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Comparative study of PSS and STATCOM-POD for Transient Stability in Microgrid

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ABSTRACT— ***The main issue considering power system security is how to reduce the overshoot and have better rate of damping of power system oscillations. Generally, PSS are used for power system oscillation damping, but inter area oscillations are not effectively damped with PSS, so FACTS devices with supplementary controller are used for effective damping of power system oscillations. A systematic approach is presented in this paper for designing of STATCOM with supplementary controllers to damp local and inter area oscillations in a micro grid. Detailed study have been carried out by applying three phase short circuit fault followed by line outage considering controllers like Power System Stabilizer (PSS) and Power Oscillation Damper (POD). Parameters of controllers are validated by performing Eigen value analysis. Here modified IEEE-14 bus system is used as the test system in which DFIG is implanted in bus 1 and MATLAB/ PSAT is used as simulation platform. The result illustrates that STATCOM-POD has better damping control than PSS.***

Keywords— PSS, POD, STATCOM, FACTS, low frequency oscillation damping

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1. INTRODUCTION

Due to the heavy growth in power demand and to reduce the generation cost, are making the existing power system network to run in its maximum possible capacity so network becomes less secure to contingencies. So as to improve the system security in addition to the local controllers like PSS and AVRs, FACTS devices with supplementary controllers are used [1],[2].

Under steady state conditions FACTS devices can be used to improve the power system security, but FACTS devices with supplementary controllers can improve transient and dynamic stability of power system [3].

Local controllers like PSS can damp local area oscillations, these local modes of oscillations are due to swinging of units at generating station with respect to rest of the power system. Inter area oscillations which are caused by two or more group of closely coupled machines being interconnected by weak tie lines cannot be damped by local controllers i.e. PSS so FACTS devices with supplementary controllers like Power Oscillation Damper (POD) are used which can damp local and inter area oscillations with comparatively lesser time than local controllers [4].

Due to any small or large disturbance electromechanical oscillations are introduced in power system which should be damped quickly so that system can move to stable state. The duration of inter area oscillations should not be more than 5 seconds. Oscillations should have at least 5% damping ratio [5], [6].

Inter area oscillations will result in some operating limitations that is reduction in power transfer in transmission lines or loss of synchronism among the generators in the system. Finally in the presence of system oscillations the operation of system becomes difficult [7].

In this paper power oscillation damping capability of PSS, STATCOM without controller and STATCOM with supplementary controller (POD) is implemented and studied. Modified IEEE-14 bus is used as test system and simulation is done using MATLAB/PSAT.

2. PARAMETER TUNING OF PSS

The block diagram of the PSS controller is shown in Fig 1 it involves a gain block with gain K_{PSS}, a signal wash-out block with washout time constant T_W, two lead-lag blocks with time constants T_1, T_2, T_3 and T_4 and an anti-windup limiter with time constant T_r [8]. The PSS will generate the necessary torque on the rotor of the electrical machines hence the phase lag between the exciter input and the machine electrical torque is compensated. PSS consists of many blocks in which the wash out block resembles a high pass filter with the time constant T_w, which offers zero resistance to the signal associated with oscillations in rotor speed and it resists steady state changes to cause disturbance in output voltage.

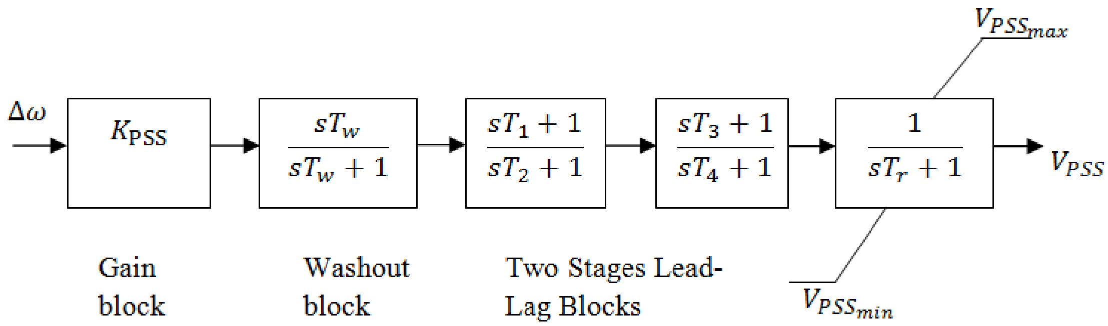

Figure 1. Transfer function block of PSS

Normally the value of time constant is taken between 0.5 to 20 seconds. Phase compensation block with time constants T_1, T_2 and T_3, T_4 supplies the suitable phase-lead characteristics so that it can compensate for the phase lag between input and the output signals. The five PSS parameters consisting of the four time constantsT_1 to T_4 and the gain K_{PSS} need to be optimally chosen for each generator to guarantee optimal system performance under various system configurations and disturbances [8].

The optimized values of PSS parameters are found by eigenvalue analysis by considering the system stability. Here voltage stability limit of the modified IEEE-14 bus system was taken as the criterion.

Table I. Optimized Value of PSS Parameters Considering System Stability

Controller	Tuned parameters considering system stability						
PSS	K_{PSS}	T_w	T_1	T_2	T_3	T_4	T_r
	5	10	0.38	0.02	0.38	0.02	0.5

3. PARAMETER TUNING OF POD

Power Oscillation Damper has same transfer function as that of PSS. Here POD is used as a supplementary control of STATCOM .Thus with the tuned POD properly controls the action of STATCOM. With STATCOM, power oscillation damping (POD) is done by dynamic control of the system voltage so that during upward portions of the power v/s time profile, the STATCOM support(s) the voltage, thereby acting to lower the motion of the rotating machine(s). Likewise, during lower portions of the power v/s time profile, the STATCOM is controlled to lessen the system voltage, thereby acting to accelerate the rotating machine(s). Hence the time required for damping the power system oscillations can be reduced to great extent [9], [10].

Table II. Optimized Value of POD Parameters Considering System Stability

Controller	Tuned parameters considering system stability						
POD	K_{POD}	T_w	T_1	T_2	T_3	T_4	T_r
	1	0.83	0.8	0.4	0.8	0.4	0.5

Fig 2 represents the improved value of each bus voltage when STATCOM was implemented to the weakest bus in modified IEEE- 14 bus system integrated with DFIG system [12], [13].

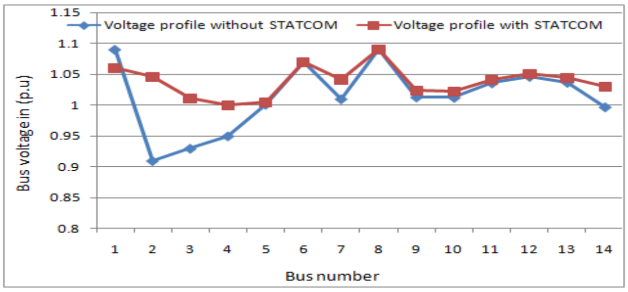

Figure. 2. Bus voltage profile in modified IEEE-14 Bus system

4. IMPLEMENTATION OF STATCOM WITH POWER OSCILLATION DAMPING CONTROLLER

For the implementation of STATCOM POD in IEEE 14 bus systems. First of all optimal location of STATCOM is found, optimal location is chosen by analyzing power flow studies. Then STATCOM is connected to the weakest bus. Here in IEEE 14 bus system the weakest bus is 14th bus. Optimal location of power system oscillation damper is same that of STATCOM. All the simulations in this paper, including the parameter tuning of PSS and POD and stability studies, were done in PSAT (Power System Analysis Toolbox). In PSAT software a three-phase short circuit is applied at bus 5 at t=1.00 (sec) and cleared at t=1.05 (sec) and line outage at t=1.05s [14]. The implemented STATCOM model is a current injection model. To exchange the reactive power between the ac system and STATCOM, the STATCOM current is always kept in quadrature to the bus voltage. In the dynamic model STATCOM assumes as a time constant regulator. The STATCOM which is connected as a shunt device in bus number 14 of modified IEEE-14 bus system provides the adequate reactive power to maintain the system stability.

The differential equation and the reactive power injected at the STATCOM node are given, respectively, by [14]:

$$i_{SH} = \left(K_r \left(\mathrm{V_{ref}} + \mathrm{V_s^{POD}} - \mathrm{V}\right) - i_{SH}\right)/T_r \qquad (1)$$

$$q = i_{SH} * V \quad (2)$$

where, I_{SH} is the shunt current of STATCOM, K_r is the time constant of stabilizer, V_{ref} is the reference voltage of regulator, V_s^{POD} is the normalized output voltage of POD, V is the bus voltage, T_r is the time constant of regulator, q is the reactive power of STATCOM.

5. SIMULATION RESULTS

To show the effectiveness of the static synchronous compensator with supplementary controller as power oscillation damper (STATCOM-POD) in damping of power system oscillations, disturbances or contingency are applied to the IEEE-14 bus test system:

A. Three phase short circuit fault:

A three phase short circuit fault is implanted on bus number 5 of modified IEEE-14 bus system at time t=1.00 sec and the fault is cleared at time t=1.05 seconds. Thus the fault clearing time is 5 ms.

Case 1: Only PSS is implemented along with the AVR of generator 1 and the results are plotted graphically for with PSS and without PSS.

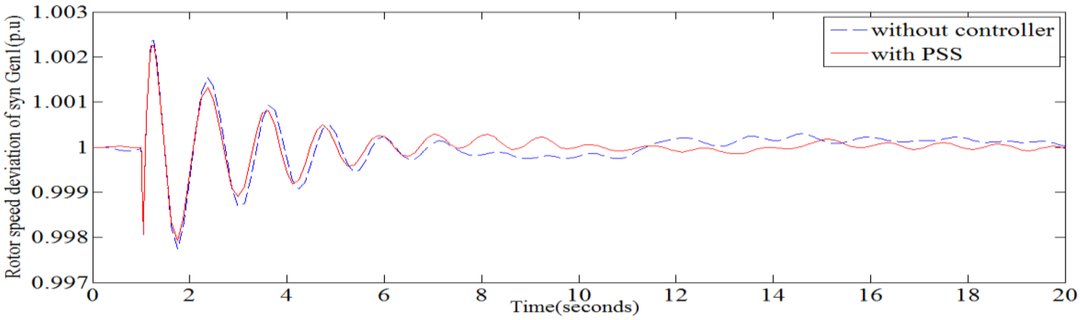

Figure 3. Time domain response of rotor speed oscillation of generator 1

Fig 3 represents the time domain response of rotor speed oscillation of generator 1 with and without PSS. It is inferred that with PSS controller the oscillations are damped faster.

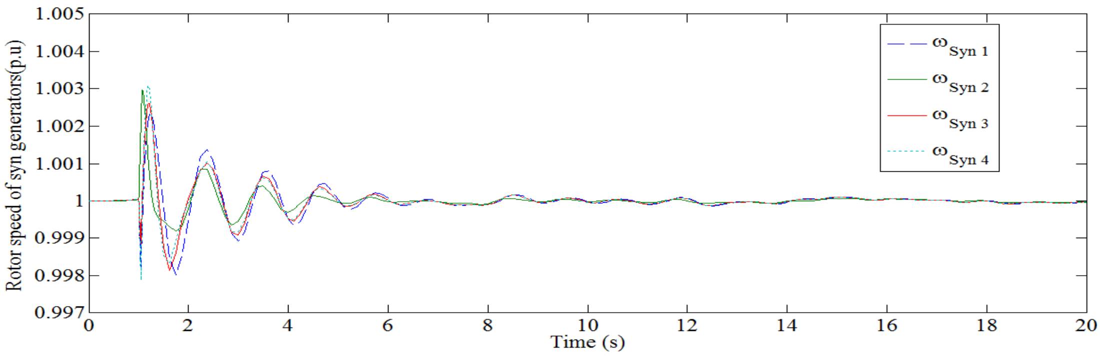

Figure 4. Time domain response of rotor speed oscillation of generators with PSS

Fig 4 represents rotor speed oscillations of different synchronous generators. From the figure it is inferred that the area under the graph is reduced compared to system oscillations without controller. Therefore the damping ratio is improved with PSS.

As it can be seen from Fig 4 that in the network without any controller the system remains stable but the power system oscillations are not damped effectively while using PSS controller the damping of low frequency oscillations are improved.

Case 2: In the second case study STATCOM with a supplementary controller i.e. POD is implemented and oscillation damping is analyzed. Here also a similar three phase short circuit fault at t=1.00sec which is cleared at t=1.05 sec.

Fig 5 represents graphical time domain response of rotor speed oscillations without controller, with STATCOM only and finally with STATCOM with supplementary controller POD whose parameters are tuned with respect to the system stability from eigenvalue analysis. From the Fig 5 it is inferred that damping rate of power system oscillations due to a three phase fault in bus no 5 is at faster rate when STATCOM with POD is used.

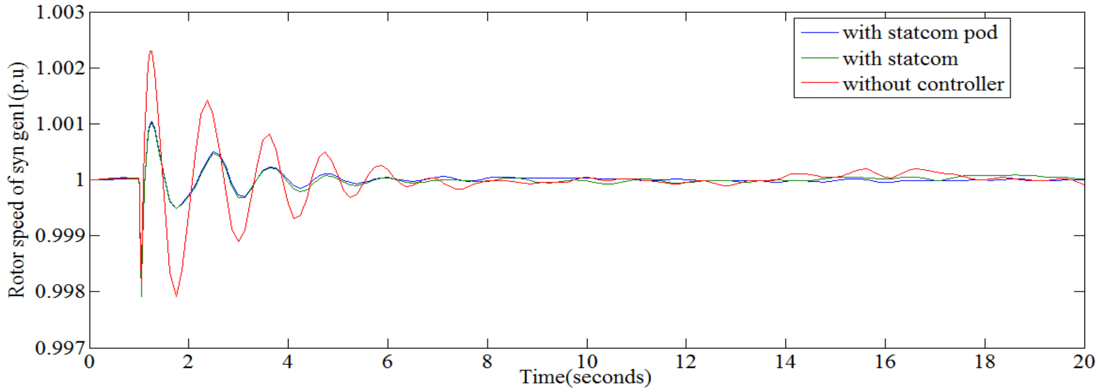

Figure 5. Time domain response of rotor speed oscillation of generator 1

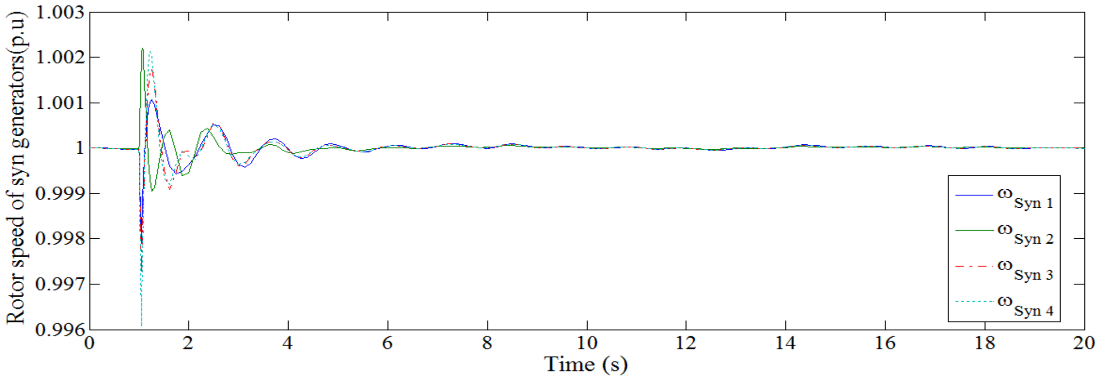

Figure 6. Time domain response of rotor speed oscillation of generators with STATCOM-POD

From the results presented in Fig 5 and Fig 6, the rotor speed deviation of generator 1 infer that STATCOM-POD has better response in terms of overshoot and settling time.

Case 3: In the third case study a comparative power system oscillation damping of PSS controller and STATCOM with POD controller is analyzed. This comparative results are plotted for transient disturbances like three phase fault which is implanted at bus number 5 of modified IEEE-14 bus system and then time domain simulations are done with the help of PSAT toolbox in MATLAB.

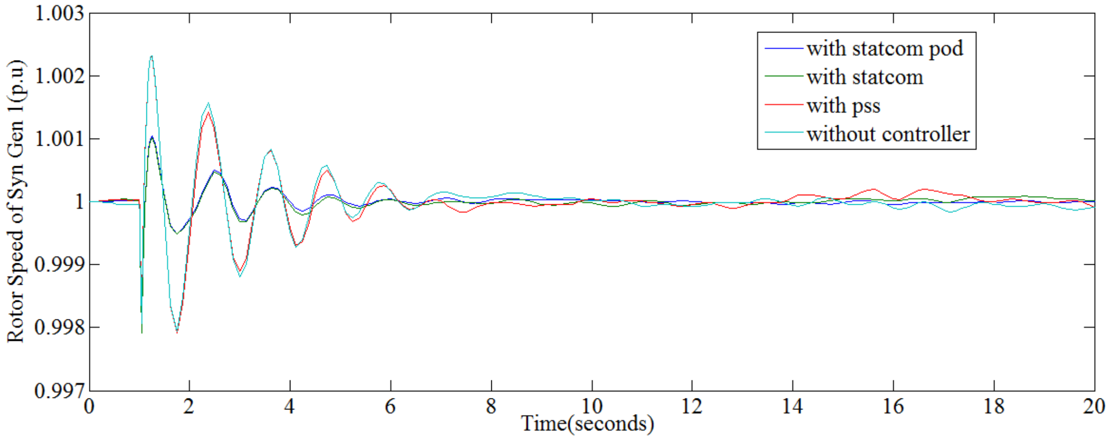

Figure 7. Time domain response of rotor speed oscillation of generator 1

Fig 7 represents the comparative results between the oscillation damping capability of STATCOM-POD and PSS. From the Fig 7 it is inferred that STATCOM-POD has better damping rate and overshoot is very much less when compared to PSS.

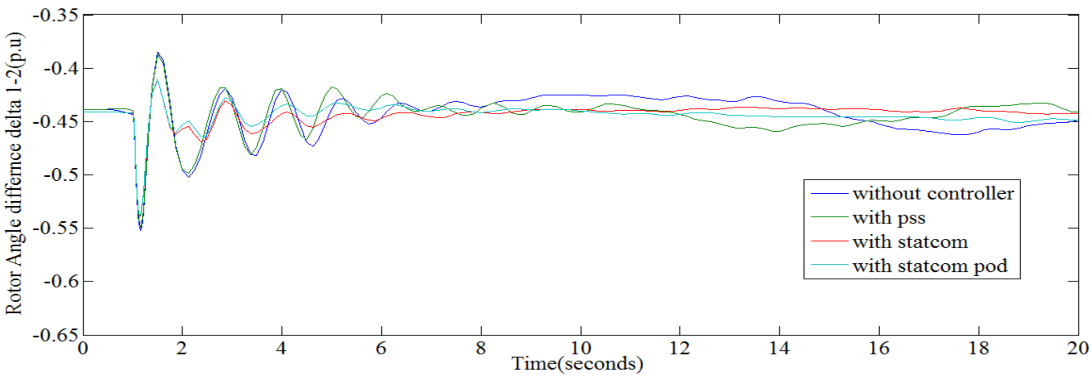

Figure 8. Time domain response of difference of rotor angle between generator 1 and 2

Fig 8 plot is done between difference of rotor angle oscillations between synchronous generator 1 and 2 with respect to time. From the comparative study of difference of rotor angle oscillations it is clear that STATCOM with POD has better damping capability with system with PSS only.

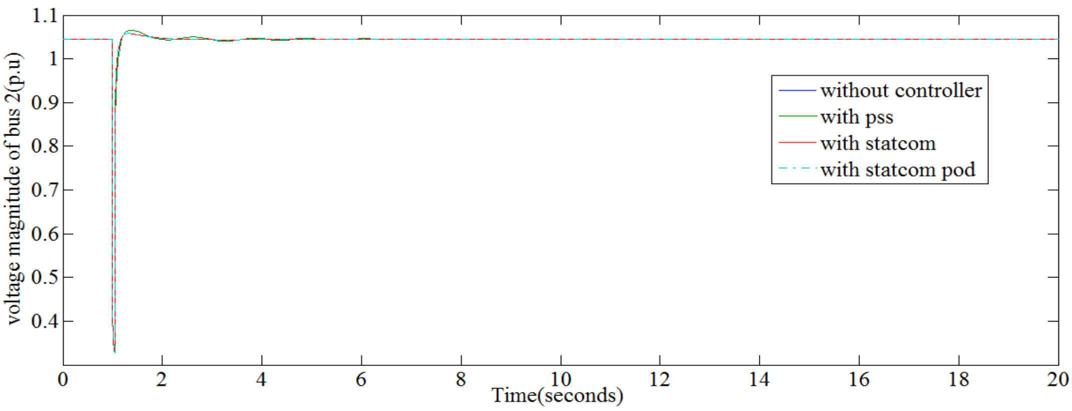

Figure 9. Time domain response of voltage at bus 2

In Fig 9 it shows that voltage stability is far improved with STATCOM-POD than PSS. From the comparative results it is inferred that STATCOM–POD has better performance results that PSS controller in terms of rotor speed, difference of rotor angle oscillations and voltage fluctuations.

Therefore in modified IEEE 14 bus system considering the improvement of dynamic performance and damping of low frequency oscillations for all variables the STATCOM with POD controller is having better results than PSS controller.

B. *Three phase short circuit followed by line outage*

A three phase short circuit fault is given at time t=1.00s and cleared at t=1.05s at bus no 5 followed by line outage between buses 2 and 4.

Case 1: with PSS only

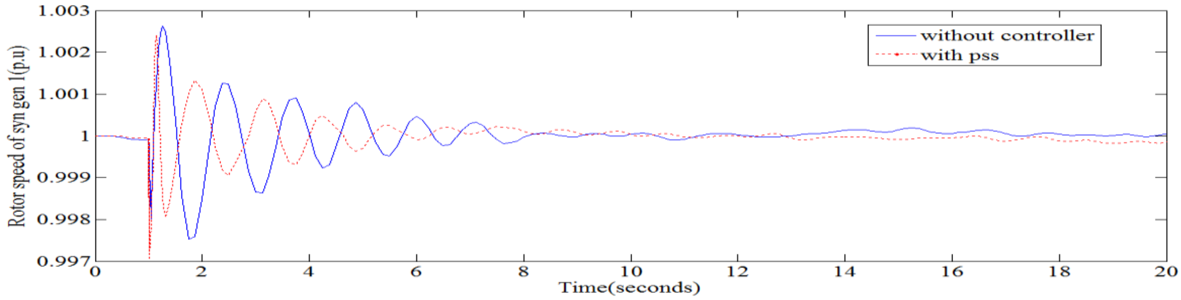

Figure.10 Time domain response of rotor speed oscillation of generator 1 with PSS

From Fig 10 it is clear that rotor speed oscillations are damped at a faster rate when the system is compared without any controller.

So from the graph it is inferred that PSS can damp the oscillations at faster rate by providing sufficient damping torque to the synchronous generator 1.Hence a balance between the synchronizing torque and damping torque is achieved so that damping ratio is improved.

Case 2: with STATCOM-POD only

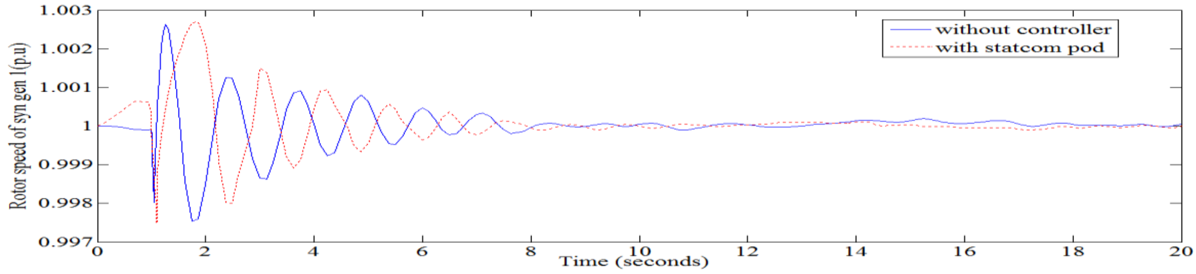

Figure 11. Time domain response of rotor speed oscillation of generator 1 with STATCOM-POD

The Fig 11 represents the comparative results of rotor speed oscillations of synchronous generator 1 with respect to time for the system without any controller and system with STATCOM-POD, it is clear that system is stable after some time for both case. But for the system with STATCOM-POD reaches to stable state much faster.

Case 3: Comparative analysis of power system oscillation damping with PSS only and STATCOM with POD as supplementary controller for three phase short circuit fault followed by line outage

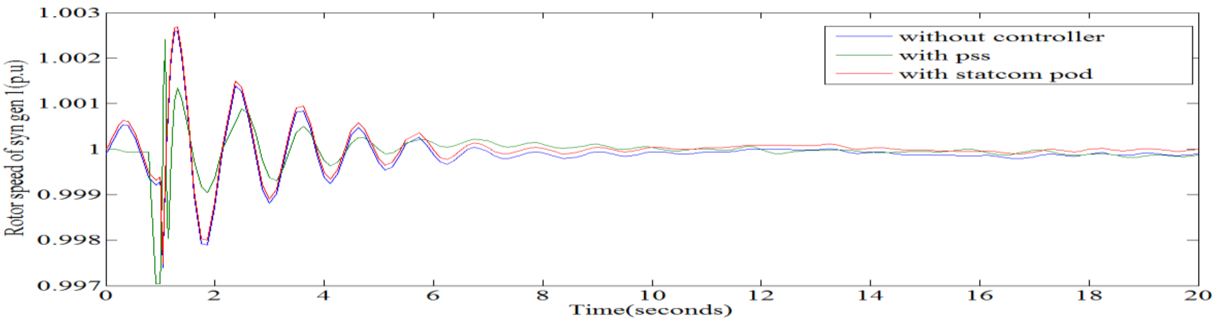

Figure 12. Comparison of time domain response of rotor speed oscillation of generator 1

From Fig 10, Fig 11 and Fig 12 , for both type of contingency applied, STATCOM-POD has better result than PSS controller for power system oscillation damping. In addition to power system oscillation damping STATCOM-POD provide better loadability and voltage profile.

6. CONCLUSION

In this paper a comparative study between STATCOM with a supplementary controller (POD) and PSS controller is done in modified IEEE 14 bus system which is implemented with a DFIG in bus 1. The implemented POD provides the stabilizing signals for STATCOM. In the first stage of the work optimal location of STATCOM is found through power flow studies for maintaining the proper voltage stability of network and to increase the system loadability. The optimal tuning of controllers are done by Eigen value analysis. Different case study is done by applying a three phase fault at bus no 5 in modified system and in the second case study a three phase fault in bus 5 followed by outage of line between bus 2 and bus 4 is implanted. For analysis graphs are plotted for rotor speed oscillations, difference of rotor angle oscillations and voltage variations with respect to time.

From the case studies it is clear that STATCOM with POD has better rate of power system oscillation damping capability than PSS controllers. The simulation results are done in MATLAB/PSAT toolbox.

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