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A Coordinated Control Scheme of PSS and STATCOM Devices for Improving Power System Oscillation

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Abstract: ***In this present era, the continuously increment in power demand results expansion of power system network which makes the existing system more sensitive and prone to instability. An important issue associated with the stability of multi-area power system is the inter-area oscillations from a multi-machine system. Generally, Power System Stabilizer (PSS) are used for power system oscillation damping, but local PSS not have global observability so Flexible AC Transmission System (FACTS) devices with supplementary controller are used for effective damping of power system oscillations. In this paper, presents the coordination control of PSS and STATCOM to damp out the inter-area oscillations from a multi-machine system. In the past era, to damp out such type of inter-area oscillations used PSS as a local controller in multi-machine system. Reactive FACTS devices, such as static synchronous compensators (STATCOM) are considered and assessed for their damping controller design. STATCOM is reactive power compensator based upon a voltage source converter which uses power electronic devices with turn-off capability as switching devices. Its main function is to support bus voltage of which it is connected to the system by providing quick response to supply or absorb reactive power. For damping power oscillations purpose, it is required to employ power oscillation damping (POD) function wherein its output is summed to voltage reference as input of STATCOM. This paper focuses on implementing POD function in STATCOM controller to damp inter area oscillations mode. Some simulations results are carried out on Kundur Two-Area Four Machine system under small disturbance. From the simulation results, it reveals that the proposed controller damp-out the inter-area oscillations effectively under small disturbance conditions.***

Keywords: Inter-area oscillation, Power System Stabilizer, STATCOM, POD

1. Introduction

As the load demand is increasing day by day the complexity of the load connected also increased to a drastic manner. This resulted in frequent grid instability problem and the past few years, the angular instability, caused by small signal oscillations, has been occurs in the power systems under certain conditions, such as transmission of a large amount of power over long distance through weak tie lines and the use of high gain exciters. These conditions introduce inter-area oscillations [0.1 Hz-1.0 Hz] in the power system and which may cause a blackout of the whole power system.

The inter area oscillations inherent to the large inter connected power system becomes more dangerous to the system's security and the quality of power supply during transient condition. Hence it can be say that the low frequency oscillations put limitations on operation of the power system and network's control security.

Some examples of power system black-outs due to inter-area oscillations are as follows. [10], [19], [20]:

a) 1977, unstable oscillations of 0.5 Hz were encountered on the interconnected power system of Scandinavia.
b) In 1980, unstable oscillations of 0.5 Hz were encountered on the interconnected power system of UK.
c) In 1982 and 1983, the State Energy Commission of Western Australia (SECWA) experienced lightly damped system oscillations in the frequency range of 0.2-0.3 Hz.
d) In 2003, unstable oscillations of 0.17 Hz were encountered on the interconnected power system of USA.
e) India-2012 with a frequency range of 0.35-0.71 Hz. [CERC, 2012]

For the transmission of large power through existing power system network, either adds the new lines with existing power system network or need high voltage compensation such as shunt compensation, to damp out the low frequency inter area oscillations. While expansion of new power system network or installation of compensation devices, more problem occurs like environmental factors, cost factors etc. Therefore, it is better to design a system with existing power system network for the improvement of electromagnetic oscillations to achieve the maximum power transfer capability of the existing power system networks.

For this, the traditional approach to damp out the inter-area oscillations by using Local Power System Stabilizer (LPSS). The basic function of PSS is to add damping to the generator rotor oscillation by controlling its excitation using auxiliary stabilizing signal. These controllers use local signals as an input signal and it may not always be able to damp out inter-area oscillations, because, the design of LPSS used local signals as input and local signal based controller do not have global observation and may does not be effectively damps out the inter-area oscillations[14].

However, at present, power electronic technologies have been implement. They are more effective in increasing the amount of transmitted power with improving the dynamic performance and more precise to control the route of the power flow. These technologies are referred to use Flexible AC Transmission System (FACTS) in power systems.

Therefore, the FACTS devices gives better performance in the damping of inter-area oscillation modes as they are installed on transmission lines and use for the purpose of control and regulating transmission system parameters. The damping mechanism given by FACTS can be concluded as system parameter (active power, reactive power, voltage, etc.) increase. So System parameter can be improve due to the designing of supplementary FACTS damping controllers. In this paper study of FACTS devices with supplementary controller is used to damp inter-area oscillations. The supplementary controller which is used in this study is the POD (power oscillation damper), which can provide the required damping torque needed for the system in addition to the synchronizing torque developed by FACTS devices. So FACTS-POD controller can be damped inter-area oscillation faster as compared to other conventional devices [21].

This paper is divided into six sections. The first section is the introduction mentioning about the problem of power oscillations and the adoption of a STATCOM to solve the power oscillation issues. Section II describes the configuration of the study power system. Section III presents the Small signal model of power system. Section V shows the simulation results of the proposed controller and the comparison results. Finally, it ends with the conclusions in section VI.

2. Study Power System

Fig-1 shows the single line Diagram of the study power system. This system consists of two symmetrical areas connected by two parallel tie-line of length 220 km and 230 kv. Each area is equipped with two identical round rotor generators rated 20 kv/900 MVA. All four generators have identical parameters, except inertia coefficient (H), which are H=6.5s for Gen-1 and Gen-2 in area-1 and H=6.175 s for Gen-3 and Gen-4 in area-2.

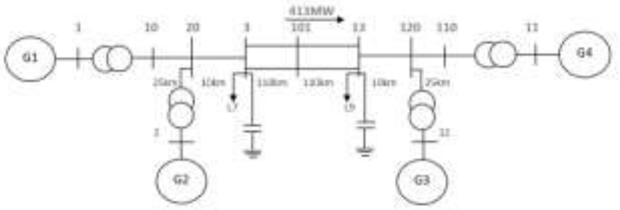

Figure 1: Kundur two-area four-machine System

3. Small-Signal Model Of Power System

The small-signal models for electrical components used in this paper are illustrated in the following sections. Both algebraic and differential equations represent the statics and dynamics of power systems.

3.1 STATCOM

A Static Synchronous Compensator (STATCOM) is a controllable source of reactive power compensation by altering the waveforms of the voltage and current of the VSC to either generate or absorb reactive power [15]. It is shunt connected to the bus bar in the locations of the power system for voltage regulations.

3.2 FACTS POD Controller Design

Supplementary control action applied to FACTS devices to increase the system damping is called Power Oscillation Damping (POD). Since FACTS controllers are located in transmission systems, local input signals are always preferred, usually the active or reactive power flow through FACTS device or FACTS terminal voltages. Fig. -2 shows the considered closed-loop system where G(s) represents the power system including FACTS devices and H(s) FACTS POD controller.

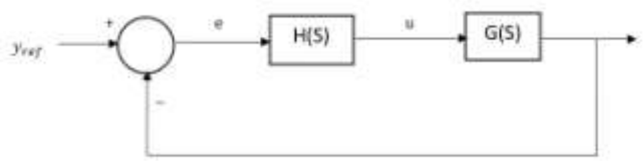

Figure 2: Closed Loop System With POD Control

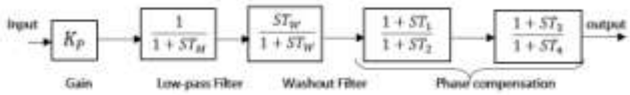

Figure 3: Block diagram of pod controller

The POD controller consists of an amplification block, a wash-out and low-pass filters and mc stages of lead-lag blocks are as shown in Figure 3. The transfer function, H(s), of the POD controller is given by

(1)

The Parameters of Power Oscillation Damping Controller (POD) are set-up by Hit and Trial Method are tabulated in Table 1.

Table 1: Parameters of POD Controller

Parameters	K_p	T_M	T_w	T_1	T_2	T_3	T_4
POD	1.5	0.1	10	0.227	0.351	0.227	0.351

3.3 Multi-Model System

In small signal stability studies, the power system is required to be linearized around a certain operating point and reorganized as a set of Differential and Algebraic equations (DAE). State-space representation is shown in the following equation:

(2)

Different from a single mode system where the power system is linearized around one operation point; a multimodal system all operating points which greatly increases the robustness of the damping controller, making it more effective under different system operating conditions. A series of linearized system models are integrated together to form the multi-model system. A series of linearized system models are integrated together to form the multi-model system:

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(3)

Where i represents operating point number, L is the total number of operating points and Δy is the selected system output used as the controller feedback signal.

4. Simulation Results of Proposed Controller

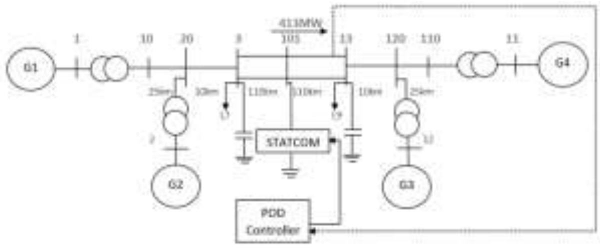

Figure 4: Two-area four-machine interconnected power system with STATCOM

The single line diagram of study power system with proposed controller as shown in figure-4. The STATCOM-POD controller is installed in shunt connected with the transmission line B-101 and B-13. This system consists of two symmetrical areas connected by two parallel tie-line of length 220 km and 230 kv. Each area is equipped with two identical round rotor generators rated 20 kv/900 MVA. All four generators have identical parameters, except inertia coefficient (H), which are H=6.5s for Gen-1 and Gen-2 in area-1 and H=6.175 s for Gen-3 and Gen-4 in area-2.

5. System performance with STATCOM

To perform the dynamic analysis of the closed loop test system for Kundur two area four machine system as shown in figure-4, a small pulse with magnitude of 5% as a disturbance was applied to the generator G1 for 12 cycles. The simulation time was of 30 seconds. Then the response of tie-line active power flow from area-1 to area-2, rotor speed, rotor speed deviation , are examined by considering the test system with LPSS and STATCOM-POD controller.

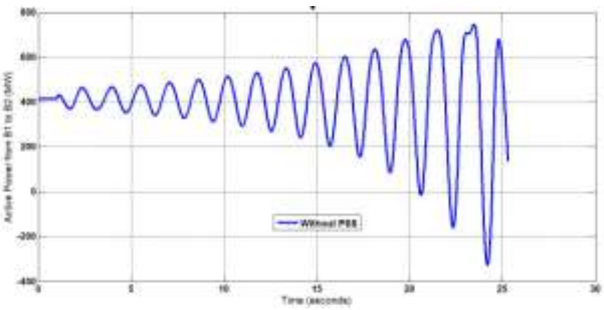

Figure 5: Tie-line active power flow without any controller

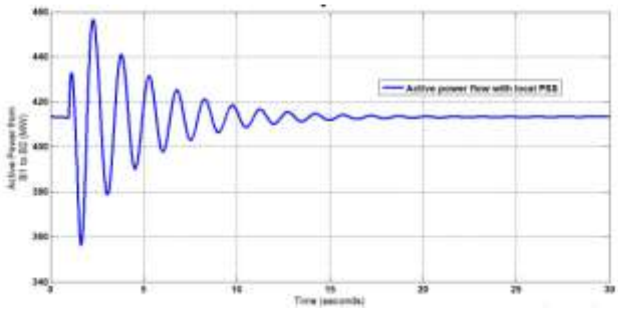

Figure 6: Tie-line active power flow with local PSS

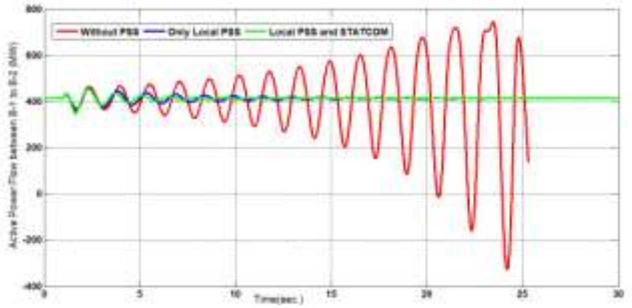

Figure 7: Tie-line active power flow with STATCOM-POD and Local PSS

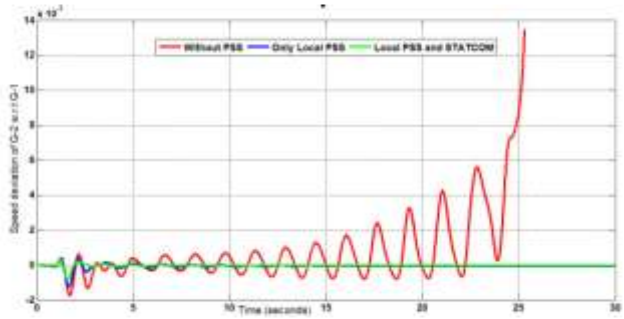

Figure 8: Speed deviation of G-2 w.r.t G-1 with STATCOM-POD and local PSS

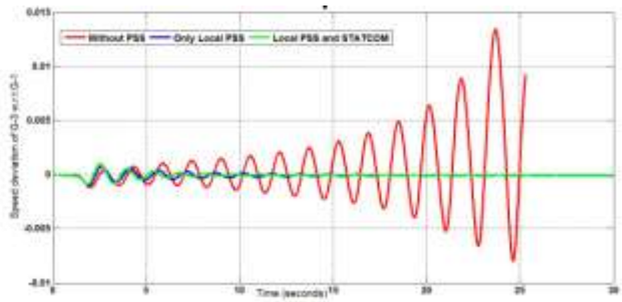

Figure 9: Speed deviation of G-3 w.r.t G-1 with STATCOM-POD and local PSS

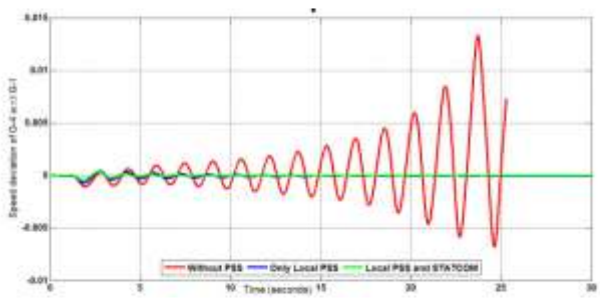

Figure 10: Speed deviation of G-4 w.r.t G-1 with STATCOM-POD and local PSS

6. Conclusion

In this paper researcher designed FACTS damping controller to damp out the inter-area oscillations in a large scale power system using STATCOM-POD controller. Some simulation results are carried out to verify the effectiveness of proposed controller under small disturbance. From the simulation results, it reveals that the proposed controller damps out the inter-area oscillations effectively.

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