Transient Stability Analysis with SSSC and UPFCfor Four Machine Two Area Test System with and without PSS using Matlab/Simulink

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Abstract: **The objective of this paper is to analyze the performance of a static synchronous series compensatorand Unified power flowcontroller with and without power system stabilizer(PSS). To illustrate the performance of the FACTS(Flexible AC Transmission systems) controller SSSC and UPFC with and without PSS, IEEE two area 11 Bus Multi-Machine power System has been considered. The designed system tested using matlab simulink software and result was compared. The simulation was run for 20 seconds. Time domain simulation method is implemented in this paper. UPFC showed better improvement in transient stability compare with SSSC. The performance was also compared with GPSS(Generic Power system Stabilizer) and MBPSS Multiband Power System Stabilizer) to see the effect of further oscillationscreated during and after fault in the system with SSSC and UPFC. The MBPSS showed better effect than GPSS to damp the further oscillations created in the system during and after fault with SSSC and UPFC.**

Keywords: **Transient Stability, SSSC, UPFC, GPSS, MBPSS, Matlab/Simulink**

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1. Introduction:

The power demand depends on load demand. If active power demand increases then speed of generators drop down and frequency of EMF decreases. If the reactive power demand increases then speed does not get affected but it is the magnitude of voltage which decreases. Thus load demand can make generators unstable. If load changes are small and stability is maintained, it is called as steady state stability. If load changes are large and sudden, still stability is maintained, it is transient stability.Stability must be maintained under any circumstances to have uninterrupted power supply[1].

Stability is the response of the Synchronous Generator, supplying power to the external network following a disturbance. Under steady operation, it runs at Synchronous speed and when there is a perturbation, small or large, then machine tends to swing. It may either get restored to its original state or new state or fall out of step. Thus, transient stability is defined as the ability of the power system to maintain synchronism when subjected to a severe transient disturbance, such as a fault on transmission facilities, sudden loss of generation, or loss of a large load. The resulting system response involves large excursions of generator rotor angles and is influenced by the nonlinear power-angle relationship. Transient stability depends on both the initialoperating state of the system and the severity of the disturbance. The transient stability can further be divided into two classes i)First-Swing Stability: for firstone second after a system fault (simple generator model & no control model). ii) Multi Swing Stability: system analysis over long period of time (more sophisticated machine model) [1,2,11].

To reduce the effect of transient stability and oscillations created in the power systems during and after faults, flexible AC transmission systems (FACTS) controllers and power system stabilizers are used in the system.FACTS controllers are capable of controlling the network condition in a very effective manner and this feature of FACTS can be exploited to improve the voltage stability, steady state and transient stabilities of a complex power system. This allows increased utilization of existing network closer to its thermal loading capacity, and thus avoiding the need to construct new transmission lines. In this paper SSSC and UPFC phasor type models are used for study [3,4].

Due to excitation and system parameter combinations under certain loading conditions can introduce negative damping into the system. In order to offset this effect and to improve system damping in general, artificial means of producing torques in phase with the speed are introduced. These are called supplementary stabilizing signals and the networks used to generate these signals are known as power system stabilizers [2].

Power System Stabilizer (PSS) is a feedback controller, for a synchronous generator which provides an additional stabilizing signal to Automatic Voltage Regulator (AVR) through voltage reference input in order to damp out Low Frequency Oscillations (LFO). The purpose of PSS is to damp out the generator rotor oscillation in the range of 0.1 to 3 Hz. To damp out the electromechanical oscillations, PSS is expected to produce an electrical torque components should be in phase with rotor speed deviation of the generator. There are two types of stabilizer (i) Generic power system stabilizer model using the acceleration power (Pa= difference between mechanical power Pm and output electrical power Peo) and a (ii) Multi-band power system stabilizer using the speed deviation (dw)[5,7,16].

2. Power System Stablizer (PSS) Models

2.1. Generic Power System Stabilizer

The Generic Power System Stabilizer (PSS) block can be used to add damping to the rotor oscillations of the synchronous machine by controlling its excitation. The disturbances occurring in a power system induce electromechanical oscillations of the electrical generators. These oscillations, also called power swings, must be effectively damped to maintain the system stability. The output signal of the PSS is used as an additional input (vstab) to the Excitation System block. The PSS input signal can be either the machine speed deviation, dw, or its acceleration power, Pa = Pm - Peo (difference between the mechanical power and the electrical power). The Generic Power System Stabilizer is modeled by the following nonlinear system:

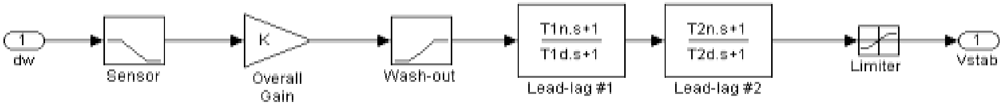

Figure 1. The Block Diagram of the Generic Power System Stabilizer

Figure 1 shows the block diagram of the generic power system stabilizer (PSS), whichcan be modeled by using the following transfer function:

$G(s) = K *[(T_{1n}.S + 1)(T_{2n.}S +1) / (T_{1d.}S+1)(T_{2d.}S+1)]$ (1)

To ensure a robust damping, the PSS should provide a moderate phase advance at frequencies of interest in order to compensate for the inherent lag between the field excitation and the electrical torque induced by the PSS action. The model consists of a low-pass filter, a general gain, a washout high-pass filter, a phase-compensation system, and an output limiter. The general gain *K* determines the amount of damping produced by the stabilizer.The washout high-pass filter eliminates low frequencies that are present in the *dw* signal and allows the PSS to respond only to speed changes. The phase-compensation system is represented by a cascade of two first-order lead-lag transfer functions used to compensate the phase lag between the excitation voltage and the electrical torque of the synchronous machine [5]

2.2. Multi-band Power System Stabilizer

The disturbances occurring in a power system induce electromechanical oscillations ofthe electrical generators. These oscillations, also called power swings, must be effectivelydamped to maintain the system's stability. Electromechanical oscillations can be classified infour main categories [1, 3, 4]:

(1) Local oscillations: between a unit and the rest of the generating station and between thelatter and the rest of the power system. Their frequencies typically range from 0.8 to 4.0Hz.

(2) Interplant oscillations: between two electrically close generation plants. Frequencies canvary from 1 to 2Hz.

(3) Interarea oscillations: between two major groups of generation plants. Frequencies aretypically in a range of 0.2 to 0.8Hz.

(4) Global oscillation: characterized by a common in-phase oscillation of all generators as foundon an isolated system. The frequency of such a global mode is typically under 0.2Hz.

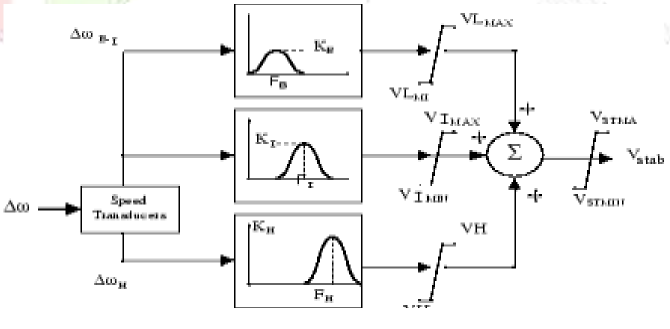

Figure 2. The Block Diagram of the Multi-band Power System Stabilizer (MB-PSS)

The need for effective damping of such a wide range, almost two decades, of electromechanical oscillations motivated the concept of the multiband power system stabilizer (MBPSS),as shown in Figure 2. Just as its name reveals, the MB-PSS structure is based onmultiple working bands. Three separate bands are dedicated to the low-, intermediate-, andhigh-frequency modes of oscillations: the low band is typically associated with the power systemglobal mode, the intermediate with the interarea modes, and the high with the local modes.Each of the three bands is made of a differential bandpass filter, a gain, and a limiter.The outputs of the three bands are summed and passed through a final limiter producing thestabilizer output *Vstab*. This signal then modulates the set point of the generator voltage regulatorso as to improve the damping of the electromechanical oscillations. To ensure robust damping,the MB-PSS should include a moderate phase advance at all frequencies of interest tocompensate for the inherent lag between the field excitation and the electrical torque induced by the MB-PSS action [4,5,8]

3. Static Synchronous Series Compensator (SSSC)

The Static Synchronous Series Compensator (SSSC) is a series device of the Flexible AC TransmissionSystems (FACTS) family using power electronics to control power flow and improve power oscillation damping on power grids. The SSSC injects a voltage Vs in series with the transmission line where it is connected.As the SSSC does not use any active power source, the injected voltage must stay in quadrature with line current. By varying the magnitude Vq of the injected voltage in quadrature with current, the SSSC performs the function of a variable reactance compensator, either capacitive or inductive. The variation of injected voltage is performed by means of a Voltage-Sourced Converter (VSC) connected on the secondary side of a coupling transformer. The VSC uses forced-commutated power electronic devices (GTOs, IGBTs or IGCTs) to synthesize a voltage V_conv from a DC voltage source as shown in fig.3[9,12,14].

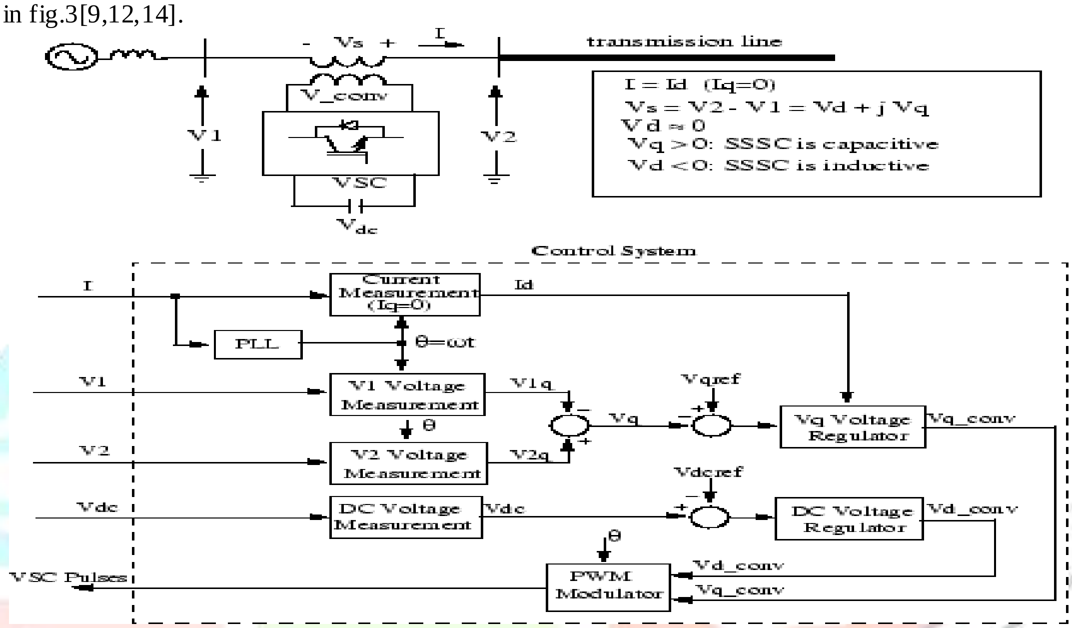

Figure3. Single-line Diagram of a SSSC and Its Control System Block Diagram

A capacitor connected on the DC side of the VSC acts as a DC voltage source. A small active power is drawn from the line to keep the capacitor charged and to provide transformer and VSC losses, so that the injected voltage Vs is practically 90 degrees out of phase with current I. In the control system block diagram Vd_conv and Vq_conv designate the components of converter voltage V_conv which are respectively in phase and in quadrature with current. Two VSC technologies can be used for the VSC as shown in fig3:

- VSC using GTO-based square-wave inverters and special interconnection transformers. Typically four three-level inverters are used to build a 48-step voltage waveform. Special interconnection transformers are used to neutralize harmonics contained in the square waves generated by individual inverters. In this type of VSC, the fundamental component of voltage V_conv is proportional to the voltage Vdc. Therefore Vdc has to vary for controlling the injected voltage.
- VSC using IGBT-based PWM inverters. This type of inverter uses Pulse-Width Modulation (PWM) technique to synthesize a sinusoidal waveform from a DC voltage with a typical chopping frequency of a few kilohertz. Harmonics are cancelled by connecting filters at the AC side of the VSC. This type of VSC uses a fixed DC voltage Vdc. Voltage V_conv is varied by changing the modulation index of the PWM modulator.

The control system consists of as shown in fig.3:

- A phase-locked loop (PLL) which synchronizes on the positive-sequence component of the current I. The output of the PLL (angle Θ=ωt) is used to compute the direct-axis and quadrature-axis components of the AC three-phase voltages and currents (labeled as Vd, Vq or Id, Iq on the diagram).
- Measurement systems measuring the q components of AC positive-sequence of voltages V1 and V2 (V1q and V2q) as well as the DC voltage Vdc.
- AC and DC voltage regulators which compute the two components of the converter voltage (Vd_conv and Vq_conv) required to obtain the desired DC voltage (Vdcref) and the injected voltage (Vqref). The Vq voltage regulator is assisted by a feed forward type regulator which predicts the V_conv voltage from the Id current measurement [9,15].

4. Unified Power Flow Controller (UPFC)

The Unified Power Flow Controller (UPFC) is the most versatile member of the Flexible AC Transmission Systems (FACTS) family using power electronics to control power flow on power grids. The UPFC uses a combination of a shunt controller (STATCOM) and a series controller (SSSC) interconnected through a common DC bus as shown on the figure 4 below.

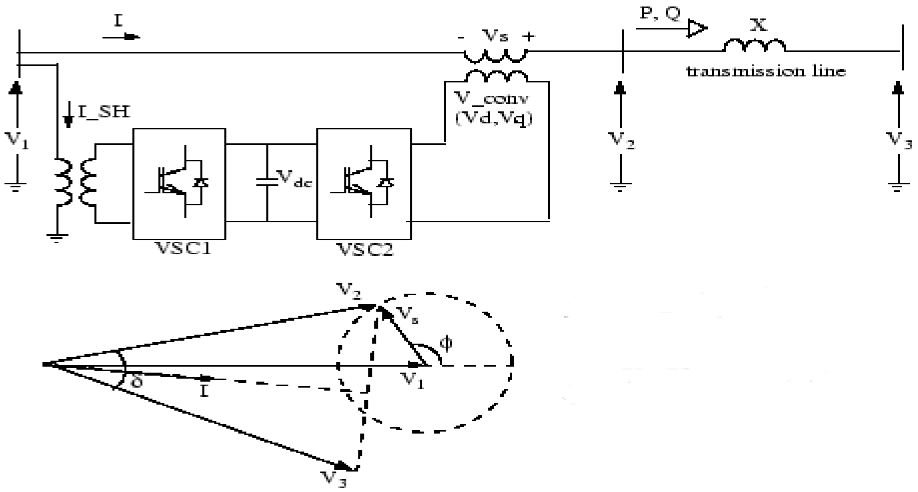

Figure 4. Single-line Diagram of a UPFC and Phasor Diagram of Voltages and Currents

$P = (V^{2}V^{3}\sin\delta) / X$ (1) $Q = V^{2}(V^{2}-V^{3}\cos\delta) / X$ (2)

This FACTS topology provides much more flexibility than the SSSC for controlling the line active and reactive power because active power can now be transferred from the shunt converter to the series converter, through the DC bus. Contrary to the SSSC where the injected voltage Vs is constrained to stay in quadrature with line current I, the injected voltage Vs can now have any angle with respect to line current. If the magnitude of injected voltage Vs is kept constant and if its phase angle ϕ with respect to V1 is varied from 0 degrees to 360 degrees, the locus described by the end of vector V2 (V2=V1+Vs) is a circle as shown on the phasor diagram. As ϕ is varying, the phase shift δ between voltages V2 and V3 at the two line ends also varies. It follows that both the active power P and the reactive power Q transmitted at one line end can be controlled [3,8,10,16]. The UPFC controllable region in the P-Q plane is the area enclosed by an ellipse, as shown on the figure 5.This figure was obtained with a 100 MVA UPFC controlling active and reactive power at one end of a 500 kV, 200-km transmission line. The following parameters have been used:

- Line: length = 200 km; reactance = 0.35 Ω /km
- System voltage: 500-kV infinite sources V1 and V3; V1=1.0 pu, 0 degrees; V3= 1.0 pu,−7.22 degrees
- Series and shunt converter rating: 100 MVA
- Series converter: nominal injected voltage = 10% of nominal line-to-ground voltage (28.9 kV); impedance (transformer leakage reactance and filters) = 0.15 pu

With V3 lagging V1 by 7.22 degrees, the natural power flow without compensation is 450 MW or 50% of the line surge impedance loading (SIL=900 MW). With an injected voltage Vs = 0.1 pu any operating point inside the larger ellipse can be obtained and active power can be varied by approximately +/- 300 MW.

In addition to allow control of the line active and reactive power, the UPFC provides an additional degree of freedom. Its shunt converter operating as a STATCOM controls voltage V1 by absorbing or generating reactive power.Both the series and shunt converters use a Voltage-Sourced Converter (VSC) connected on the secondary side of a coupling transformer. The VSCs use forced-commutated power electronic devices (GTOs, IGBTs, or IGCTs) to synthesize a voltage from a DC voltage source. The common capacitor connected on the DC side of the VSCs acts as a DC voltage source. Two VSC technologies can be used for the VSCs:

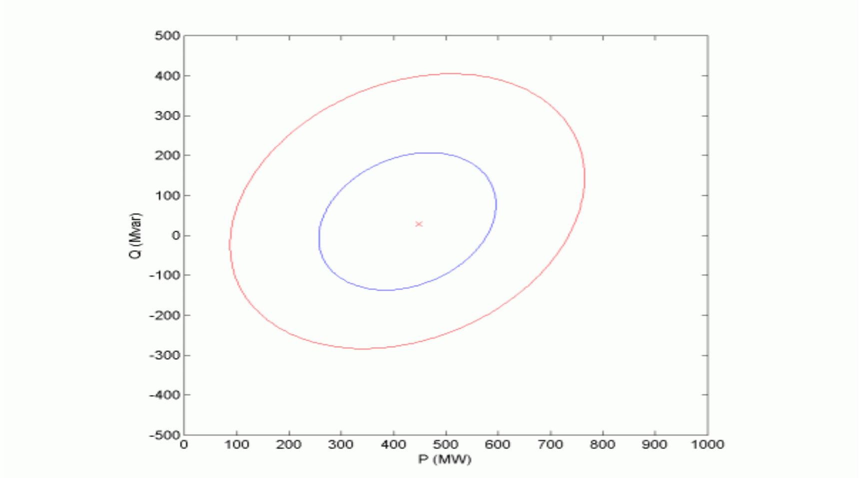

Figure 5. Controllable Region for a 100 MVA UPFC Connected on 500 kV, 200-km line

- VSC using GTO-based square-wave inverters and special interconnection transformers. Typically four three-level inverters are used to build a 48-step voltage waveform. Special interconnection transformers are used to neutralize harmonics contained in the square waves generated by individual inverters. In this type of VSC, the fundamental component of voltage is proportional to the voltage Vdc. Therefore Vdc has to vary for controlling the injected voltage.
- VSC using IGBT-based PWM inverters. This type of inverter uses Pulse-Width Modulation (PWM) technique to synthesize a sinusoidal waveform from a DC voltage with a typical chopping frequency of a few kilohertzes. Harmonics are cancelled by connecting filters at the AC side of the VSC. This type of VSC uses a fixed DC voltage Vdc. Voltage is varied by changing the modulation index of the PWM modulator[3].

4.1 Control System of UPFC

- The shunt converter operates as a STATCOM. For a description of its control system, refer to the Static Synchronous Compensator (Phasor Type). In summary, the shunt converter controls the AC voltage at its terminals and the voltage of the DC bus. It uses a dual voltage regulation loop: an inner current control loop and an outer loop regulating AC and DC voltages.
- Control of the series branch is different from the SSSC. In an SSSC the two degrees of freedom of the series converter are used to control the DC voltage and the reactive power. In case of a UPFC the two degrees of freedom are used to control the active power and the reactive power. A simplified block diagram of the series converter is shown below.

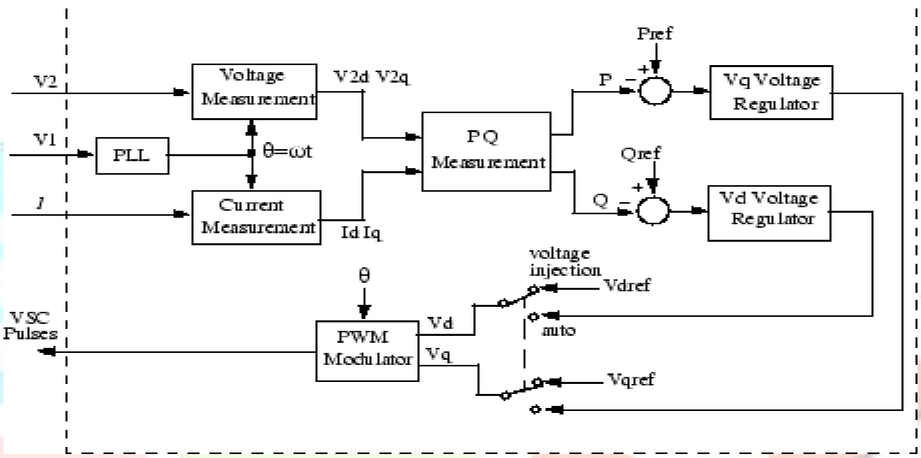

Figure 6. Simplified Block Diagram of the Series Converter Control System

- The series converter can operate either in power flow control (automatic mode) or in manual voltage injection mode. In power control mode, the measured active power and reactive power are compared with reference values to produce P and Q errors. The P error and the Q error are used by two PI regulators to compute respectively the Vq and Vd components of voltage to be synthesized by the VSC. (Vq in quadrature with V1 controls active power and Vd in phase with V1 controls reactive power). In manual voltage injection mode, regulators are not used. The reference values of injected voltage Vdref and Vqref are used to synthesize the converter voltage[3].

5. Simulation Model and Results:

The Matlab software is used to analysis of transient stability of the multi-machine, IEEE (Kundur's Two-Area System) two area 11 Bus -bus power system network with SSSC and UPFC which are connected at bus 7 as shown in figure 8 & 9. The system contains eleven buses and two areas, connected by a weak tie between bus 7 and 9. Totally two loads are applied to the system at bus 7 and 9. Two shunt capacitors are also connected to bus 7 and 9 as shown in the figure 8&9.The system comprises two similar areas connected by a weak tie. Each area consists of two generators, each having a rating of 900 MVA and 20 kV. All four machines are equipped with a steam turbine and governor(STG), excitation system and power system stabilizer(PSS).The left half of the system is identified as area 1 and the right half is identified as area 2. The saturation of the synchronous machines are not identical. Both SSSC and UPFC used for this model have same rating of +/- 200 MVA and the reference voltage is set to 1 pu for both SVC and STATCOM. The loads and reactive power supplied A: PL = 967 MW QL = 100MVAr QC = 187MVAr B: PL= 1767 MW QL = 100MVAr Qc = 187 MVAr. The transmission system nominal voltage is 230kV. The base MVA of the system is 100 and system frequency is 60 Hz. All the time constants are in seconds. The transient stability analysis has been carried out by monitoring the performance of the generators (G1,G2,G3&G4) and different buses. The transient stability analysis of this power system network have been considered when three phase fault occurs at bus 8 at time t = 1s and cleared at 2.1s. The total duration of fault is 1.1s. It is observed that the system quickly losses its stability after fault clearing as shown in figure11. In order not to pursue unnecessary simulation, the Simulink Stop block is used to stop the simulation when angle difference reaches 3*360. Figure no. 10, shows the Waveforms of without three phase fault, here the system is stable so does not required facts and pss devices in this case. During & post fault condition shown in fig 12 to 17, we observed the terminal voltage and speed of all generators. The terminal voltage reached to zero pu during fault and increased up to 1 pu and settle to 1 pu after fault. During fault speed of all generators increased up to 1.03 pu due to sudden decrease in load and settle to 1 pu after fault.

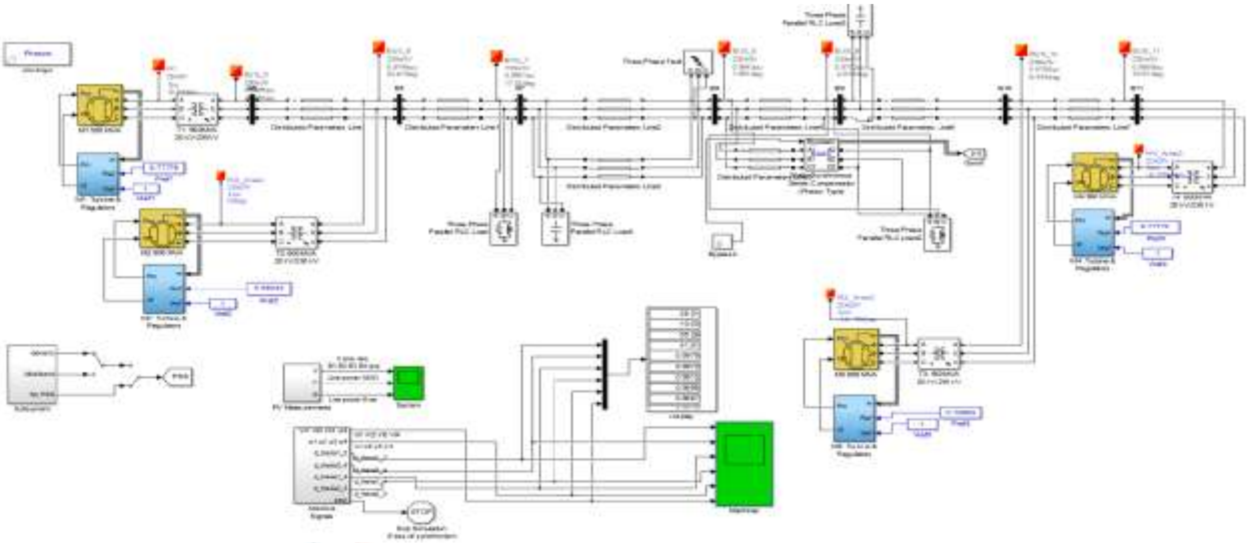

Figure8. Simulink model of 3 machine 9 bus system with SSSC

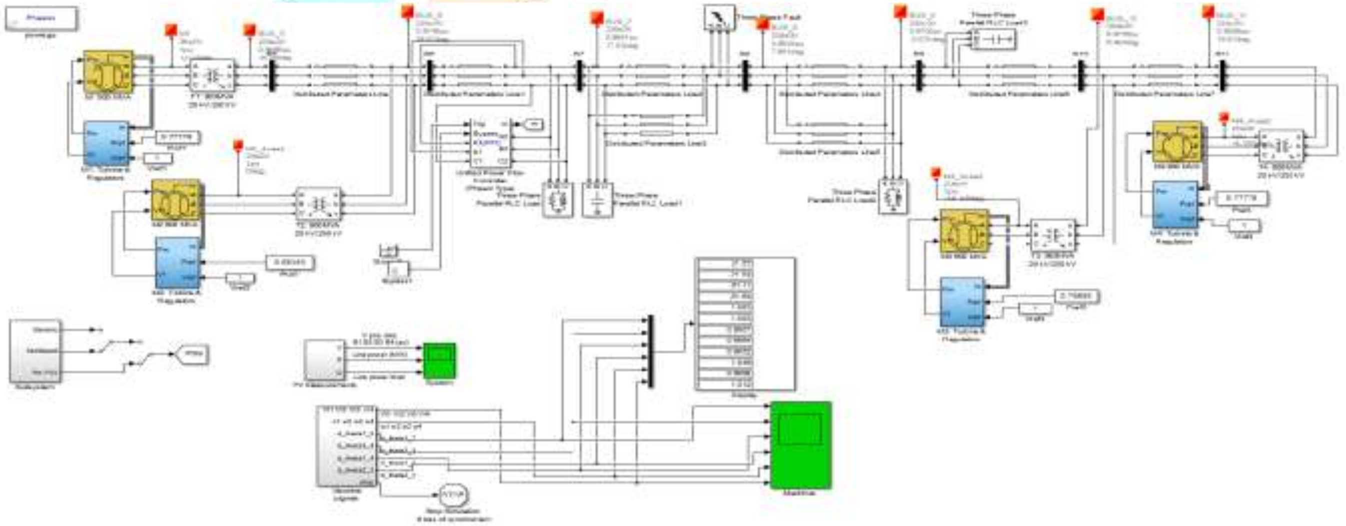

Figure9. Simulink model of 3 machine 9 bus system with UPFC

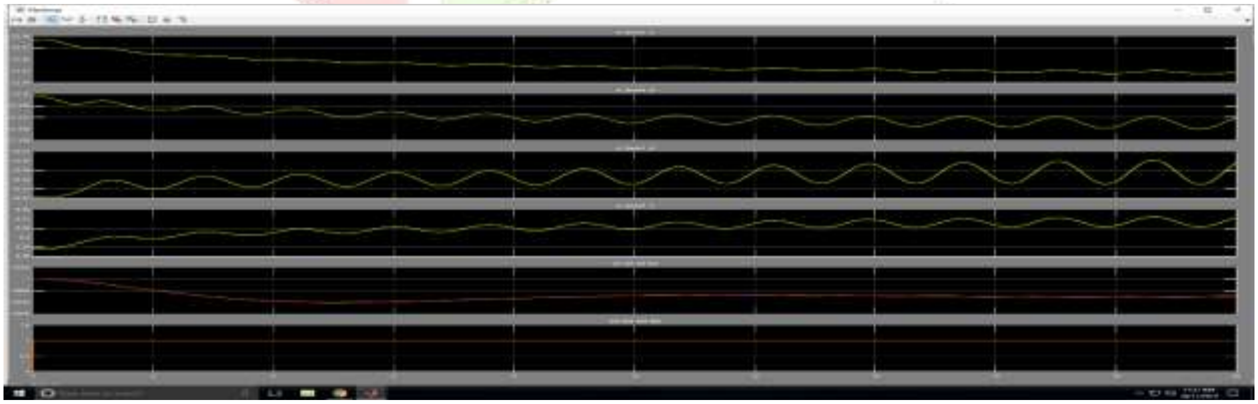

Figure10. Waveform of without three phase fault – (i) Rotor angle deviation between generator G1,G2,G3& G4 (ii) Speed of rotor machine G,G2,G3& G4 (iii) Stator Voltage of G1,G2,G3& G4

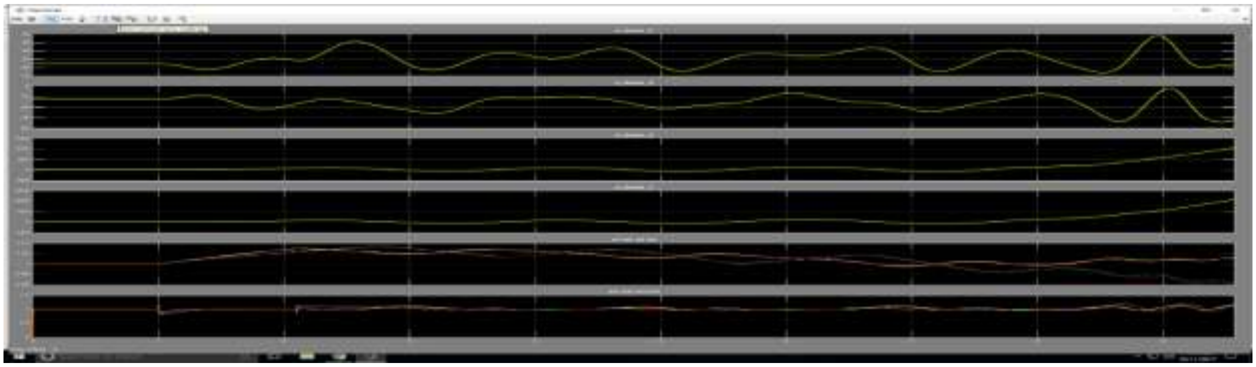

Figure11. Waveform of with three phase fault – (i) Rotor angle deviation between generator G1,G2,G3&G4 (ii) Speed of rotor machine G,G2,G3&G4 (iii) Stator Voltage of G1,G2,G3&G4

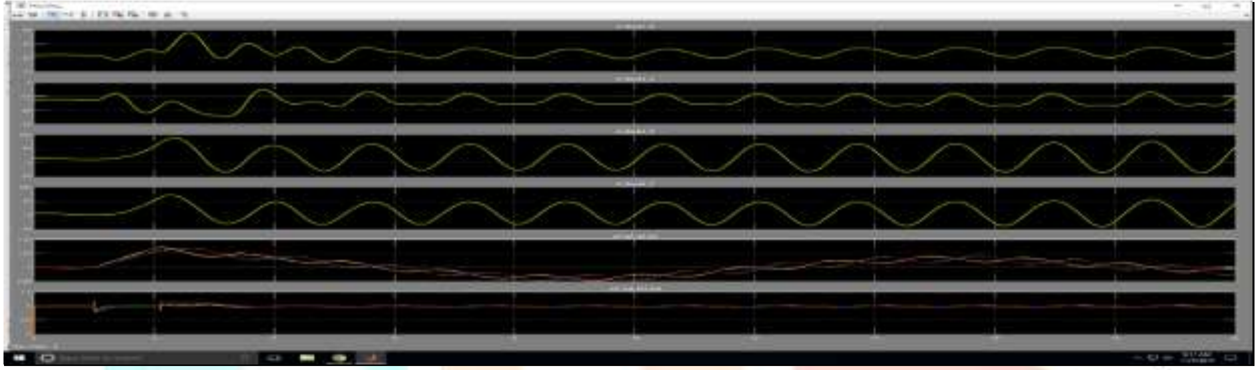

Figure12. Waveform of with three phase fault and SSSC –(i) Rotor angle deviation between generator G1,G2,G3&G4 (ii) Speed of rotor machine G1,G2,G3&G4 (iii) Stator Voltage of G1,G2,G3&G4

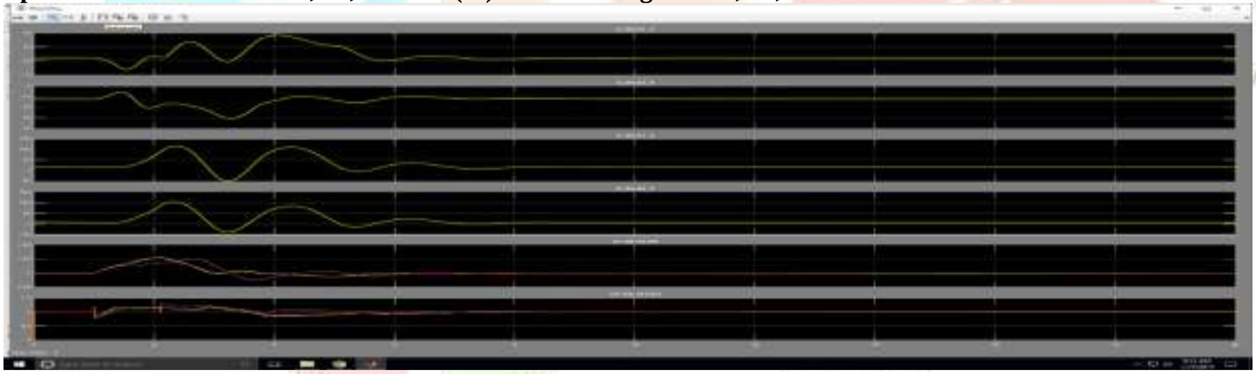

Figure13. Waveform of with three phase fault SSSC&GPSS –(i)Rotor angle deviation between generator G1,G2,G3&G4 (ii) Speed of rotor machine G1,G2,G3&G4 (iii) Stator Voltage of G1,G2, G3&G4

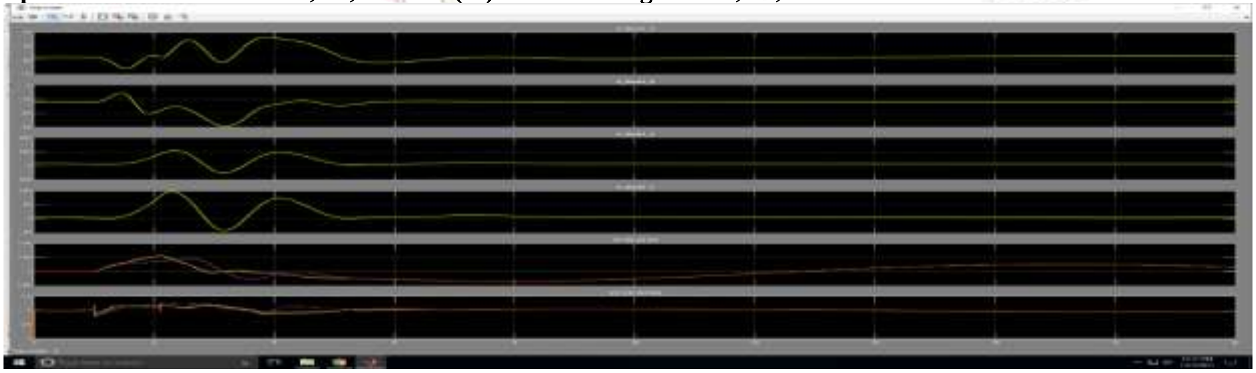

Figure14. Waveform of with three phase fault and SSSC&MBPSS – (i) Rotor angle deviation between generator G1,G2,G3&G4 (ii) Speed of rotor machine G1,G2,G3&G4 (iii) Stator Voltage of G1,G2, G3&G4

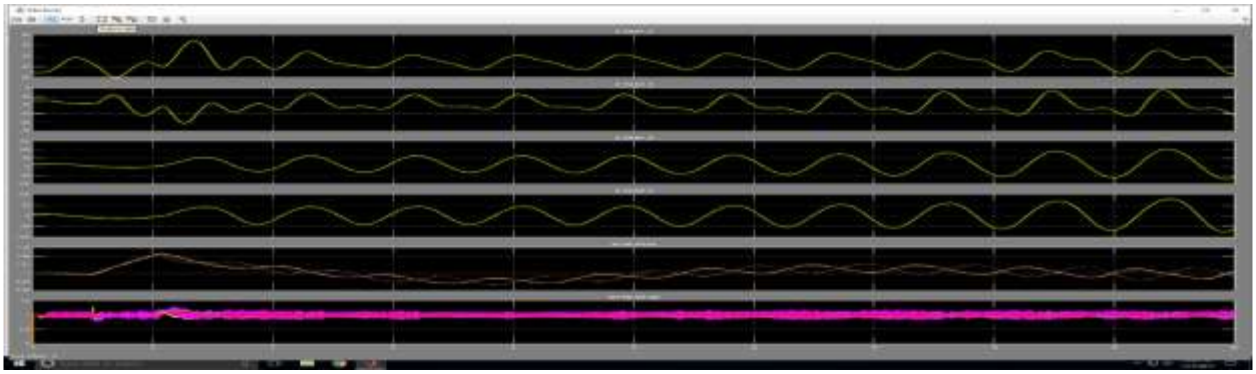

Figure15. Waveform of with three phase fault and UPFC–(i) Rotor angle deviation between generator G1,G2,G3&G4 (ii) Speed of rotor machine G1,G2,G3&G4 (iii) Stator Voltage of G1,G2, G3&G4

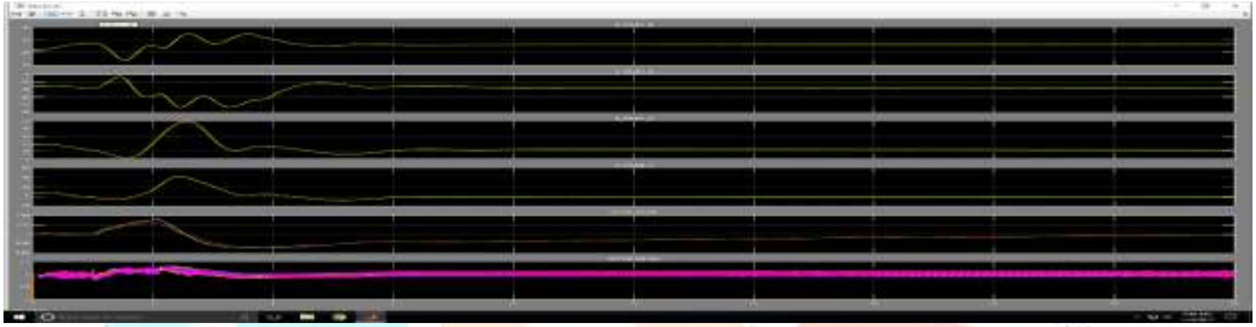

Figure16. Waveform of with three phase fault and UPFC&GPSS – (i) Rotor angle deviation between generator G1,G2,G3&G4 (ii) Speed of rotor machine G1,G2,G3&G4 (iii) Stator Voltage of G1,G2,G3 &G4

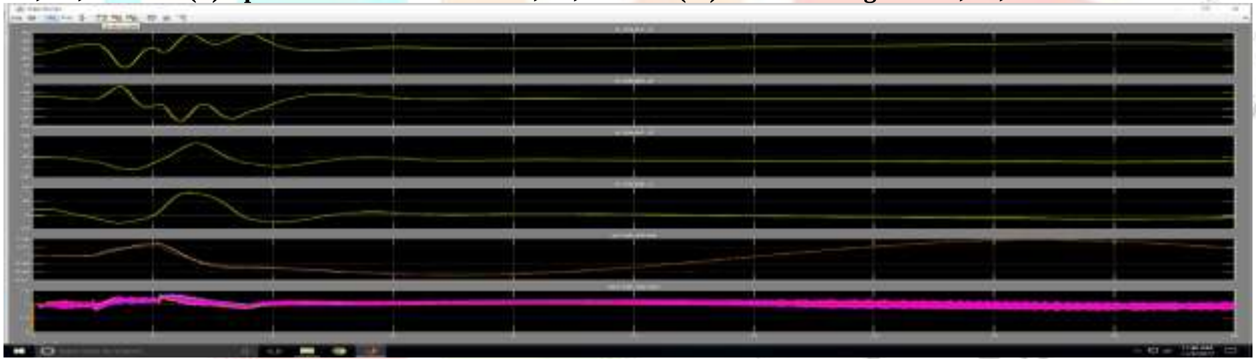

Figure17. Waveform of with three phase fault and UPFC&MBPSS – (i) Rotor angle deviation between generator G1,G2 and G3 (ii) Speed of rotor machine G1,G2,G3&G4 (iii) Stator Voltage of G1,G2,G3&G4

5.1 Comparison between of SSSC and UPFC with and without PSS:

From simulation results shown in figure 12 to 17 comparison is made between the above facts devices with and without PSS for stability enhancement of IEEE 11 bus system as shown in table 1 and 2. From table1&2, it is clear that UPFC with MBPSS is the effective combination for stability enhancement over SSSC with MBPSS as the post fault settling time and angle deviation obtained from UPFC with MBPSS is less as compared to that obtained from SSSC with MBPSS.

Table.1 Comparison between SSSC and UPFC with and without PSS for power system stability enhancement

IEEE 11 Bus system with	Power system stability Enhancement	Stability time for d_theta 1_2 (in sec)	Stability time for d_theta 3_4 (in sec)	Stability time for d_theta 1_4(in sec)	Stability time for d_theta 2_3(in sec)
SSSC	YES	20	20	20	20
UPFC	YES	20	20	20	20
SSSC&GPSS	YES	9	9	9	9
UPFC&GPSS	YES	7.5	7.5	7.5	7.5
SSSC&MBPSS	YES	8.5	8.5	8.5	8.5
UPFC&MBPSS	YES	7.5	7.5	7.5	7.5

Table.2 Comparison of angle deviation

IEEE 9 Bus system with	Angle deviation d_theta 1_2 (min. and max. in deg)	Angle deviation d_theta 3_4 (min. and max. in deg)	Angle deviation d_theta1_4 (min. and max. in deg)	Angle deviation d_theta2_3 (min. and max. in deg)
SSSC	+15 to +38	-5 to -25	-50 to +90	-50 to +80
UPFC	+22.5 to +38	-5 to -21	-52 to +100	-70 to +80
SSSC&GPSS	+15 to +39	-5 to -31	-60 to +130	-49 to +101
UPFC&GPSS	+5 to +35	-6 to -27	0 to +50	-10 to +41
SSSC&MBPSS	+5 to +38	-5 to -30	-50 to +105	-55 to +100
UPFC&MBPSS	+14 to +35	-7 to -28	-10 to +50	-10 to +30

6. Conclusion: (a) The dynamic behavior of the power system is compared with the presence of SSSC and UPFC in the system in the event of a major disturbance. Then the performance of UPFC for power system stability improvement is compared with the SSSC. It is clear from the simulation results that there is a considerable improvement in the system performance with the use of UPFC for which settling time in post fault is found to be around 20 sec. and angle deviation between all 4 generators is less as compared to SSSC as shown in table no.2.

(b) The dynamic behavior of the power system is also compared with the presence of SSSC with PSS and UPFC with PSS in the system in the event of a major disturbance. Then the performance of UPFC with MBPSS for power system stability improvement is compared with the SSSC incorporated with MBPSS . It is clear from the simulation results that there is a considerable improvement in the system performance with the use of UPFC with MBPSS for which settling time in post fault is found to be around 7.5 sec. and angle deviation between all 4 generators is less as compared to SSSC with MBPSS as shown in table no.2.

REFERENCES:

[1] *Prabha Kundur*, “Definition and Classification of Power System Stability” IEEE TRANSACTIONS ON POWER SYSTEMS © 2004 IEEE

[2]P.M.Anderson,A.A. Fouad, “Power System Control and stability”, The Iowa stateUniversity Press, AMES, IOWA, U.S.A.

[3] Narain G. Hingorani, Laszlo Gyugyi, “Understanding FACTS : concepts and technology of flexible AC transmission systems”

[4]*Gaber Shabib, “*COORDINATED DESIGN OF A MB-PSS AND STATCOM CONTROLLER TO ENHANCE POWER SYSTEM STABILITY” International Journal of Electrical Engineering and Technology (IJEET), Volume 3, Issue 2, July - September (2012).

[5] Lin Xu, “Coordinated Control of SVC and PSS for Transient Stability Enhancement of Multi-Machine Power system”TELKOMNIKA, Vol. 11, No. 2, February 2013.

[6] Mr. Pradeepkumar S. Mahapure, ‘Comparison of FACTS Devices for Power System Transient Stability Improvement”*INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, NSTRUMENTATION AND CONTROL ENGINEERING Vol. 2, Issue 6, June 2014*

[7] Apoorv H Prajapati, “BASIC CONCEPT OF POWER SYSTEM STABILIZER FOR POWER SYSTEM STABILITY AND COMPARISON OF DIFFERENT DESIGN METHODS”*International Journal For Technological Research In Engineering Volume 1, Issue 11, July-2014*

[8] Garima Aggarwal,“MATLAB/SIMULINK MODEL OF MULTI-MACHINE (3-Machine, 9-Bus) WSCC SYSTEM INCORPORATED WITH HYBRID POWER FLOW CONTROLLER” 2015 Fifth International Conference on Advanced Computing & Communication Technologies

[9] Ishwar Lal Yadav, “Stability Enhancement for Transmission Lines using Static Synchronous Series Compensator” International Journal of Engineering Research & Technology (IJERT) Vol. 4 Issue 02, February-2015

[10] Ritesh Ukandrao Chirde,“Enhancement of Power System Stability by using Power System Stabilizer and UPFC” International Journal of Engineering Research & Technology (IJERT) ,Vol. 4 Issue 05, May-2015
[11] Divya Prakash, “Enhancing Stability of Multi-Machine IEEE 9 Bus Power System Network Using PSS” International Journal of Advanced Research in Electrical,Electronics and Instrumentation Engineering, Vol. 4, Issue 5, May 2015.

[12] PRATIK RAO,"ENHANCEMENT OF POWER FLOW USING SSSC CONTROLLER" International Journal of Electrical, Electronics and Data Communication, Volume-3, Issue-6, June-2015

[13] P. Suresh, "TRANSIENT STABILITY PERFORMANCE ANALYSIS OF AN IEEE9 BUS POWER SYSTEM USING FACTS DEVICE" *International Journal of Computational Research and Development (IJCRD)),Volume 1, Issue 2, 2016*

[14] Rizan A. Ali,"Improve Power Stability & Damping Oscillation in Multi Machine System Using (SSSC) with POD Controller" Int'l Journal of Computing, Communications & Instrumentation Engg. (IJCCIE) Vol. 3, Issue 2 (2016)

[15] Abhinav L. Purkar1,"Improvement of Multi-Machine Power System Stability Using SSSC"International Journal for Research in Applied Science & Engineering Technology (IJRASET) *Volume 4 Issue IV, April 2016*

[16] Sandeep Kaur, "Transient stability using facts controller" IJLTET,Volume 7,1 may 2016

[17] K. Revath, "Performance Analysis of Facts Controllers for Transient Stability Enhancement of Four Machine Two Area Test System" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 6, Issue 7, July 2017.

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