Stability Enhancement in Multimachine Power System by FACTS Controller

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***Abstract*—The machine dynamics response to any impact in the system is oscillatory. In past, the size of power system is smaller; therefor the period of oscillation was not much greater than one second. Today large capacity of generator and system interconnected with the greater system inertias and relatively weaker ties results in longer period of oscillation followed by perturbation. These are the situations in which dynamic stability is concern. The enhancement of dynamic stability becomes very important for reliability and continuity of power system. Now power electronic based FACTS (Flexible AC Transmission system) devices are established to enhance the power transmitting capacity and also mitigation of oscillatory period of system at the time of fault. The case study of two area system is taken for analysis. Fault is created for observation of different parameter of machine and transmission system like rotor angle waveform, settling time, voltage of machine, active power of machine and transmission voltage. The different fault analysis says that FACTS controllers help to improve dynamic stability. Among all FACTS devices, UPFC(Unified Power Flow Controller) seen more suitable for enhancement of dynamic stability of two area and multi area system. MATLAB simulation is used to do analysis for different system.**

Keywords— Power Systems, Power System Stability, Dynamic Stability, Flexible AC Transmission Systems (FACTS), FACTS Controllers

I. INTRODUCTION

Stable operation of power system required a continuous match between energy input to the prime movers and the electrical load in the system. Continuous change is normal for an operating system. Fortunately, the changes are usually in small increments, as customer load increase or decrease. Each load increase or decrease must be accompanied by a corresponding change in input to the prime mover of the generation on the system. If mechanical input does not rapidly match the power used by the load and the system losses, system speed (frequency) and voltage will deviate from normal. Major power system has elaborate equipment and methods of sensing frequency deviations and making changes in the generation schedule to correct it. Changes in load and generation result in relative changes in the position of generator rotors that must all operate in synchronism if the power system is to remain stable. Power system stability is primarily concern with variation in rotor speed, rotor position and generator loads.

Power system stability, in general term may be defined as its ability to respond to a perturbation from its normal operation by returning to a condition where the operating is again normal.

Dynamic stability is the ability if power system to remain in synchronism after the initial swing (transient stability period) until the system has settle down to the new study state equilibrium condition. When sufficient time has elapsed after a perturbation, the governors of the prime mover will react to increase or decrease energy input as may be required, to reestablish a balance between energy input and the existing electrical load. This usually occurs in about 1 to 1.5 second after the perturbation.

The period between the time the governor begins to react and the time that steady state equilibrium is reestablish in the period when dynamic stability characteristic of a system are effective. Dynamic stability studies cover longer real time interval, perhaps 5 to 10 second occasionally upto30 second depending on the inertia of system and the characteristics of governor. During this period the governor open or close the valve as required to increase or decrease the prime movers, and the tie line controller to restore tie line flow to normal. Usually when system sense the speed drop, they will act to open the throttle valve to admit more steam into turbine to arrest the decline speed (frequency)and accelerate the system back to normal speed. This still a condition of system unbalanced, because energy input now exceeding the load and the speed will increasing beyond the normal, where the governor again to reduce energy input. As a result, oscillation of energy output and machine rotor energy will occur if the system is dynamically stable, the oscillation will be damped, that is reduce in magnitude, after a few swing then system will settle down to an steady state condition with energy input equal to an electrical load of the system.

As power systems became interconnected, areas of generation were found to be prone to electromechanical oscillations. These oscillations have been observed in many power systems worldwide. With increased loading conditions and interconnections the transmission system became weak and inadequate, also load characteristics added to the problem causing spontaneous oscillations [1]. Unified Power Flow Controller (UPFC) is the most widely used FACTS device to control the power flow and to optimize the system stability in the transmission line. The controller used in the control

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mechanism has an important effect on the performance of UPFC. According to this, the performance of UPFC for several modes of operations using different control mechanisms based on Proportional-Integral (PI) and PID based controllers has been studied [2]. FACTS devices have four well- known types which are used in many power systems in the world [3]. „ Single ‟ type controller is the types of FACTS that installed in series or shunt in an AC transmission line, while „ unified ‟ type controller are the combined converters type of FACTS controllers like UPFC and HVDC. The following types of FACTS devices are VSC type based controllers. Speed deviation signal was used as the damping controller input. Damping improvement in a SMIB system using STATCOM & SSSC was investigated using energy function approach

.Classical Model was used for the synchronous machines and the FACTS devices were modeled as simple current and voltage sources. The proposed technique is then applied to a single-machine system and for some faults (local modes) in a multi-machine system to evaluate the additional damping provided by a STATCOM and a SSSC [4]. This paper presents a comprehensive review on enhancement of power system stability such as rotor angle stability, frequency stability, and voltage stability by using different FACTS controllers such as TCSC, SVC, SSSC, STATCOM, UPFC, and IPFC in an integrated power system networks. Also this paper presents the current status of the research and developments in the field of the power system stability such as rotor angle stability, frequency stability, and voltage stability enhancement by using different FACTS controllers in an integrated power system networks [5]. The IEEE 14 Bus is modeled using the elements of Simulink. The effectiveness of the proposed controllers, the improvements in power quality and in voltage profile is demonstrated. In the simulation, the results of the proposed Model for the SVC and STATCOM Controllers are determined. Then, they are compared with results obtained from the SVC with the conventional PID Controller [6]. This is a review paper to analyze the current trends in FACTS and D-FACTS to improve the performance of power system performance. It contains work which has been carried out by various researchers in the field of FACTS and D-FACTS [7]. The dissertation aims to define power system stability more precisely, provide a systematic basis for its classification, and discuss linkages to related issues such as power system reliability and security [8]. This book is concerned with some aspects of the designing problem, particularly the dynamic performance of interconnected power system characteristics of various components during normal operating condition and abnormal condition. And effect of overall performance will be examining [9].

II. POWER SYSTEM STABILITY

Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical perturbation, with most of the system variables bounded so that practically the entire system remains intact.

A. Rotor Angle Stability

It is the ability of the system to remain in synchronism when subjected to a perturbation. The rotor angle of a generator depends on the balance between the electromagnetic torque due to the generator electrical power output and mechanical torque due to the input mechanical power through a prime mover. Remaining in synchronism means that all the generators electromagnetic torque is exactly balanced by the mechanical torque. If in some generator the balance between electromagnetic and mechanical torque is disturbed, due to perturbation in the system, then this will lead to oscillations in the rotor angle.

B. Steady State Stability

Steady state stability is the stability the power system attains after slight unbalance. Suppose a small amount of load is disconnected. Then there is a mismatch in the power system so power flow will fluctuate, voltage in diff part will rise suddenly & for small duration frequency mismatch will be there. But after a very short duration again the power system will regain its steady state.

C. Transient Stability

Transient stability corresponds to the stability attained after a large mismatch. Suppose somewhere a fault occurs & suddenly a large part of load is bypassed. Then there is a large unbalance in the system. Then also gradually the system attains the stability.

D. Dynamic Stability

Dynamic stability is like transient stability but here help of an external device is taken to regain the stability whereas in transient stability the stability was attained within the power system itself without the help of any external device.

Dynamic stability is the ability of power system to remain in synchronism the initial swing (transient stability period) until the system settle down to new steady state equilibrium condition. When sufficient time elapsed after perturbation, the governors of the prim over will react to increase or decrease the energy input, as may be required, to obtaining the balance between energy input and the existing electrical load. The period between the time the governor begins to react and the time has steady state equilibrium is reach the period when dynamic stability characteristics of a system are affective.

III. FACTS CONTROLLER

The objective of incorporating FACTS is into the power system lines are similar to HVDC but greater flexibility are involved like improving real power transfer capability in the lines, prevention of sub- synchronous resonance (SSR)oscillations and damping of power swings [6].

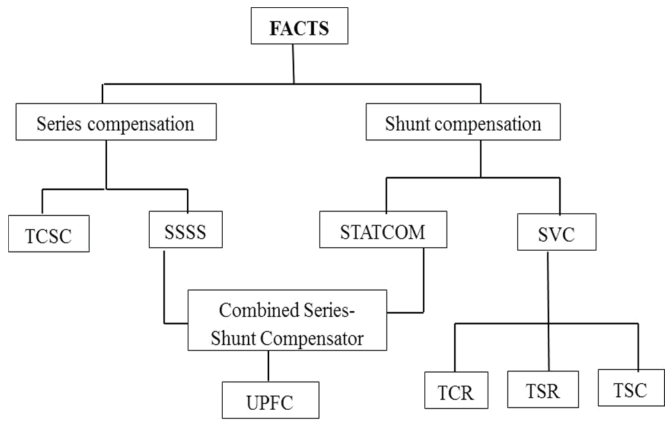

Fig. 1. Classification of FACTS devices [7]

A. Static VAR Compensator (SVC)

A shunt connected static VAR absorber whose output is adjusted to exchange capacitive or inductive current so as to control specific parameter of electrical power system. These comprised capacitor bank fixed or switched or capacitor bank and switched reactor bank in parallel. These compensator draw reactive power (leading or lagging) from the line regulating voltage, improve steady state or dynamic stability reduced voltage flicker. In HVDC system, compensator provides the required reactive power and damp out sub harmonic oscillation. It is also called static VAR switches.

B. Static Synchronous Compensator (STATCOM)

Static synchronous compensator operated as shunt connected devices that are capacitive or inductive output current can be controlled independent of the ac system voltage. Its operation is counter part of SVC. It can be based of voltage and current sourced convertor. STATCOM can be designed to be an active filter to absorb harmonic of system.

C. Static Series Synchronous Compensator(SSSC)

Static Series Synchronous Compensator is operated without an external electric energy source as a series compensator whose output voltage is an quadrature with and controllable independently of, the line current for the purpose of increasing or decreasing the overall reactive voltage drop across the line and controlling the transmission power. SSSC operating like STATCOM but its output voltage is in series with the line. Thus it"s controlled the voltage across the line and hence its impedance.

D. Unified power flow controller (UPFC)

A combination of static synchronous compensator (STATCOM) and Static series compensator (SSSC) connected via DC link to pass flow of real power between the series output terminal of SSSC and shunt output terminal of STATCOM. Also controlled the flow real and reactive without an external electrical energy source.

IV. PERFORMANCE ANALYSIS

a. Critical Clearing Angle by Analytical Method

In paper a generator deliver a power 420MW taken as a Reference value. A fault takes place reducing the maximum power 200MW. Before the fault power is 420MW. After the clearing of the fault, it is 460MW. So by equal area criteria critical clearing angle is found.

Pm = 420MW= 1 PU
Pre fault Pm1 = 420MW =1PU
During fault Pm2 = 200MW =0.476 PU
Post fault Pm3 = 460MW =1.095 PU

$$\delta 0 = \sin^{-1}\frac{Pm}{Pm1} \quad (1)$$

$$\delta 0 = \sin^{-1}\frac{1}{1} \quad (2)$$

$$\delta 0 = 1.57 rad \quad (3)$$

$$\delta max = \pi - \sin^{-1}\frac{Pm}{Pm3} \quad (4)$$

$$\delta max = \pi - \sin^{-1}\frac{1}{1.095} \quad (5)$$

$$\delta max = 1.99\ rad \quad (6)$$

$$\cos\delta cr = \frac{Pm(\delta max - \delta 0) Pm\cos\delta 0 + Pm3\cos\delta max}{Pm3 - Pm2} \quad (7)$$

$$\delta cr = 87.67^{\circ} = 88^{\circ} \quad (8)$$

So by analytical method has obtained the Value of Critical Clearing Angle is 88° from equation (8). And value obtained by simulation modeling without FACTS controller is 105°.

b. Waveform of Simple Model without FACTS Controller

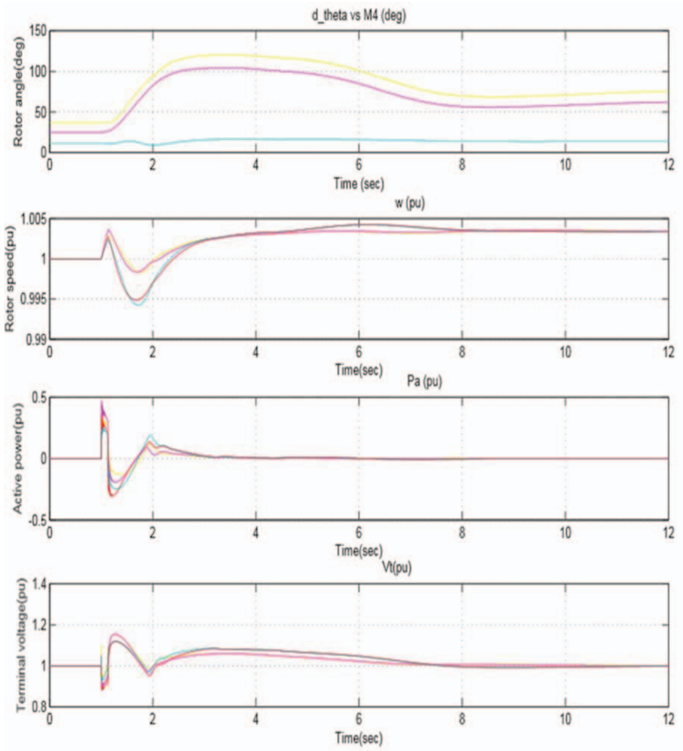

Fig. 2. Rotor angle, power Vs Time without FACTS Controller

First wave form of fig. 2 indicate rotor angle of synchronous machine verses time. Maximum peak of waveform is 105°.And settling time at post fault condition is 12 sec.

c. Waveform of SVC Connected FACTS Controller

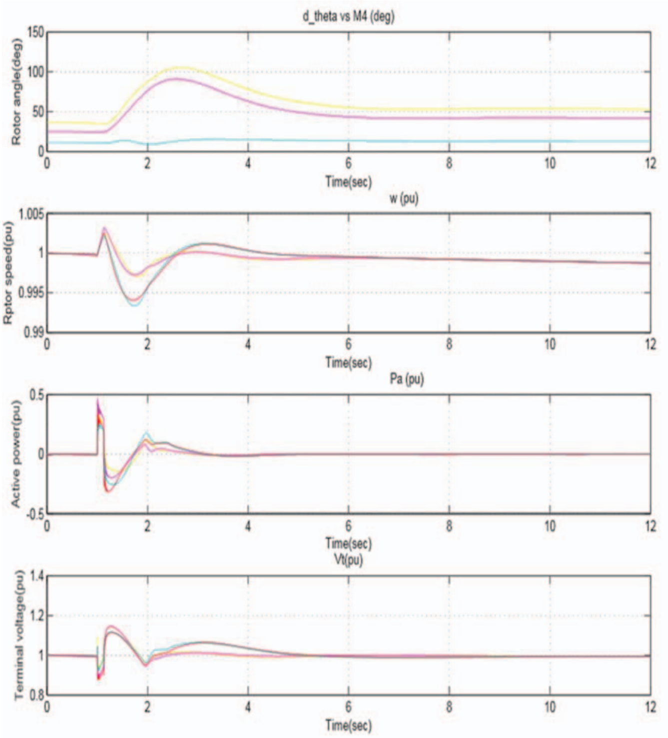

Fig. 3. Rotor angle, power Vs Time with SVC FACTS Controller

First wave form of fig. 3 indicate rotor angle of synchronous machine verses time. Maximum peak of waveform is 105°.And settling time at post fault condition is 6 sec.

d. Waveform of STATCOM Connected FACTS Controller

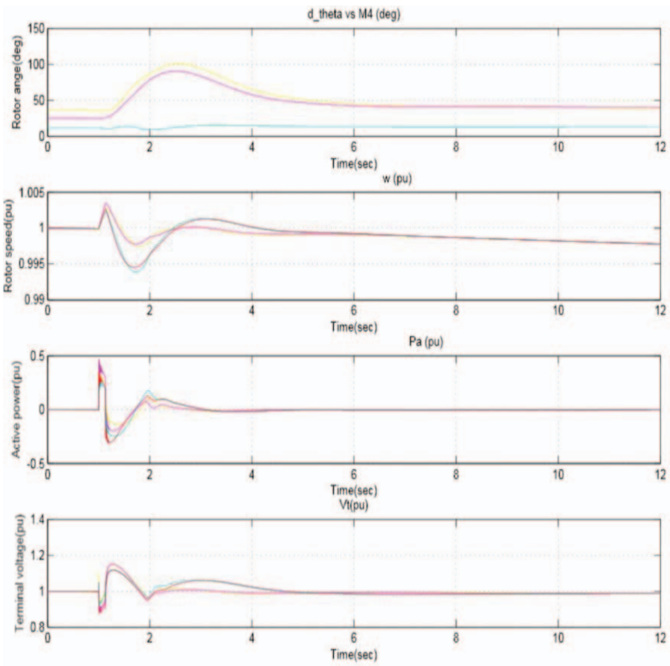

Fig. 4. Rotor angle, power Vs Time with STATCOM FACTS Controller

First wave form of fig. 4 indicate rotor angle of synchronous machine verses time. Maximum peak of waveform is 100° .And settling time at post fault condition is 5.9 sec.

a. Waveform of SSSC Connected FACTS Controller

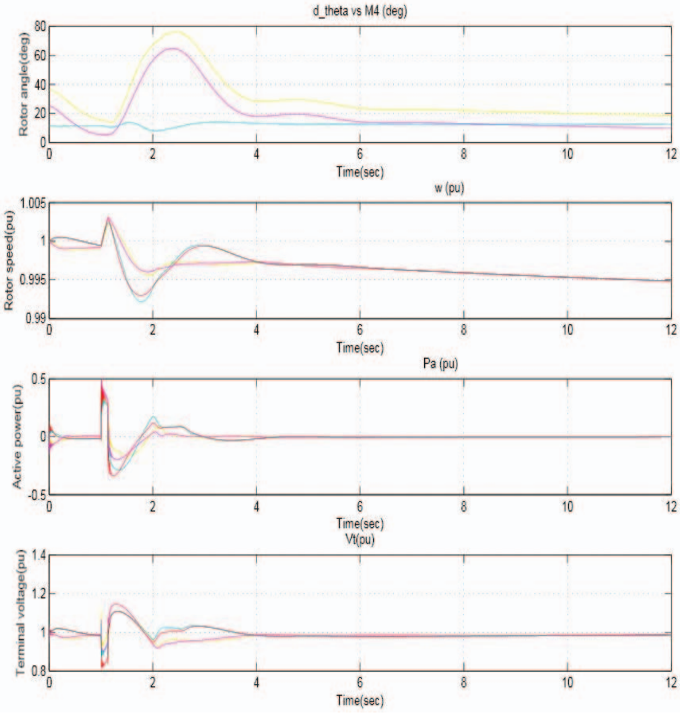

Fig. 5. Rotor angle, power Vs Time with SSSC FACTS Controller

First wave form of fig. 5 indicate rotor angle of synchronous machine verses time. Maximum peak of waveform is 80°.And settling time at post fault condition is 6 sec.

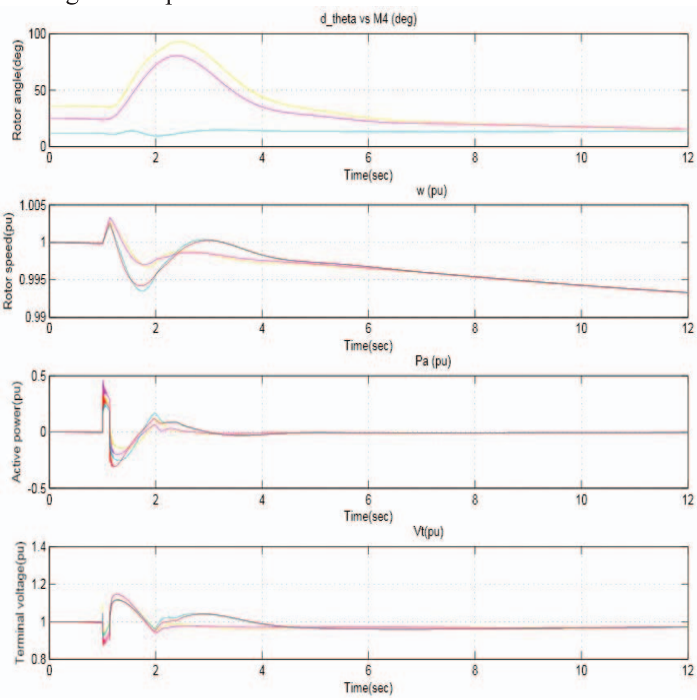

Fig. 6. Rotor angle, power Vs Time with UPFC FACTS Controller

First wave form of fig. 6 indicate rotor angle of synchronous

Machine verses time. Maximum peak of waveform is 95°.And settling time at post fault condition is 5.5 sec.

TABLE I. Comparison between FACTS Devices for dynamic Stability Enhancement in multimachine power system

Two area power system	Power system stability enhancement	Settling time in post fault period(sec)
UPFC	YES	5.5
STATCOM	YES	5.9
SVC	YES	6
SSSC	YES	6
Without FACTS	NO	12

Analysis of FACTS controller is given by this paper and result of that is compare in table I. This table is summarized of graph obtained between rotor angle verses time at the time of fault condition. In this table four FACTS controller are giving Settling time at post fault condition. Time required for settle down the system at new steady period is 5.5 sec for UPFC, while in remaining FACTS controller like STATCOM it is 5.9sec, In SVC and SSSC it is 6 sec. And without FACTS time required is 12 sec. So UPFC is bets FACTS controller as stability point of view.

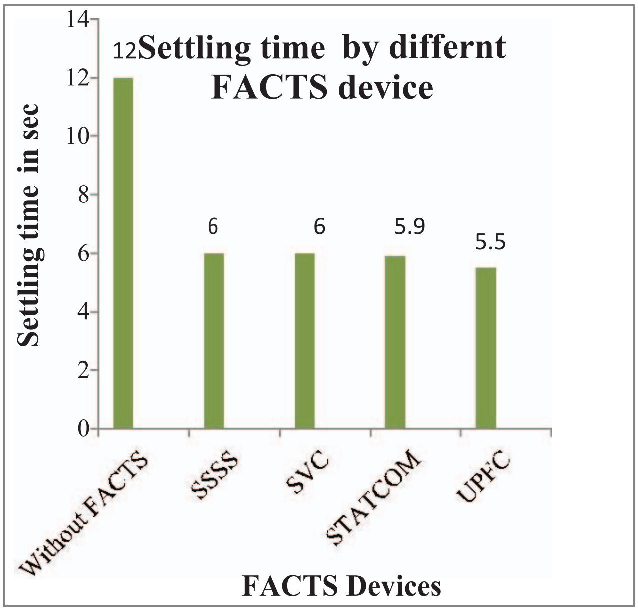

Fig. 7. Settling time of Different FACTS devices

Graphical representation of settling time for different FACTS controllers as mentioned in table I is represented by fig. 7. Therefor different FACTS controller is compared and fined that STATCOM is better than SVC and UPFC is better than SSSC. Time required for settle down the system is 5.5 sec by connecting UPFC FACTS controller. This time is smaller as comparisons with other FACTS controller. So finally UPFC is best FACTS controller as compare to other stabilizer as stability point of view.

CONCLUSION

The performances are analyzed for different FACTS controller with application of fault. First two area system is considered where fault are created and observations are made for settling time. The same type of fault is applied with FACTS controller. The results of settling time for different FACTS controller are compared. In shunt connected FACTS device STATCOM is more reliable at stability point of view. The settling time of STATCOM is small as compare to SVC in shunt connected FACTS controller. UPFC is combined shunt and series connected FACTS stabilized, so overall performance of UPFC is much faster than other FACTS controller. This performance analysis is done with the help of MATLAB Simulink modeling.

REFERENCES

[1] J.Gokula Krishnan, N.Senthil Kumar, M.Abdullah Khan, “On the optimal tuning of FACTS based stabilizers for dynamic stability enhancement in multimachine power systems”, IEEE Conference, 2011.

[2] N.K.Sharma, P.P.Jagtap, “Modelling and application of Unified Power Flow Controller (UPFC)” Third International Conference on Emerging Trends in Engineering and Technology, IEEE pp 350-355, 2010.

[3] N.G. Hingorani, L. Gyugyi, "Understanding FACTS," New York: IEEE Press, pp. 2, 29, 135, 300 and 417.

[4] M.H.Haque, “Damping improvement by FACTS devices: A comparison between STATCOM and SSSC”, Electric power systems research, Vol.76, No. 9-10, pp.865- 872, 2007.

[5] Arun Kumar and G. Priya, “Power system stability enhancement using FACTS controllers”, IEEE press, 2012.

[6] Galu Papy Yuma and Galu Papy Yuma, “Damping of Oscillations of the IEEE 14 bus power system by SVC with STATCOM”, IEEE press, 2012.

[7] Kakkar, V., & Agarwal, N. K “Recent trends on FACTS and D FACTS”. In modern electric power systems (MEPS), proceedings of the international symposium IEEE. pp. 1-8, 2010.

[8] IEEE/CIGRE Joint Task Force on Stability Terms and Definitions, “Definition and classification of power system stability”, IEEE Transaction. on Power System Stability., Vol. 19, No. 2, pp. 1387 1400, May 2004.

[9] P. M. Anderson, A. A. Fouad, “Power system control and stability”,second edition IEEE press.