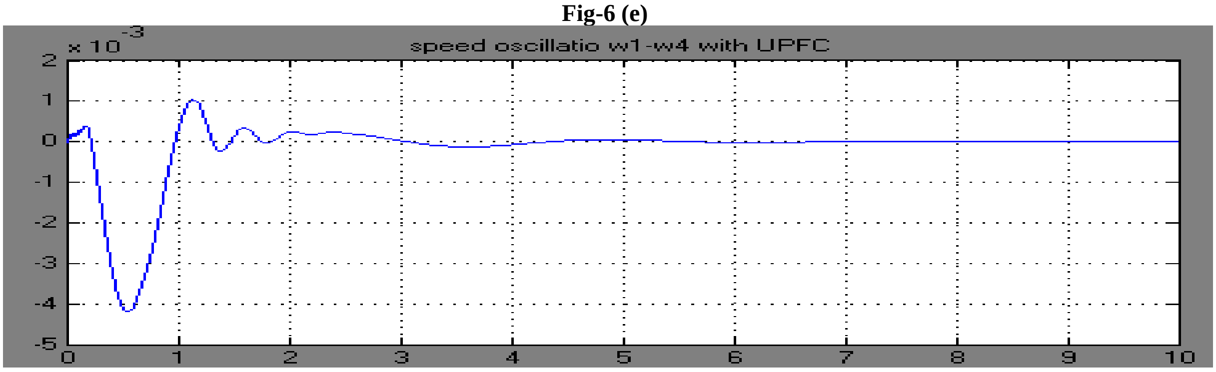

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Fig-6 (f)

Fig.6 (a-f) response curves with UPFC controlled

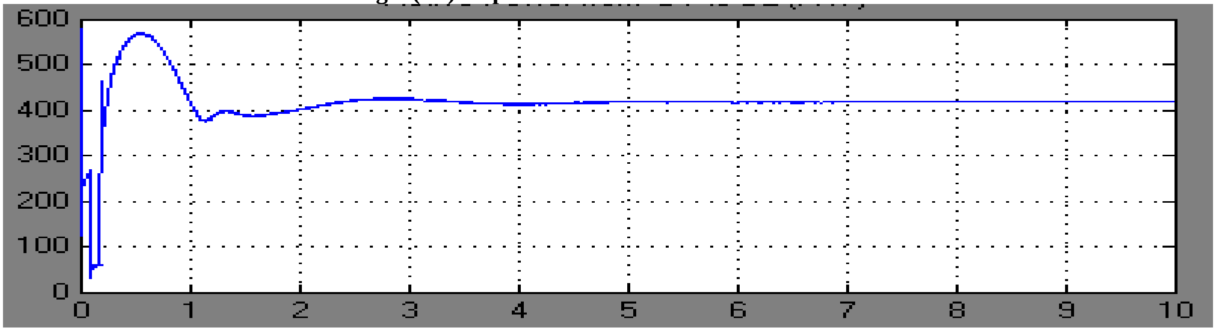

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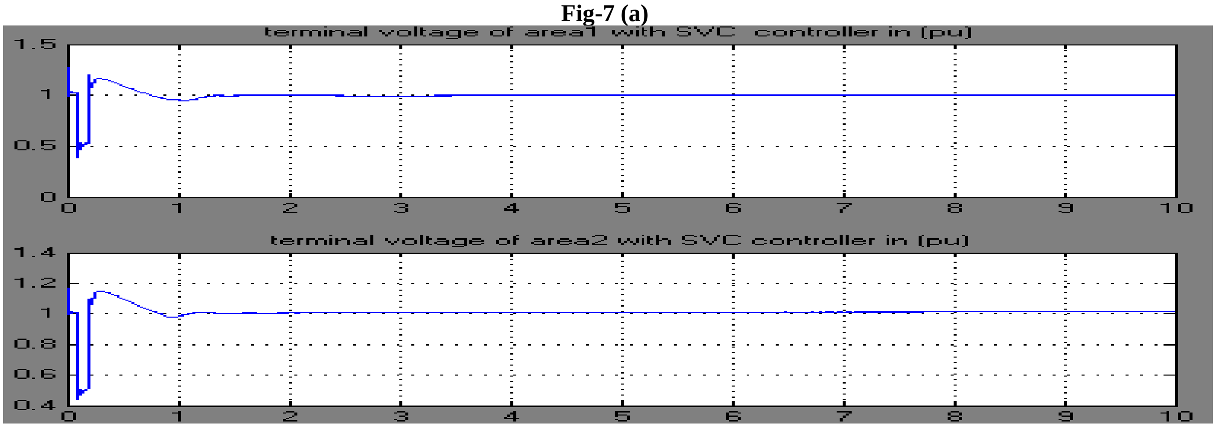
Fig-7 (a)



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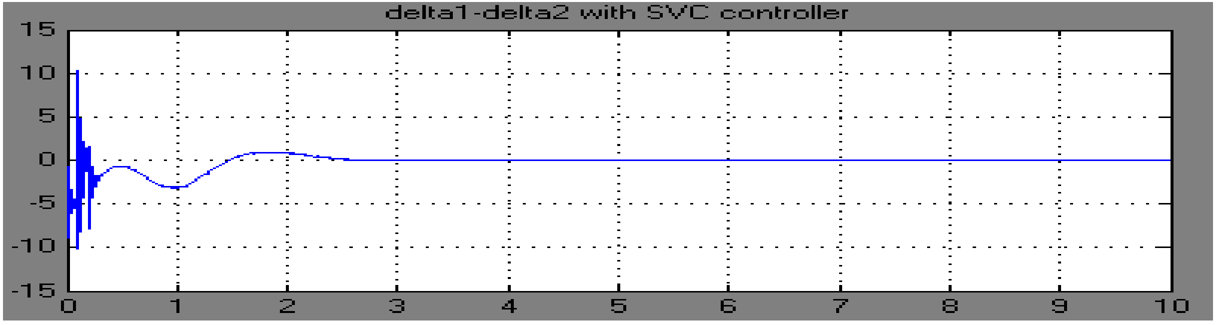

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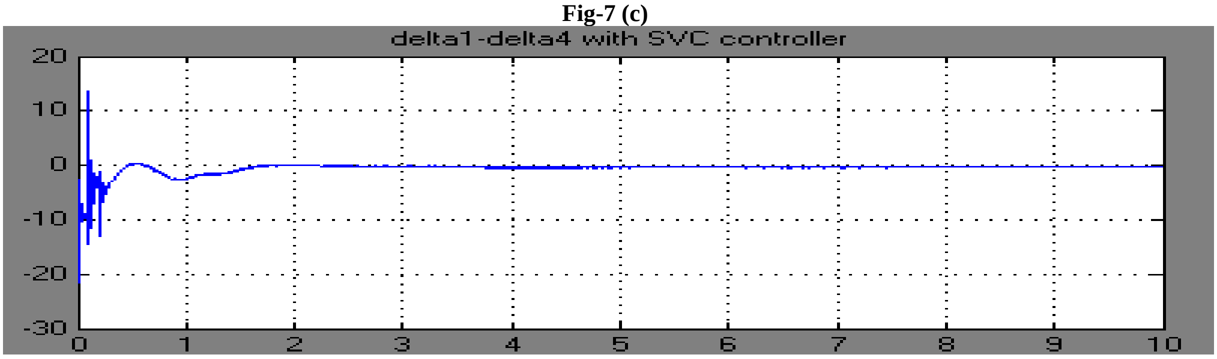

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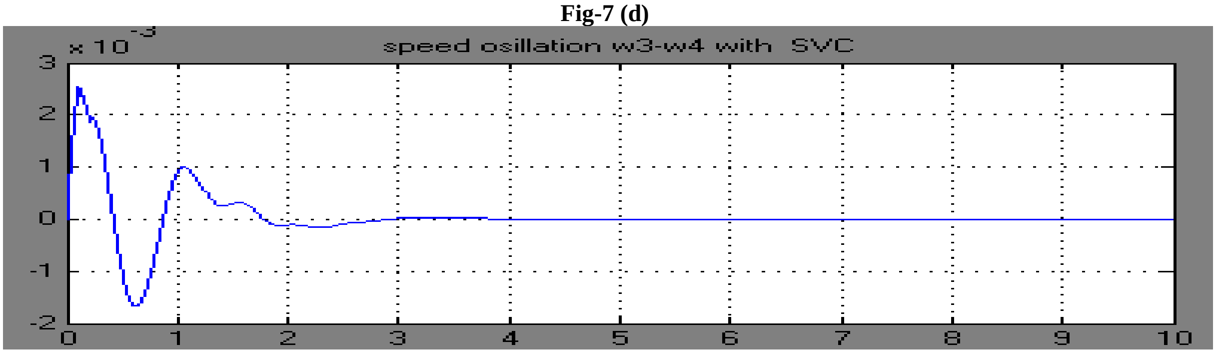

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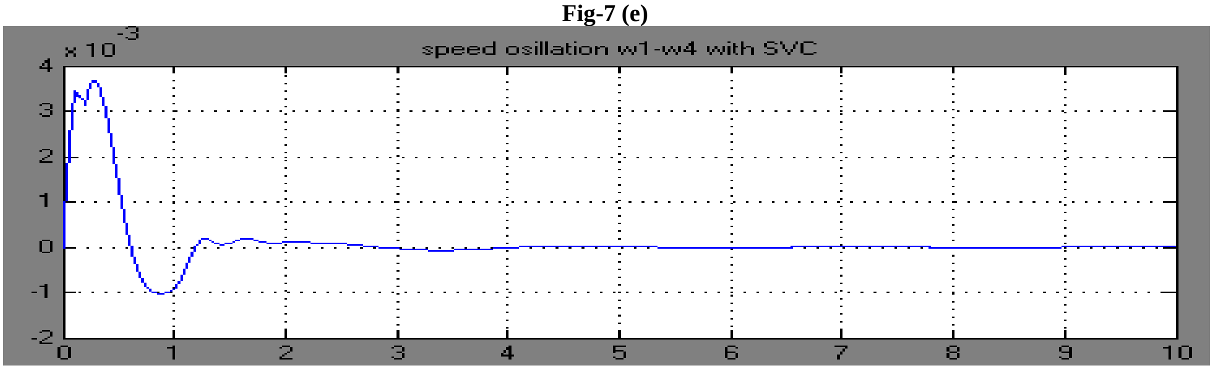


Time in seconds

Fig-7 (f)

Fig.7 (a-f) response curves with SVC controller

Comparison between UPFC and SVC for power system stability enhancement

From the simulation results a comparison is made for stability enhancement of multi-machine power system without FACTS devices and with shunt and series FACTS devices shown in Fig-5(a-f), Fig-6(a-f) and Fig-7(a-f) respectively. It is investigated that the UPFC is the effective FACTS device for stability enhancement of the system.

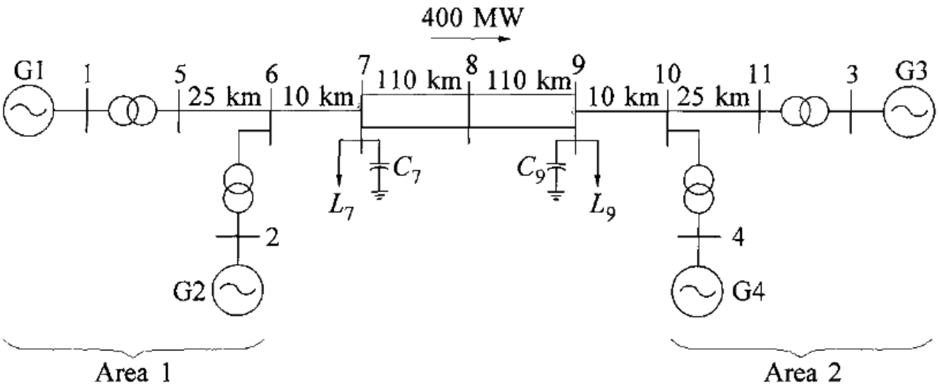
V. CONCLUSION

In this paper, the power system stability improvement of a multi-machine power system by various FACTS devices such as SVC and UPFC is analysed. The dynamics of the system is studied at the event of a major disturbance. Then the performance of the UPFC for power system stability improvement is compared with SVC. It is clear from the simulation results that there is a considerable improvement in the system performance with the presence of UPFC for which the settling time is reduced.

APPENDIX

The system consists of two similar areas connected by a weak tie. Each area consists of two coupled units, each having a rating of 900 MVA and 20kV. The generator parameters in per unit on the rated MVA and kV base are:

$X_d = 1.305$	$X'_d = 0.296$	$X''_d = 0.252$	$X_q = 0.474$	$X''_q = 0.243$
$X_l = 0.18$	$T'_d = 0.01$	$T''_d = 0.53$	$T''_q = 0.1$	H= 6.5 (for G1 to G4)



The transmission system nominal voltage is 230kV. the parameters of the lines in per unit on 100MVA, 230kV base are:

R=0.0001 pu/km xl= 0.001 pu/km bc= 0.00175 pu/km

The system is operating with area 1 exporting 400MW to area 2, and the generating units are loaded as follows:

G1: P = 700MW Q = 185 MVAr Et = 1.03∟20.20
G2: P = 700MW Q = 235 MVAr Et = 1.01∟10.50
G3: P = 719MW Q = 176 MVAr Et = 1.03∟-6.80
G4: P = 700MW Q = 202 MVAr Et = 1.03∟-17.00

The loads and reactive power supplied

A: PL = 967 MW QL = 100MVAr QC = 187MVAr
B: PL= 1767 MW QL = 100MVAr Qc = 187 MVAr

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