



International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijircce.com

Vol. 8, Issue 3, March 2020

Optimized Allotment of Smart Devices System for Power Quality Improvement and Control using D-FACTS

N.Sivakumar¹, A.Sathyapriya²

Professor and Head, Department of Electrical and Electronics Engineering, Jayalakshmi Institute of Technology, India¹

PG Scholar, Department of Electrical and Electronics Engineering, Jayalakshmi Institute of Technology, India²

ABSTRACT: Inter-area oscillations are turned to be a severe problem in a large inters connected power systems. Hence inter-area oscillations cause severe problems like damage to generators, reduce the power transfer capability of transmission lines, increase line losses, increase wear and tear on network components etc. This paper is to enhance the stability of power system by damping inter-area oscillations. Implementation of new equipment consists of high power electronics based technologies such as FACTs and proper controller design has become a essential to provide better damping performance than Power System Stabilizer (PSS). With development of Wide Area Measurement System (WAMS), remote signals have become as feedback signals to design Wide Area Damping Controller (WADC) for FACTs devices. Simulation studies are carried out in Power System Analysis Toolbox (PSAT) environment to evaluate the effectiveness of the proposed SVC of large area power system. Results show that the proposed SVC based damping controllers to improve the damping performance of the system in the event of small disturbances.

KEYWORDS: Power System Stabilizer, Wide-Area Measurement System, Wide-Area Damping Controller, Static VAR Compensator, Flexible AC Transmission system, Power Oscillation Damper.

I. INTRODUCTION

Electric power systems are constituted by the interconnection of a huge number of different components. They can be considered among the most complex systems to be a planned and safely operated. This complexity arises as a consequence of large amount of devices contemporaneously in operation, each one with its own internal dynamics, that however interact with each other, giving rise to a complex collective behavior. The wide geographic extension of electric power systems that can span entire countries and even continents, adds greater complexity to the issue connected to their analysis and control [3].

Power system stability is the ability of an electric power system for a given initial operating conditions to regain a state of operating equilibrium after being subjected to a physical disturbances, with most system variables bounded. So that practically the entire systems remain intact. C.Nagarajan et al [2,6,16] has studies Power system stability can be classified as voltage stability, Rotor angle stability and Frequency stability. Among these types Inter-area oscillation comes under rotor angle stability [1], [9], [13].

For any given situation, the rotor angle stability of the system depends on whether or not the deviations in angular positions of the rotors result in sufficient restoring torque. Loss of synchronism can occur between one machine and the rest of the system, or between groups of machines, with synchronism maintained within each group after separating from each other. The change in electromagnetic torque of a synchronous machine following a perturbation can be resolved into two components [1], [6], [9]:

- Synchronizing torque component, in phase with rotor angle deviation.
- Damping torque component, in phase with the speed deviation.



International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijirccce.com

Vol. 8, Issue 3, March 2020

If oscillation occurs between a large group of machines and rest of the system then such kind of oscillations are known as inter-area mode oscillations. Typical oscillation frequency range from 0.1HZ to 0.8HZ. In order to damp such electromechanical oscillations traditionally we use Power system stabilizers on generator excitation control system. Power system stabilizers are effective but usually they are designed for local modes and in large power systems they cannot able to provide enough damping for inter-area modes [3],[7],[11].

In this paper, Static Var Compensator (SVC), a shunt FACTS device has been widely used in power systems. SVC can increase the transmittable power by regulating the voltage and damping the power oscillations. While the main purpose of SVC is for voltage control, a proper supplementary control signal to SVC voltage control loop can provide damping to inter-area oscillations. Damping of inter-area oscillations are evaluated in PSAT software. The output of both fault conditions and fault condition with FACTS controller of power system is obtained with time domain specifications.

II. POWER SYSTEM UNDER STUDY

In this study the well-known New England 10-machine 39-bus test power system is employed as examples for large power systems, to demonstrate the proposed approach. Test systems were implemented using the software tool Power System Analysis Toolbox (PSAT) via the PSAT Simulink library as shown below. Implementing the New England 39-bus test system in PSAT.

In this sub-section, the New England 10-machine 39-bus test system implementation in PSAT is completely described. It should be emphasized that the methodology of the proposed approach is applicable to any other system in a similar manner. Synchronous machines are initiated after power flow computations.

A PV or a slack generator is required to impose the desired voltage and active power at the machine bus. Synchronous machines controls such as AVRs or Turbine Governors are not included in the machine models. Furthermore, the voltage ratings of all system equipments in kV need to be specified in PSAT environment. However, the New England 39-bus test systems data are provided based on per unit values. The voltage ratings for all machines were decided to be 400 kV. Then, the voltage ratings of the other equipments were chosen according to the existing transformers in the system [1],[4],[8].

The slack generator (bus 1), which is directly connected to the system without any transformer. Therefore, based on the voltage ratings chosen for the system equipments, the slack generator should be connected to a 400 kV bus, that indeed there is no generator working with this voltage level in practice. Each generator was described by a two-axis fourth-order model with a uniform damping ($k = D_i/M_i$) equal to 0.01. Besides one slack bus and 9 PV buses. The test system consists of additional 30 PQ buses. However, only 19 buses in the system have nonzero real and reactive loads. All loads were modeled as constant impedance model.

The contingency is a three-phase short-circuit ground fault at bus 36. This contingency is randomly chosen to illustrates the proposed methodology. However, the number of contingency scan be increased according to the needs of the user, without any problem related to the formulation. A fault can be model and then carried out the time-domain simulations in order to determine the critical clearing time by visualizing generators rotor angles at the 36 bus.

III. FACTS CONTROLLER DESIGN

Power Oscillation Damper (POD) together with their coordination of FACTS device has been developed for enhancing system stability. However, the use of POD may not be, in some cases, effective in providing sufficient damping for inter-area oscillations, particularly with increasing transmission line loading over long distances. Drawing on the availability of FACTS devices at present, which have been developed primarily for active power and/or reactive power flow and voltage control functions in the transmission system, more effective measures have been proposed for improving system damping. Proposed an optimization based technique for control coordination of POD and FACTS controllers for optimal oscillations damping in multi-machine power system. Damping of power system oscillations between inter connected areas is very important for the system secure operation [6], [15], [16].

International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijircce.com

Vol. 8, Issue 3, March 2020

POD co-ordinates with FACTS devices are used to enhance system stability. In large power systems, using only conventional POD may not be able to provide sufficient damping for inter-area oscillations. In these cases FACTS power oscillation damping controllers are effective solutions. But uncoordinated local control of FACTS devices and POD may cause destabilizing interactions in power system [12], [13].

In optimization based approach has been suggested for power system optimization and coordination of FACTS controllers to a significant transient stability improvement and effective power oscillation damping. The problem of poorly damped, low frequency oscillations, associated with the generator rotor swings has been a matter of concern to power engineers for a long time. Damping of electro-mechanical oscillations between interconnected synchronous generators is necessary for secure system operation. This increases the operational dynamic stability margin of power system [11], [12], [14].

A. Characteristics of FACTS controller

A static VAR compensator (SVC) is a shunt connected static VAR generator or absorber whose output is adjusted to exchange capacitive or inductive current so as to maintain or control specific variables of the electrical power system (typically bus voltage) [2], [3]. A typical topology of SVC comprises a parallel combination of a thyristor controlled reactor and a fixed capacitor as shown in Figure 1.

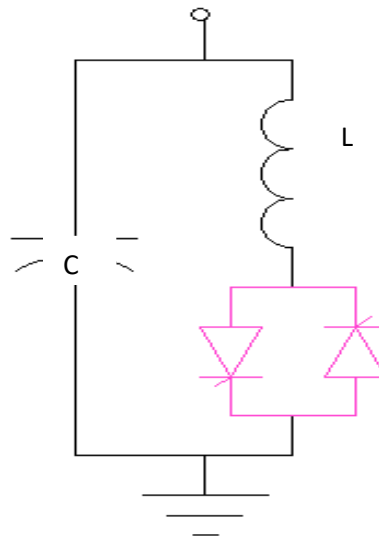


Fig.1. Typical Topology of SVC.

B. Design of Power Oscillation Damper

To damp electromechanical oscillations in power system, supplementary control action can be applied to some FACTS devices to increase the system damping. The supplementary control is called power oscillation damping (POD). Since the FACTS devices are located in transmission systems, local input signals are always preferred, usually the active or reactive power allow through the FACTS device. POD control is applied very often on PSS. In that case the local rotor speed is the input signal for POD controller.

International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijircce.com

Vol. 8, Issue 3, March 2020

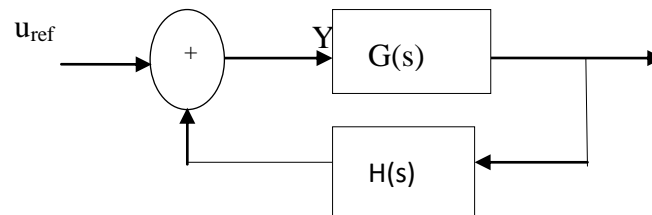


Fig. 2. Closed loop system with POD

Figure 2 shows the closed-loop system where $G(s)$ represents the power system and $H(s)$ the FACTS POD controller and it consists of an amplification block, a wash-out and a low-pass filters and m_c stages of lead-lag blocks. The transfer function, $H(s)$ of the POD controller is given by Equation

$$H(s) = K \frac{1}{1+ST_m} \frac{ST_w}{1+ST_w} \left[\frac{1+ST_{lead}}{1+ST_{lag}} \right]^{m_c} = K_1(s) \quad (1)$$

K is a positive constant gain and $H(s)$ is the transfer function of the wash-out and lead-lag blocks. T_m is a measurement time constants and T_w is the washout time constant. T_{lead} and T_{lag} are the lead and lag time constant respectively.

$$\alpha_c \frac{T_{lead}}{T_{lag}} = \frac{1 - \sin \frac{\phi_{comp}}{m_c}}{1 + \sin \frac{\phi_{comp}}{m_c}} \quad (2)$$

$$T_{lag} = \frac{1}{\omega \sqrt{\alpha_c}} \quad (3)$$

$$T_{lead} = T_{lag} \alpha_c \quad (4)$$

Where m_c is the number of compensation stages (usually $m_c = 2$).

IV. TEST SYSTEM DESCRIPTION

In this paper, the SVC is used to damp power oscillations on a power grid following a three-phase fault which is more severe. The power system consists of three areas when fault is introduced in area 2 at the bus 36 consists of generator 7.

International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijircce.com

Vol. 8, Issue 3, March 2020

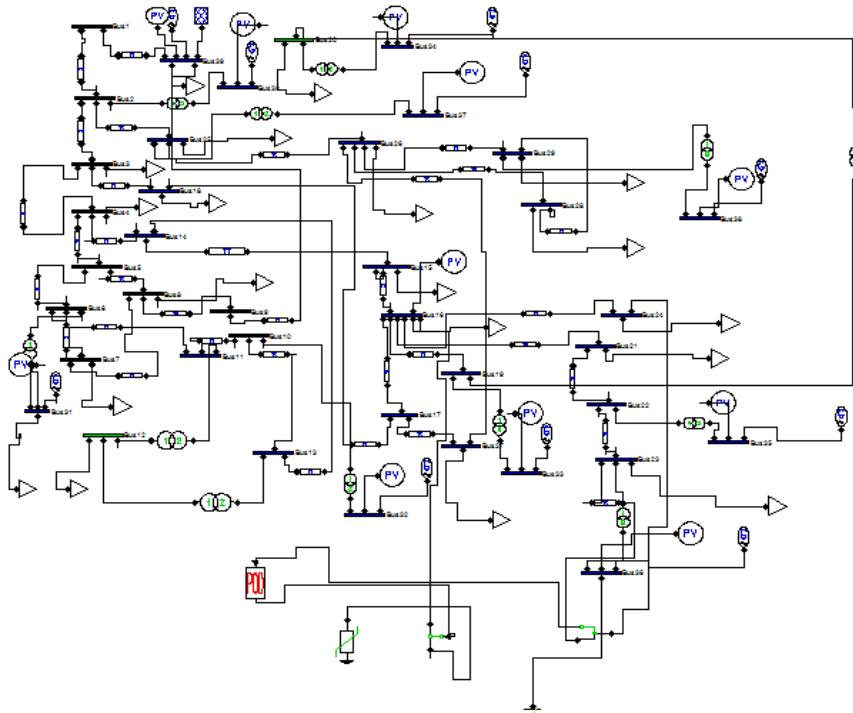


Fig .3.Simulation Diagram of 39 Bus System with

FACTS controller

V. RESULTS AND DISCUSSION

A. Healthy system (without fault)

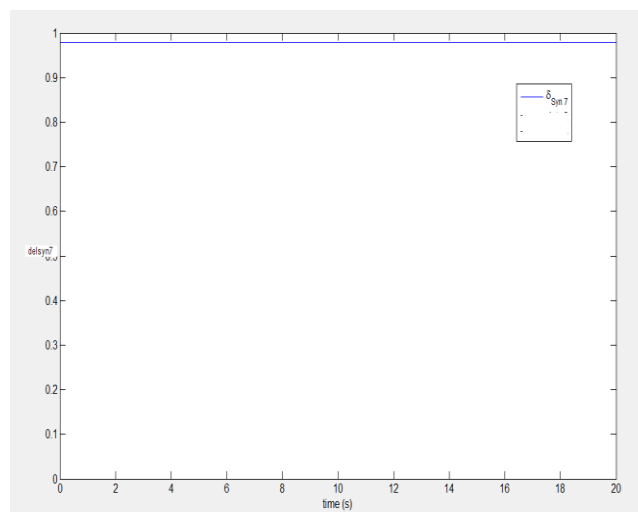


Fig.4.Rotor Angle of Machine 7

International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijirce.com

Vol. 8, Issue 3, March 2020

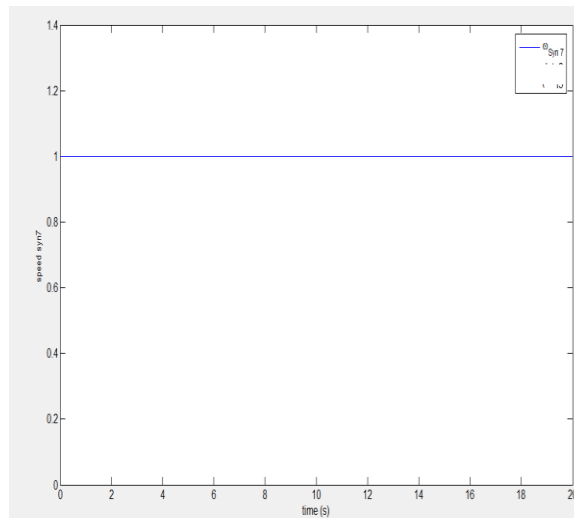


Fig .5.Rotor Speed of Machine 7

B. System with Fault

In order to simulate the system behavior under large disturbance conditions (With fault at bus 36 where machine 7 is connected) without FACTS controller.

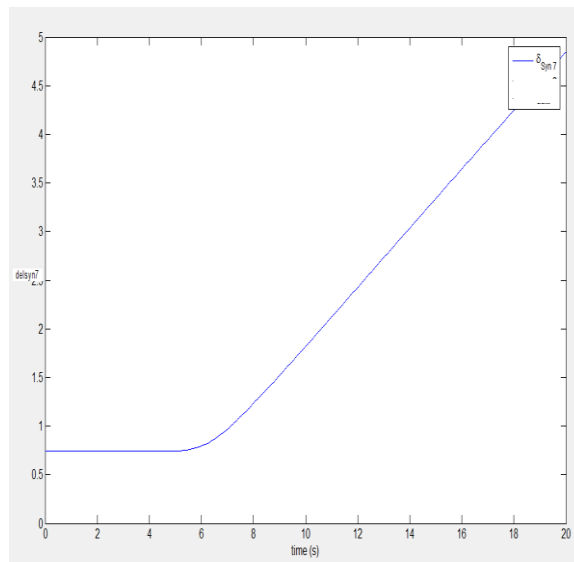


Fig. 6.Rotor Angle of Machine 7 without FACTS controller and with fault at 36 bus.

International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijirce.com

Vol. 8, Issue 3, March 2020

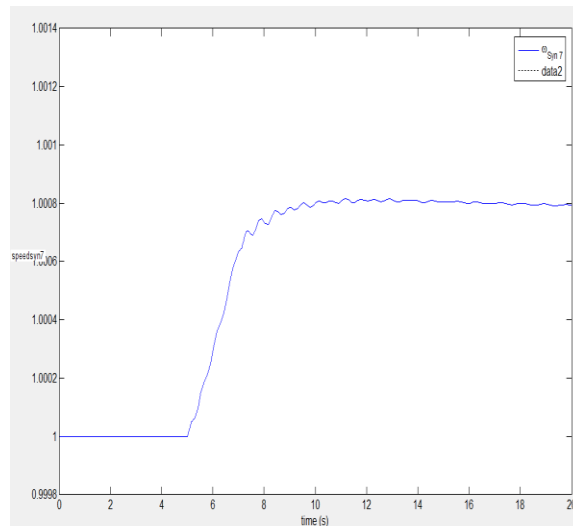


Fig .7.Rotor Speed of Machine 7without FACTs controller and with fault at 36 bus

C.System with FACTs Controller

In order to simulate the system behavior under large disturbance conditions (With fault at bus 36 where machine 7) with FACTs controller.

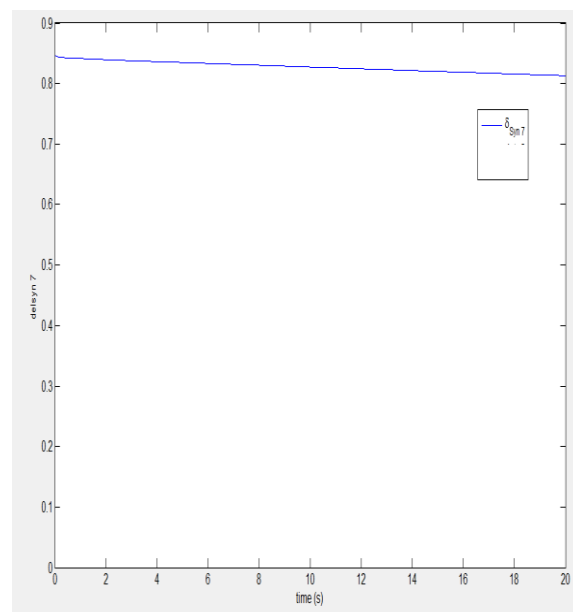


Fig .8.Rotor Angle of Machine 7with FACTs controller

International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijircce.com

Vol. 8, Issue 3, March 2020

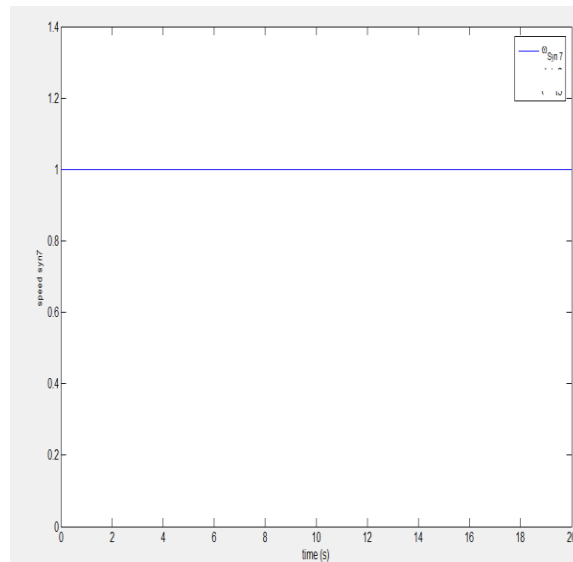


Fig .9.Rotor Speed of Machine 7 with FACTS controller

Figure 4 and Figure 5 clearly depicts that there is no deviation in the rotor angle and there is no speed deviation in the machine 7 when there is no fault in the system. If the fault is introduced in the system at the bus 36, a machine 7 connected to the bus 36 oscillates due to insufficient damping torque and insufficient synchronizing torque. When such oscillations persists it will causes steady increase in rotor angle and speed of machine and it results instability. In order to maintain the stability of system, these oscillations are damped as quickly as possible. The results, due to the fault are shown in Figure 6 and Figure 7.

PSSs damp the inter-area oscillations by changing the excitation of the system and it takes more time to damp these oscillations. FACTS controller provide better damping compared to PSSs. The results are shown in Figure 8 and Figure 9. FACTS controller retain the stability of the system by damping the inter-area oscillations.

VI. CONCLUSION

The enhancement of rotor angle stability in a power system is done by using different FACTS Controllers and it is analysed with the help of PSAT software. The New England 10-machine39-bus test power system power system was used as examples to demonstrate the proposed approach. The results show that the power system oscillations are damped out very quickly with the help of SVC based damping controllers in few seconds.

These results show that the use of SVC is improved dynamic response and at the same time faster than other conventional controllers. Moreover, this approach is also simple and easy to be realized in power systems.

REFERENCES

- [1] Bindeshwar Singh, "Applications of FACTS Controllers in Power Systems for Enhance the Power System Stability: a State-Of-The-Art", International Journal of Reviews in Computing Vol. 6, 15th July 2011.
- [2] C.Nagarajan and M.Madheswaran - 'Stability Analysis of Series Parallel Resonant Converter with Fuzzy Logic Controller Using State Space Techniques'- *Electric Power Components and Systems*, Vol.39 (8), pp.780-793, May 2011
- [3] Malihe M. Farsangi, Hossein Nezamabadi-pour, Yong-Hua Song Kwang Y. Lee " Placement of SVCs and Selection of Stabilizing Signals in Power Systems", *IEEE Transactions on Power Systems*, Vol. 22, No. 3, August 2007
- [4] Tridib K. Das, SandhyaR. Jetti, and Ganesh K. Venayagamoorthy "Optimal Design of SVC Damping Controllers with Wide Area Measurements Using Small Population Based PSO", *IEEE transactions* July 16-21, 2006



International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijircce.com

Vol. 8, Issue 3, March 2020

- [5] Niches Kumar Sharma, Arindam Ghosh, "A Novel Placement Strategy for FACTS Controllers", IEEE Transactions on Power Delivery, Vol. 18, No. 3, July 2003
- [6] E Geetha, C Nagarajan, "Induction Motor Fault Detection and Classification Using Current Signature Analysis Technique", 2018 Conference on Emerging Devices and Smart Systems (ICEDSS), 2nd and 3rd March 2018, organized by mahendra Engineering College, Mallasamudram, PP. 48-52,2018
- [7] Sreelal Elamana, A.Rathinam "Inter-area Oscillation Damping by Unified Power Flow Controller-Superconducting Magnetic Energy Storage Integrated System", International Journal of Engineering and Advanced Technology (IJEAT) Vol-2, Issue-3, Feb 2013
- [8] A.Karami, S.Z. Esmaili "Transient Stability Assessment of Power Systems Described with Detailed Models using Neural Networks", ELSEVIER 29 August 2012.
- [9] Balarko Chaudhur, Rajat Majumder, and Bikash C. Pal "Wide-Area Measurement-Based Stabilizing Control of Power System Considering Signal Transmission Delay", IEEE Transactions on Power Systems, vol. 19, No. 4, November 2004 .
- [10] Hasan Fayazi Boroujeni, Meysam Eghtedari, Ahmad Memaripour and Elahe Behzadipour "The Designed HS Based Stabilizer is Exerted to Damping LFO in Study System", Indian Journal of Science and Technology, Vol. 4 No. 12, Dec2011.
- [11] P.Kundur, "Power System Stability and Control", New York: McGraw- Hill, 1994.
- [12] J. Chow, J. Sanchez-Gasca, H. Ren, and S. Wang, "Power system damping controller design using multiple input signals", IEEE Control Syst. Mag., vol. 20, Aug. 2000.
- [13] J. Chow, J. Sanchez-Gasca, H. Ren, and S. Wang, "Power system damping controller design using multiple input signals", IEEE Control Syst. Mag., vol. 20, Aug. 2000.
- [14] A.E.Hammad, "Analysis of Power System Stability Enhancement by Static VAR Compensators", IEEE Transaction.PWRS, 1986.
- [15] M. A. Abido, "Analysis of Power System Stability Enhancement via Excitation and Facts-Based Stabilizers", Electric Power Components and Systems, Volume 32,1 January 2004.
- [16] C. Nagarajan, M.Madheswaran and D.Ramasubramanian- 'Development of DSP based Robust Control Method for General Resonant Converter Topologies using Transfer Function Model'- *Acta Electrotechnica et Informatica Journal* , Vol.13 (2), pp.18-31, April-June.2013
- [17] M. Noroozian, M. Ghandhari, G. Andersson, J. Gronquist, and I. Hiskens, "A Robust Control Strategy for Shunt and Series Reactive Compensators to Damp Electromechanical Oscillations", IEEE Trans. On Power Delivery, Vol. 16, No. 4, October 2001.
- [18] M. Noroozian and G. Andersson, "Damping of Power System Oscillations by use of Controllable Components", IEEE Transaction, On Power Delivery, Vol. 9, No. 4, October 1994.
- [19] K.R. Padiyar, "Power System Dynamics - Stability and Control", Second Edition, Hyderabad: B.S. Publications, 2002.