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# Application of Unified Power Flow Controller (UPFC) for Damping Power System Oscillations – A Review

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## Abstract

*This paper proposes the application of Unified Power Flow Controller (UPFC) for damping power system oscillations. An additional power oscillation damping (POD) controller is used along with the UPFC main controller for this purpose. The simulation is carried out in MATLAB/simulink which shows promising results.*

*Keywords- Unified Power flow controller (UPFC), FACTS, Power oscillation damping (POD) controller, Power system oscillations.*

## 1. Introduction

The electricity is considered as the backbone for industrial revolution. Today the demand and consumption of electrical energy has increased steadily. To meet this increasing demand very complex interconnected power systems are built. These complex networks are subjected to power oscillations. Power oscillations can be defined as the change in machine rotor angle around its steady state value at the natural frequency of the total electromechanical system due to disturbance. There are different types of oscillations occurring in power system, they are: local oscillations, inter-area oscillations, inter-plant oscillations and global oscillations. Damping of these oscillations is important so as to maintain the system stability. The application of UPFC for damping power system oscillations is presented in this paper.

## 2. Methods for Damping Power System Oscillations

Several methods are used to damp the power oscillations. One of the traditional methods is to use power system stabilizer (PSS). PSS proves to be robust and effective in damping the oscillations in the power system. But as the system size increases especially in large interconnected power systems, PSS does not provide sufficient damping. Also it affects the voltage profile of the large system. Another method is to use HVDC links to damp the power oscillations. It uses active power on parallel ac lines or other signals in the HVDC control system to add damping to the system. With the advancement in technology, today FACTS devices are used for this purpose. The concept of FACTS i.e. flexible a.c. transmission system was introduced by Dr. N. Hingorani in 1988 [15]. FACTS devices are power electronics based controllers for a bulk power system. These devices not only improve the power flow in the transmission lines but can effectively damp the power oscillations. Several FACTS devices like SSSC, STATCOM, TCSC, UPFC, SVC etc. are used to damp the oscillations. This paper concentrates on UPFC for damping the oscillations.

## 3. Unified Power flow controller (UPFC)

Unified power flow controller (UPFC) is a series shunt FACTS device. It consists of a combination of SSSC in series and STATCOM in shunt with the transmission line. These two voltage source converters are connected by a common d.c. link capacitor. Fig.1 shows the schematic diagram of UPFC. The series part injects the voltage of controllable magnitude in the transmission line to control the real and reactive power of the power system. The shunt part is used to maintain the voltage across the d.c. link capacitor and the bus voltage where it is connected by injecting the current of controllable magnitude in the system. Each voltage source converter can control the magnitude and phase angle of the output voltages of series and shunt converters by controlling the amplitude of modulation index($m_B, m_E$) and phase-angle($\delta_B, \delta_E$) of series and shunt respectively [17].

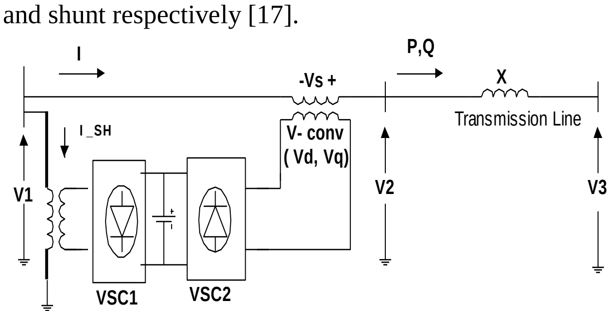


Fig.1 Schematic diagram of UPFC

## 4. UPFC for Damping Power Oscillations

UPFC main control consists of series and shunt controller. These controllers do not provide adequate damping. Hence, an additional damping controller known as power oscillations damping (POD) controller is used in conjunction with the main controller of UPFC for this purpose. The construction of POD controller is similar to PSS. Fig.2 shows the block diagram of POD controller. It consists of a gain block, washout block and two lead-lag blocks.

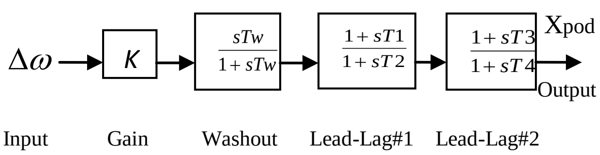


Fig.2 Block diagram of POD controller

The input to the POD is the change in speed or change in real power and output is the damping signal Xpod. M.A.Furini et.al [18] has suggested the classical control techniques for adjusting the POD parameters so as to obtain the desired output.

## 5. The Study System

Fig.3 shows a single line diagram of the study system i.e. two area power system which is used to investigate the effect of UPFC for damping the power system oscillations.

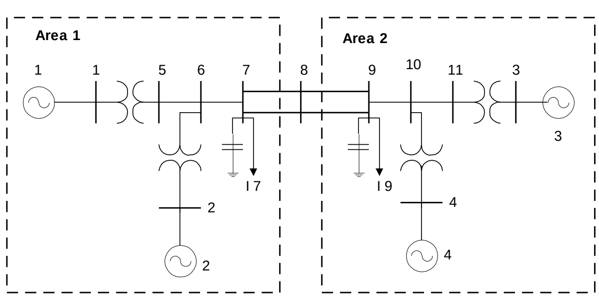


Fig.3 Two area power system

The system consists of two areas namely area-1 and area-2 connected with a tie line of 230kV and 220km length. Each area is equipped with two generators. The rating of the parameters are same except the inertia constant, H= 6.5s for area-1 and H=6.175s for area-2. Area-1 transmits 400kW power to area-2. Graham Roger [16] has suggested two area power system to study different types of oscillations such as local oscillations, inter-area, inter-plant and global oscillations. In local oscillations generator-1 oscillates against generator-2 in area-1 or generator-3 oscillates against generator-4. The inter-plant oscillations occur between closely connected generators whereas when generators of area-1 oscillate against generators of area-2 then this is termed as inter-area oscillations. Global oscillations are usually between large groups of generators. Thus the two area power system provides a better understanding of these oscillations.

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## 6. Simulation and Results

This section presents the analysis of the two area power system during disturbance with UPFC, its POD controller as well as PSS. The simulation is carried out for 12s on MATLAB/simulink platform. The disturbance is created by a three phase fault of 0.1s near bus-B7.The fault occurs at 2.5s and clears after 2.6s. The UPFC is connected near bus-B8. Fig.4 (a)-(d) shows the simulation results for active power in MW from area-1 to area-2 without any controller and with combination of UPFC, POD and PSS whereas fig. 4 (e) shows the result for rotor angle of generator-1 i.e. G1 relative to G4 with the same operating conditions. Fig. 4(d) shows the comparison between the response for PSS alone, with UPFC+PSS and with UPFC+PSS+POD where the result with UPFC+PSS+POD are found to be satisfactory. Similarly fig. 4(e) shows the comparative results for rotor angle G1 relative to G4 where again the combination of UPFC+PSS+POD shows dynamic performance in damping the power system oscillations.

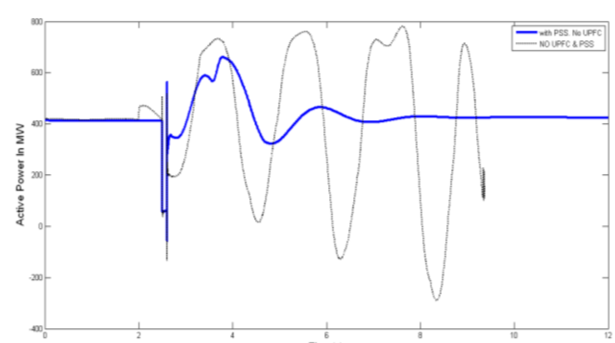


Fig. 4(a) Active power in MW with PSS alone and without PSS and UPFC

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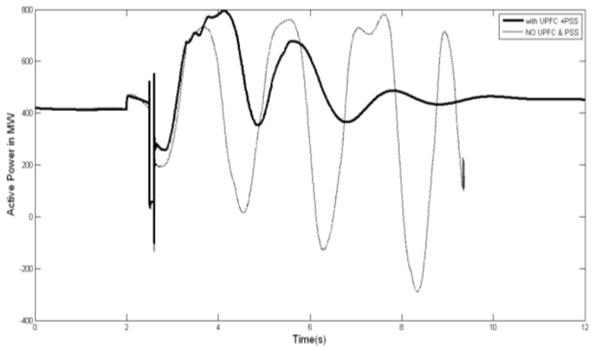


Fig. 4(b) Active power in MW with and without PSS and UPFC

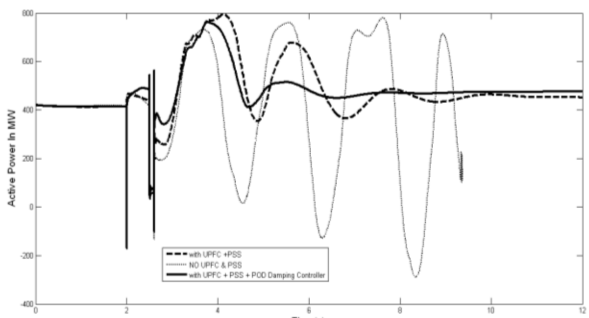


Fig. 4(c) Active power in MW with UPFC+POD+PSS and without PSS and UPFC

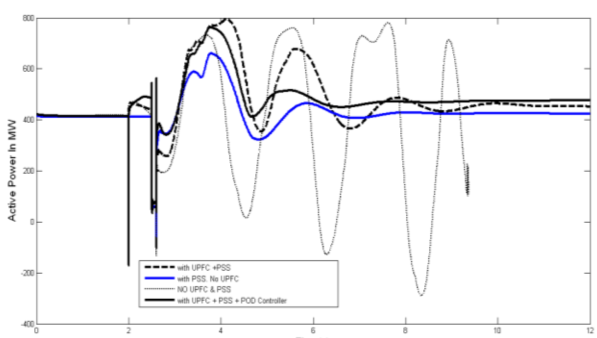


Fig. 4(d) Comparison between simulation response for UPFC+POD+PSS, UPFC+PSS+ No POD and only PSS for Active power in MW

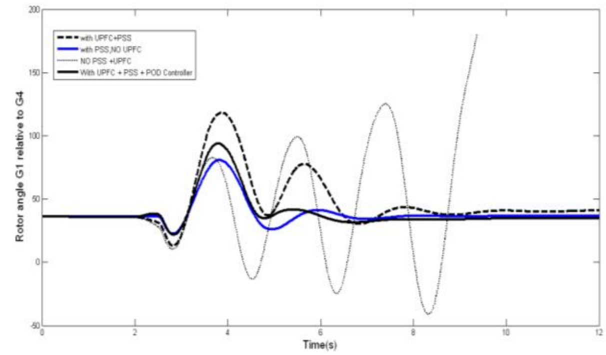


Fig. 4(e) Rotor angle G1 relative to G4 in degrees.

## 7. Conclusions

This is a review paper showcasing the application of UPFC for damping power system oscillations. The two area power system was used to analyse the role of UPFC for damping the oscillations. It was observed that the results with UPFC, POD and PSS show satisfactory performance as compared with only UPFC & PSS. Thus it can be concluded that for effective damping of power system oscillations, UPFC requires an additional power oscillations damping (POD) controller.

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