Global Journal of Researches in Engineering: F
Electrical and Electronics Engineering
Volume 14 Issue 2 Version 1.0 Year 2014
Type: Double Blind Peer Reviewed International Research Journal
Publisher: Global Journals Inc. (USA)
Online ISSN: 2249-4596 & Print ISSN: 0975-5861

Design of STATCOM for Power System Stability Improvement

By Sohel Hossain, Atiqur Rahman Khan & Jannat-E-Noor
Khulna University of Engineering & Technology (KUET), Bangladesh

Abstract- This paper presents the model of a STATCOM which is controlled externally by a newly designed Power Oscillation Controller (POC) for the improvements of power system stability and damping effect of an on line power system. The proposed POC consists of two controllers (PID & POD). PID parameters has been optimized by Zigler Necles close loop tuning method. Machine excitation has been controller by using excitation controller as required. Both single phase and three phase faults has been considered in the research. In this paper, A power system network is considered which is simulated in the phasor simulation method & the network is simulated in three steps; without STATCOM, With STATCOM but no externally controlled, STATCOM with Power Oscillation Controller (POC). Simulation result shows that without STATCOM, the system parameters becomes unstable during faults. When STATCOM is imposed in the network, then system parameters becomes stable. Again, when STATCOM is controlled externally by POC controllers, then system voltage & power becomes stable in faster way then without controller. It has been observed that the STATCOM ratings are only 20 MVA with controllers and 200 MVA without controllers. So, STATCOM with POC controllers are more effective to enhance the voltage stability and increases power transmission capacity of a power system .So STATCOM with POC & excitation controllers, the system performance is greatly enhanced.

Keywords: STATCOM, voltage regulator, power system controller, PID, POD, power oscillation controller (POC), MATLAB simulink.

GJRE-F Classification : FOR Code: 090607

Design of STATCOM for Power System Stability Improvement

Sohel Hossain [α], Atiqur Rahman Khan [σ] & Jannat-E-Noor [ρ]

Abstract- This paper presents the model of a STATCOM which is controlled externally by a newly designed Power Oscillation Controller (POC) for the improvements of power system stability and damping effect of an on line power system. The proposed POC consists of two controllers (PID & POD). PID parameters has been optimized by Zigler Necles close loop tuning method. Machine excitation has been controller by using excitation controller as required. Both single phase and three phase faults has been considered in the research. In this paper, A power system network is considered which is simulated in the phasor simulation method & the network is simulated in three steps; without STATCOM, With STATCOM but no externally controlled, STATCOM with Power Oscillation Controller (POC). Simulation result shows that without STATCOM, the system parameters becomes unstable during faults. When STATCOM is imposed in the network, then system parameters becomes stable. Again, when STATCOM is controlled externally by POC controllers, then system voltage & power becomes stable in faster way then without controller. It has been observed that the STATCOM ratings are only 20 MVA with controllers and 200 MVA without controllers. So, STATCOM with POC controllers are more effective to enhance the voltage stability and increases power transmission capacity of a power system .So STATCOM with POC & excitation controllers, the system performance is greatly enhanced.

Keywords: STATCOM, voltage regulator, power system controller, PID, POD, power oscillation controller (POC), MATLAB simulink.

I. Introduction

Power system stability improvements is very important for large scale system. The AC power transmission system has diverse limits, classified as static limits and dynamic limits[1- 2].Traditionally, fixed or mechanically switched shunt and series capacitors, reactors and synchronous generators were being used to enhance same types of stability augmentation[3]. For many reasons desired performance was being unable to achieve effectively. A STATCOM is an electrical device for providing fast-acting reactive power compensation on high voltage transmission networks and it can contribute to improve the voltage profiles in the transient state and therefore, it can improve the qualities and performances of the electric services[3]. An STATCOM can be controlled externally by using properly designed different types of controllers which can improve voltage stability of a large scale power system. In previous study Authors has d signed a PID controller which has tuned by Triple Integral Differential (TID) tuning method [4]. However, in this study, With a view to get better performance, A new Power Oscillation Controller (POC) has been designed & proposed for STATCOM to injects Vqref externally for the improvement of power system stability. Therefore, thyristor based STATCOM with POC controllers has been used to improve the performance of power system.

Authors α σ: Dept. of EEE, Khulna University of Engineering & Technology (KUET) Bangladesh. e-mails: sohelheee@gmail.com, nirjhor.kuet@gmail.com

Author ρ: Department of EEE, Rajshahi University of Engineering & Technology (RUET). Lecturer, Dept. of EEE, Varendra University Bangladesh. e-mail: farah1809@yahoo.com

II. Control Concept of STATCOM

A static synchronous compensator (STATCOM), also known as a "static synchronous condenser" ("STATCON"), is a regulating device used on alternating current electricity transmission networks. It is based on a power electronics voltage-source converter and can act as either a source or sink of reactive AC power to an electricity network. If connected to a source of power it can also provide active AC power. It is a member of the FACTS family of devices. Usually a STATCOM is installed to support electricity networks that have a poor power factor and often poor voltage regulation. A STATCOM is a voltage source converter (VSC)-based device, with the voltage source behind a reactor. The voltage source is created from a DC capacitor and therefore a STATCOM has very little active power capability. However, its active power capability can be increased if a suitable energy storage device is connected across the DC capacitor. The reactive power at the terminals of the STATCOM depends on the amplitude of the voltage source [5].diagram.

III. Power System Model

This example described in this section illustrates modeling of a simple transmission system containing 2- hydraulic power plants [Fig.1]. STATCOM has been used to improve transient stability and power system oscillations damping. The phasor simulation method can be used.

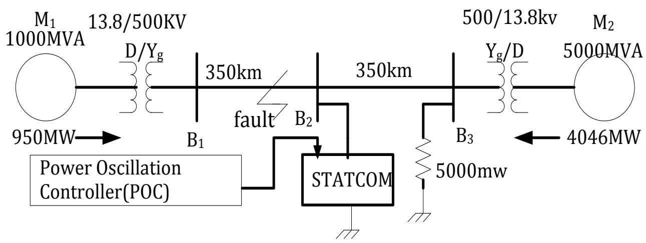

Figure 1 : Single line diagram of 2-machine power system

A single line diagram represents a simple 500 kV transmission system is shown in Fig.1 [6].In the proposed plan because resistor is low cost than potential transformer. A 1000 MW hydraulic generation plant (M1) is connected to a load centre through a long 500 kV, total 700km transmission line. A 5000 MW of resistive load is modelled as the load centre. The remote 1000 MVA plant and a local generation of 5000 MVA (plant M2) feed the load. A load flow has been performed on this system with plant M1 generating 950 MW so that plant M2 produces4046 MW. The line carries 944 MW which is close to its surge impedance loading (SIL = 977 MW). To maintain system stability after faults, the transmission line is shunt compensated at its centre by a 200MVAR STATCOM [Fig.2].The STATCOM does not have any controller unit. Machine & STATCOM parameters has been taken from reference [5].The complete simulink model of STATCOM with power system controller is shown in Fig.4. To maintain system stability after faults, the transmission line is shunt compensated at its centre by a 200MVAR STATCOM with power system controller. The two machines are equipped with a hydraulic turbine and governor (HTG) [Fig.2], excitation system. Any disturbances that occur in power systems due to fault, can result in inducing electromechanical oscillations of the electrical generators. Such oscillating swings must be effectively damped to maintain the system stability.

IV. Simulation Results

The load flow solution of the above system is calculated and the simulation results are shown below. Two types of faults: A. single line to ground fault & B. Three phase fault have been considered.

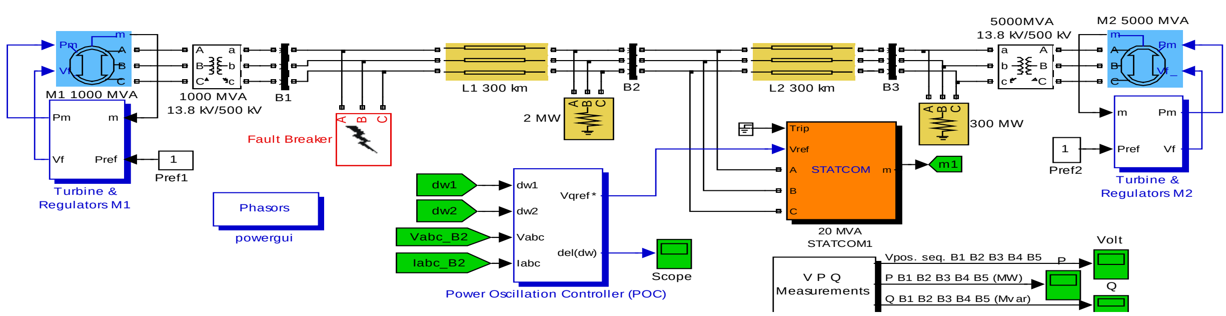

Figure 2 : Complete simulink model of 2-machine power system

a) *Single line to ground fault*

Consider a 1-phase fault occurred at 0.1s & circuit breaker is opened at 0.2s (4-cycle fault), Without STATCOM, the system voltage, power & machines oscillates goes on unstable [Fig. (3, 5)]. But if STATCOM (without controller) is applied then voltage becomes stable within 3s [Fig.4], power becomes within 3s [Fig.6]. All results has been summarized in table-I.

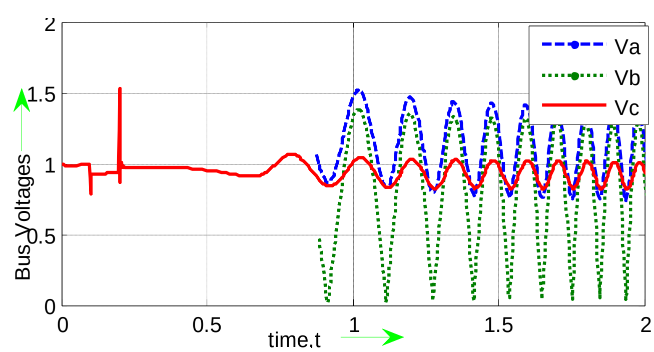

Figure 3 : Bus voltages for 1-phase fault (without STATCOM)

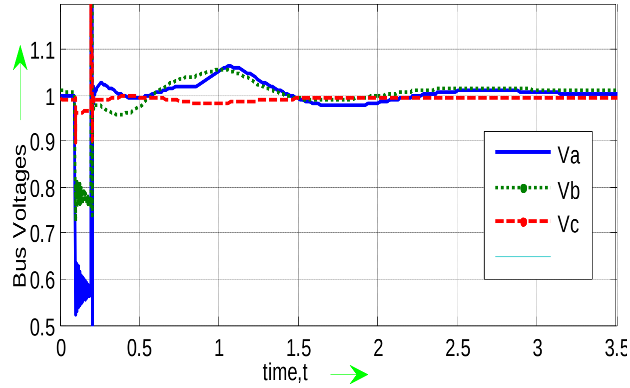

Figure 4 : Bus Voltages in p.u for 1-phase fault (with STATCOM)

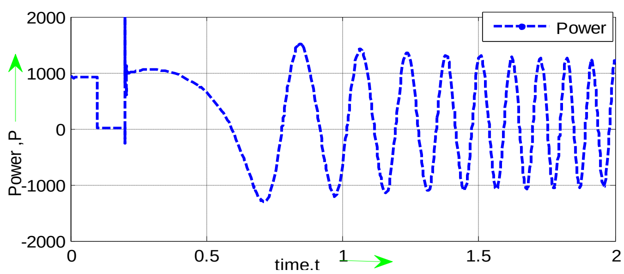

Figure 5 : Bus power, P in MW during fault (Without STATCOM)

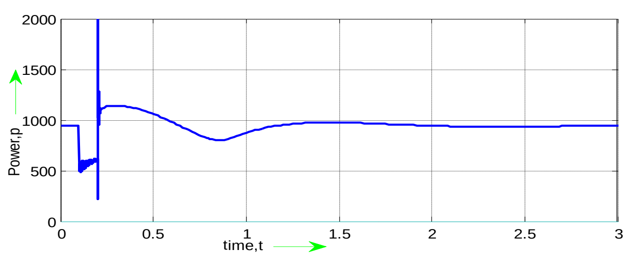

Figure 6 : Bus Power (P) in MW for 1-Ø faults (with STATCOM)

V. Design of Power Oscillation Controller (POC)

The proposed Power Oscillation controller consists of two parts, A. Proportional Integral Derivative (PID) controller which is tuned by Zieglar-Nicles method [4] & Power Oscillation Damping (POD) controller. PID controller takes input as machines angular speed deviation & get an error signal & POD controller takes input as line voltage & line current & after damp out the oscillation it also gives as error signal. Finally, the proposed power oscillation controller takes input as all parameters of power system network i.e. Vabc, Iabc, dω & it gives an error signal (Vqref) which injects STATCOM for improvement of power system stability.

a) Designed of PID Controller

The process of selecting the controller parameters to meet given performance specifications is called PID tuning. Most PID controllers are adjusted on-site, many different types of tuning rules have been proposed in the literature [4]. Using those tuning rules, delicate & fine tuning of PID controllers can be made on-site. Also automatic tuning methods have been developed and some of the PID controllers may possess on-line automatic tuning capabilities [4].
The PID controller has three term control signal[4],

$$u(t) = K_p e(t) + \frac{K_p}{T_i}\int e(t)dt + K_p T_d \frac{de(t)}{dt} \qquad (1)$$

In Laplace Form,

$$\frac{U(s)}{E(s)} = K_p\left(1 + \frac{1}{T_i} + T_d s\right)$$

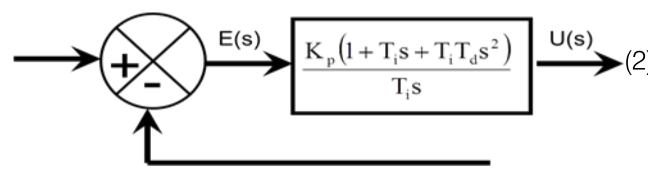

Figure 7 : Block diagram of PID controller parameters

For selecting the proper controller parameters, Ziegler-Nichols PID Tuning [4], Second Method is described below.

In the 2nd method, the parameter is selected as Ti= ∞ ,Td=0. Using the proportional controller action [Fig.4] only increase Kp from 0 to a critical value Kcr. At which the output first exhibits sustained oscillations [Fig.9].

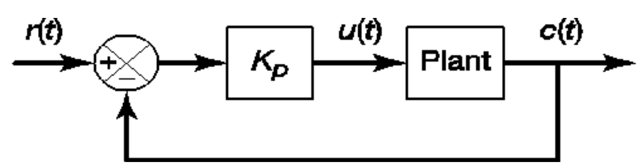

Figure 8 : PID controller is in proportional action

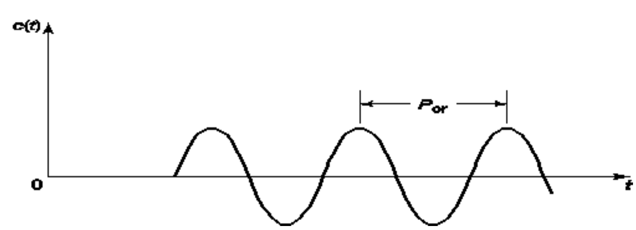

Figure 9 : Determination of sustained oscillation (Pcr)

Thus the critical gain Kcr & the corresponding period Pcr are experimentally determined. Ziegler and Nichols suggested that the values of the parameters Kp Ti Td should set according to the following formula.

Kp=0.6Kcr, Ti=0.5Pcr, Td=0.125Pcr

Notice that the PID controller tuned by the 2nd method of Ziegler-Nichols rules gives,

$$G_C(s) = K_p\left(1 + \frac{1}{T_i * S} + T_d S\right) \quad (3)$$

$$G_C(s) = 0.6K_{cr}\left(1 + \frac{1}{0.5P_{cr} * S} + 0.125P_{cr} S\right) \quad (4)$$

$$G_C(s) = 0.075K_{cr} * P_{cr} \frac{\left(S + \frac{4}{P_{cr}}\right)^2}{S} \quad (5)$$

Thus the PID controller has a pole at the origin and double Zeros at S= - 4/Pcr [Fig.10].

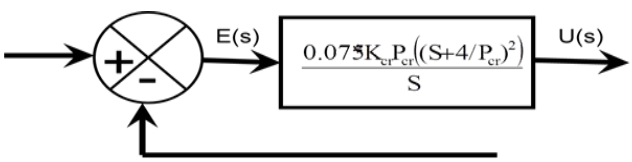

Figure 10 : PID controller with tuning parameters

The critical gain (Kcr) for which the plant output gives a sustained oscillation [Fig.9] is determined for this network (Kcr=200) & corresponding period of Pcr [Fig.9] is also determined from Fig.9 & found Pcr=0.2.Thus the transfer function or parameters of PID controller is determined based on Ziegler-Nichols tuning method [Eq. (1)] which is shown in fig.11 (a, c). During faults the machines angular speed deviation (dω) & mechanical power (Pm), line voltage, line current, power all are changed. So, dω & pm are taken as the input parameters of newly designed PID controller. The proposed PID controlled SVC simulink model is shown in the fig.11.

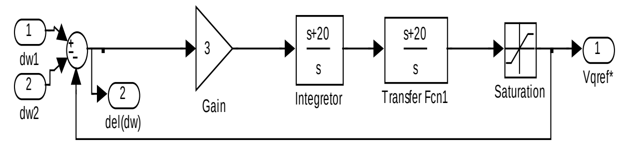

Figure 11 : Internal Structure of PID Controller

b) Designed of POD Controller

The Power Oscillation Damping Controller [Fig.12] takes input as Vabc, Iabc & it convert it as power. If no faults has occurred then switch remains open. But when fault occurred then switch becomes closed & after filtering or dampout oscillation, it also gives an error signal & finally two error signal has been added & this is Vqref.

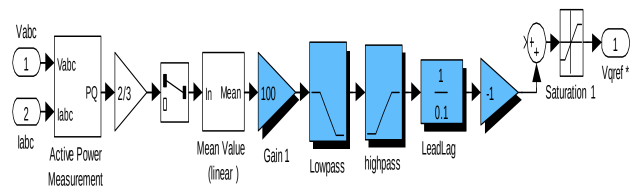

Figure 12 : Internal Structure of POD controller

c) Power Oscillation Controller (POC)

The proposed Power Oscillation Controller consists of both two controllers (PID & POD) [Fig.13] which injects Vqref in STATCOM further improve the power system stability.

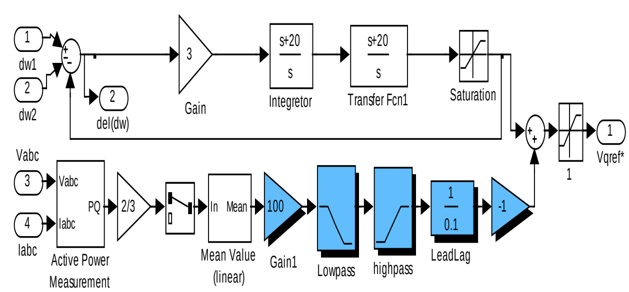

Figure 13 : Internal Structure of Power Oscillation Controller (POC)

VI. Design of Excitation Controller

Alternator prime mover consists of Hydraulic turbine governor (HTG) & Excitation block [Fig.14].

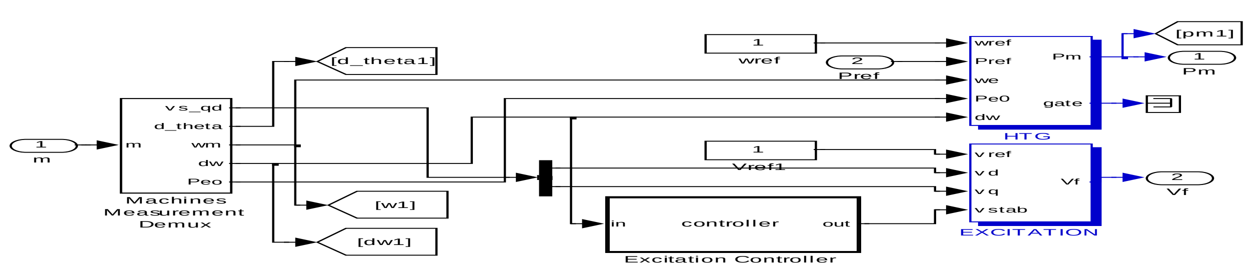

Figure 14 : HTG & Excitation block with controller

Global Journal of Researches in Engineering (F) Volume XIV Issue II Version I Year 2014

Alternator state can be sensed by a feedback. If any faults occur in network then HTG changes the speed of machine & Machine excitation can be changed by excitation controller. Inside the excitation controller, a MATLAB program has been sets so that machine excitation will change as required to regain system stability.

VII. Simulation Results with POC

The network remains same [Fig.2], just simple STATCOM is replaced by power system controlled STATCOM. During fault, machines speed deviation (dω) & Line voltage (Vabc), Line current (Iabc) are always monitored by power system controller & taking input of those oscillation, after processing as shown in Fig.13, it reduces damping of power system oscillation & helps STATCOM to improve stability. Two types of faults has been considered: A. Single line to ground fault and B. Three phase fault.

a) Single line to ground fault

During 1-phase faults, if POC is used as STATCOM controller then, the system voltage becomes stable within 0..25s with 0% damping [Fig.15] & Power (P,Q) becomes stable within 0.25s [Fig.16].

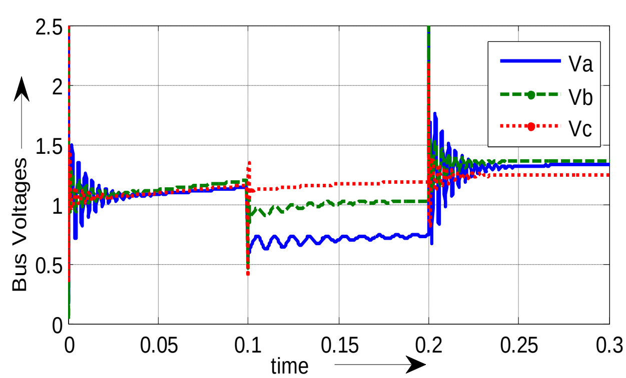

Figure 15 : Bus voltage in p.u for 1-Ø fault (with POC)

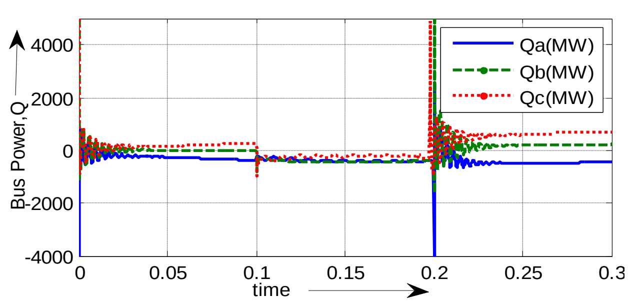

Figure 16 : Bus Power,Q for 1-Ø fault in MW (with POC)

b) Three phase fault

During 3-phase faults, If POC is used as STATCOM controller then, the system voltage becomes stable within 0.25s [Fig.17] & Both power, P becomes stable within 0.25s [Fig.18].

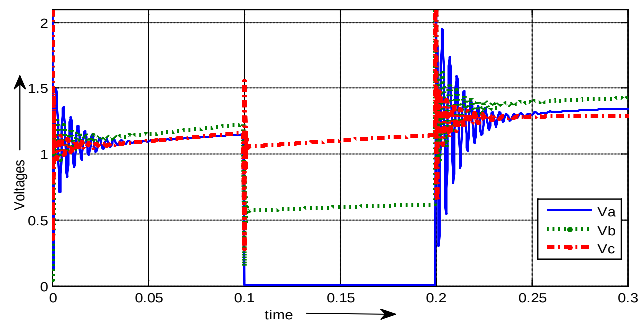

Figure 17 : Bus voltages in p.u for L-L fault (with POC)

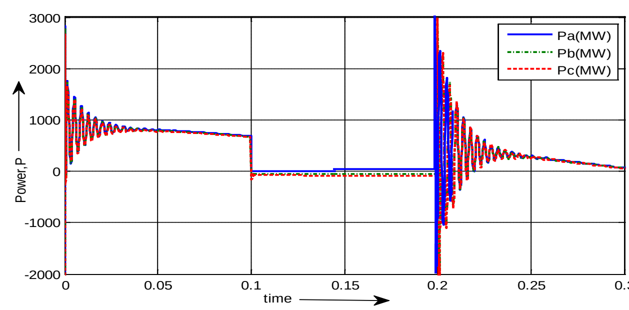

Figure 18 : Bus power, P in MW for L-L fault (with POC)

VIII. Results & Conclusion

The performance of the proposed Power Oscillation Controller with STATCOM has been summarized in the table-I. In table-I, α (infinite time) means the system is unstable, STATCOM rating in MVA. The network is simulated in three steps; without STATCOM, With STATCOM only, STATCOM with proposed Power Oscillation Controller (POC) & Excitation controller.

Table 1 : Performance of proposed Power Oscillation Controller

Controller Status		1-Ø fault (Stability time)		3-Ø fault (Stability time)	
Controller	STATCOM Rating	Volt	P,Q	Volt	P,Q
No STATCOM	0 MVA	α	α	α	α
STATCOM	200 MVA	3s	3s	5s	5s
STATCOM + POC	20 MVA	0..25s	0.25s	0.25s	0.25s

IX. Conclusion

This paper presents the power system stability improvement i.e. voltage level, machine oscillation damping, real power system model of STATCOM without or with proposed Power Oscillation Controller for different types of faulted conditions. POC is also a very efficient controller then others for STATCOM to enhance the power system stability. From above results, this proposed Zigler-Nicles close loop tuning method for selecting PID controller parameters & POD, In combine, Power Oscillation Controller may be highly suitable as a STATCOM controller because of shorter stability time, simple designed, low cost & highly efficient controller. Machines DC Excitation can also be controlled easily by using excitation controller. Rather that, If POC controller is used then only small rating of STATCOM becomes enough for stabilization of robust power system within very shortest possible time for both steady state & dynamic conditions. These proposed Power Oscillation Controller can be applied for any interconnected multi-machine power system network for stability improvement.

These controller can be applied to another FACTS devices namely SSSC, UPFC whose controllers may be controlled externally by designing different types of controllers which also may be tuned by using different algorithm i.e. Fazzy logic, ANN, Genetic algorithm, FSO etc. for both transient and steady state stability improvement of a power system.

References Références Referencias

1. Hasan Fayazi Boroujeni, Mehran Amani and Mostafa Abdollahi, Dynamic Stability Improvement by Using STATCOM in a Multi Machine Environment, Research Journal of Applied Sciences, Engineering and Technology 4(18): 3505-3509, 2012 ISSN: 2040-7467, September 15, 2012, Iran.
2. Furini, M.A., A.L.S. Pereira and P.B. Araujo, 2011. Pole placement by coordinated tuning of Power System Stabilizers and FACTS-POD stabilizers. Int. J. Elec. Power Energ. Syst., 33(3): 615-622.
3. Ye, Y., Kazerani, M., and Quintana, V.H., 2005. Current-source converter. Based STATCOM: Modeling and control. IEEE Transactions on Power Delivery 20(2): 795-800.
4. *Habibur, Dr. Fayzur, Harun,* "Power System Stability Improvement By Using SVC With TID Tuned PID Controller", IJARCET, ISSN-2278-1323 (online), India,Vol:1, Issue:8, October-2012,Pp. 93-98.
5. http://en.wikipedia.org/wiki/STATCOM.
6. "MATLAB Math Library User's Guide", by the Math Works. Inc.
7. Lehn, P.W. and M.R., El-Moursi, M.S. and A.M. Sharaf, 2006. Novel reactive power controllers for the STATCOM and SSSC. Electric Power Systems Research 76(4): 228-241.
8. M. A. Abido, Analysis and assessment of STATCOM based damping stabilizers for power system stability enhancement, Electric Power Systems Research, Vol. 73, pp. 177-185, 2005.