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ENHANCING THE PERFORMANCE AND STABILITY OF UPFC CONTROL BY CREATING CO-ORDINATION BETWEEN SERIES AND SHUNT CONVERTERS

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Abstract-*This paper proposes a reliable real and reactive power coordination controller for unified power flow controller (UPFC). UPFC is combination of series converter, that controls the transmission lines real and reactive power flow along with a shunt converter that controls the bus voltage or shunt reactive power and a DC link capacitor voltage. In UPFC, during steady state, the shunt converter is supplied with the real power of series converter. During transient conditions due to lack of coordination between series and shunt converter's it may lead to instability, high voltage excursion occurs because there is lack of reactive power coordination. To limit this high voltage excursions and for real power coordination, a new real and reactive power coordination controller has been designed in MATLAB/SIMULINK. The results of an typical power system with the proposed real and reactive power controller shows the improvement in the performance of the UPFC control.*

Key Words: UPFC (FACTS), Real power coordination controller, Reactive power coordination controller, Series converter and Shunt converters.

1. INTRODUCTION

UPFC is the combination of both Static Compensator (STATCOM) and Static Variable Compensator (SVC) and it is a hybrid FACTS device by which we can control both the series and shunt parameter's of the transmission line simultaneously due to which the complexity of control variables interact with each other. UPFC is having series and shunt converters coupled by a common DC link Capacitor. The shunt converter of the UPFC controls the UPFC bus voltage/shunt reactive power and the dc link capacitor voltage. The series converter of the UPFC controls the transmission line real/reactive power flows by injecting a series voltage of adjustable magnitude and phase angle. The interaction between the series injected voltage and the transmission line current leads to real and reactive power exchange between the series converter and the power system. During transient conditions, the series converter real power demand is supplied by the dc link capacitor.

In this paper, a UPFC control system that includes the real and reactive power coordination controller has been designed and its performance evaluated. Sections 2 describes the basic control strategy for a UPFC. Section 3 provides the details of the real and reactive power coordination controller.

2. CONTROL STRATEGIES FOR UPFC

2.1 Shunt Converter Control

The shunt converter of the UPFC controls the UPFC bus voltage/shunt reactive power and the dc link capacitor voltage. In this case, the shunt converter voltage is decomposed into two components. One component is in-phase and the other in quadrature with the UPFC bus voltage. De-coupled control system has been employed to achieve simultaneous control of the UPFC bus voltage and the dc link capacitor voltage.

2.2. Series Converter Control

The series converter of the UPFC provides simultaneous control of real and reactive power flow in the transmission line. To do so, the series converter injected voltage is decomposed into two components. One component of the series injected voltage is in quadrature and the other in-phase with the UPFC bus voltage. The quadrature injected component controls the transmission line real power flow. This strategy is similar to that of a phase shifter. The in-phase component controls the transmission line reactive power flow. This strategy is similar to that of a tap changer.

3. REAL AND REACTIVE POWER COORDINATION CONTROLLER

3.1 Real Power Coordination Controller

To understand the design of a real power coordination controller for a UPFC, consider a UPFC connected to a transmission line as shown in Fig. 1. The interaction between the series injected voltage (V_{se}) and the transmission line current (I_{se}) leads to exchange of real power (P_{se}) between the series converter and the transmission line.

To understand the design of a real power coordination controller for a UPFC, consider a UPFC connected to a transmission line as shown in Fig. 1. There is exchange of real power (P_{se}) between series converter and the transmission line because of interaction between series injected voltage (V_{se}) and the transmission line current (I_{se}).The dc link capacitor voltage (V_{dc}) either increase or decrease depending on the direction of the real power flow from the series converter due to the real power demand of the series converter (P_{se}) . The shunt converter controller senses and controls the dc link capacitor voltage (V_{dc}) and the real power flow from it, and is retained to its scheduled value. During the same time, the real power demand of the series converter is sensed by the shunt converter controller and controls the dc link capacitor voltage (V_{dc}). Thus, the shunt and the series converter operation are in a way separated from each other.

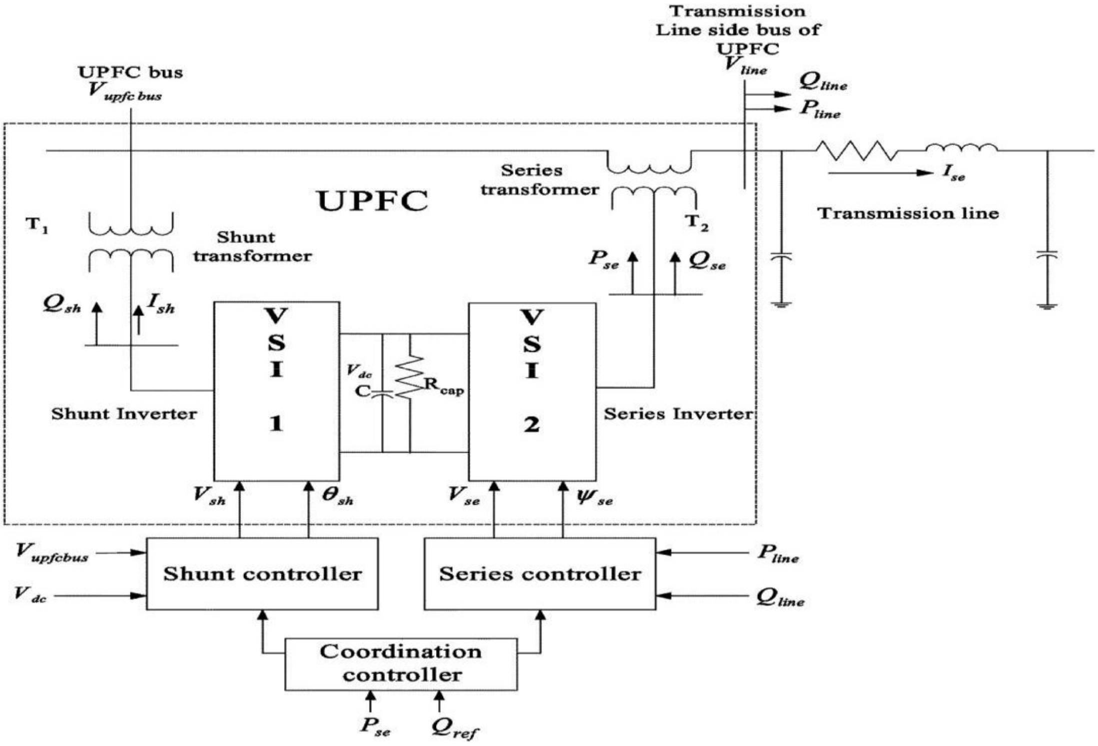

Fig-1.UPFC Control

To provide for proper coordination between the shunt and the series converter control system, a feed-back from the series converter is provided to the shunt converter control system. The feedback signal used is the real power demand of the series converter (P_{se}). The real power demand of the series converter (P_{se}) is converted into an equivalent D-axis current for the shunt converter (i_{Dse}). By doing so, the shunt converter responds immediately to a change in its D-axis current and supplies the necessary series converter real power demand. The equivalent D-axis current (i_{Dse}) is an additional input to the D-axis shunt converter control system as shown in Fig. 2. Equation (1) shows the relationship between the series converter real power demand (P_{se}) and the shunt converter D-axis current (i_{Dse}).

$$i_{DSE} = \frac{P_{se}}{V_{UPFC\ BUS}} \qquad (1)$$

The real power demand of the series converter P_{se} is the real part of product of series converter injected voltage V_{se} and the transmission line current I_{se}. V_{upfc}, i_{Dse} represent the voltage of the bus to which the shunt converter is connected and the equivalent additional D-axis current that should flow through the shunt converter to supply the real power demand of the series converter.

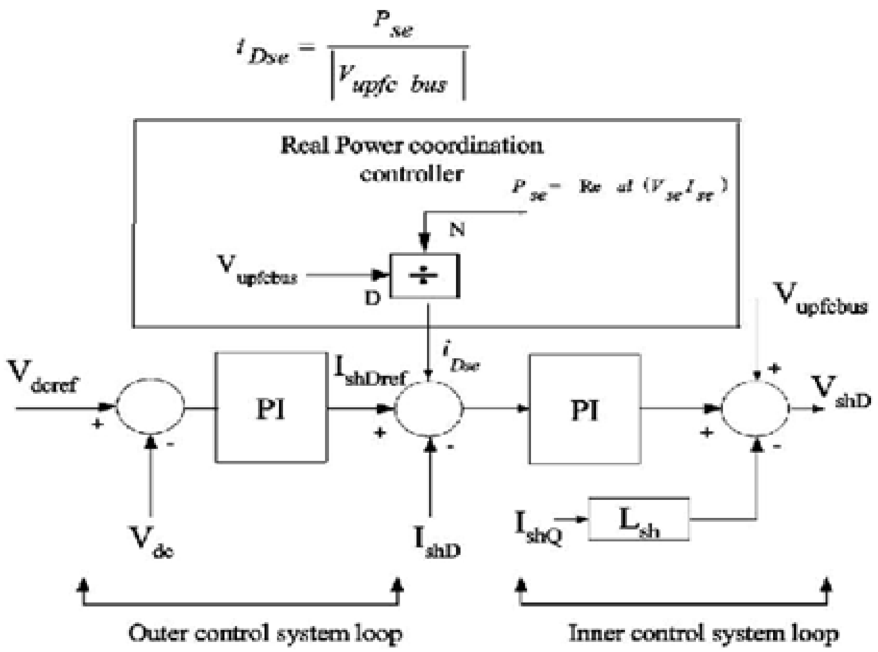

Fig-2. D-axis shunt converter control system with real power coordination controller.

As shown in Fig. 2, the equivalent D-axis additional current signal (i_{Dse}) is fed to inner control system, thereby increasing the effectiveness of the coordination controller. Further, the inner control system loops are fast acting PI controllers and ensure fast supply of the series converter real power demand (P_{se}) by the shunt converter.

3.2 Reactive Power Coordination Controller

The in-phase component (V_{seD}) of the series injected voltage which has the same phase as that of the UPFC bus voltage, has considerable effect on the transmission line reactive power (Q_{line}) and the shunt converter reactive power (Q_{sh}). Any increase/decrease in the transmission line reactive power (Q_{line}) due to in-phase component (V_{seD}) of the series injected voltage causes an equal increase/decrease in the shunt converter reactive power (Q_{sh}). In short, increase/decrease in trans-mission line reactive power is supplied by the shunt converter. Increase/decrease in the transmission line reactive power also has considerable effect on the UPFC bus voltage. The mechanism by which the request for transmission line reactive power flow is supplied by the shunt converter is as follows. Increase in transmission line reactive power reference causes a decrease in UPFC bus voltage. Decrease in UPFC bus voltage is sensed by the shunt converter UPFC bus voltage controller which causes the shunt converter to increase its reactive power output to boost the voltage to its reference value. The increase in shunt converter reactive power output is exactly equal to the increase requested by the transmission line reactive power flow controller (neglecting the series transformer T_2 reactive power loss). Similarly, for a decrease in transmission line reactive power, the UPFC bus voltage increases momentarily. Fig. 3 shows the shunt converter Q-axis control system with the reactive power coordination controller.

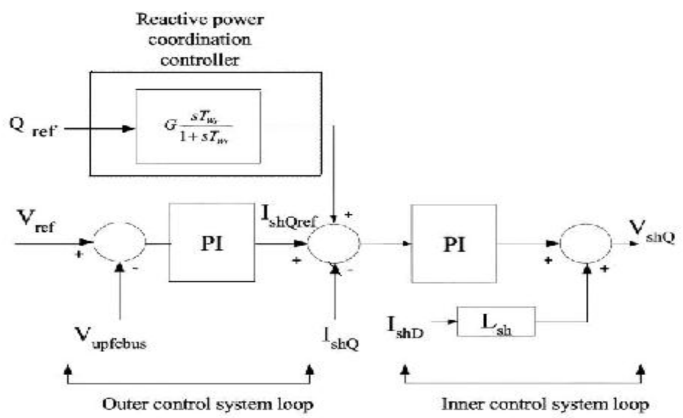

Fig-3. Shunt converter Q-axis controller with reactive power coordination controller

4. UPFC SIMULATION MODEL

MATLAB/SIMULINK software has been used to model the UPFC. The shunt converter has been modelled as a 4-module converter. The series converter consists of two sets of converters. One set of converter is used for the real power flow control and the other set of converter is used for the reactive power flow control. Re-cent advances in high voltage IGCT technology allow for higher switching frequencies with lower losses. This allows for practical implementation of PWM control.

5. SIMULATION RESULTS

5.1Simulation System of UPFC Real Power Model

Fig 5.1 shows the power system with UPFC considered to study the response of the power system to step changes in transmission line real power flow reference. The UPFC is located at the center of 100 km 365kV transmission line. The initial power flow in the transmission line is 450 MW. At 0.3 sec the transmission line real power reference changes from 450 to 300 MW. At 0.6 sec, the reference is changed from 300 to 450 MW.

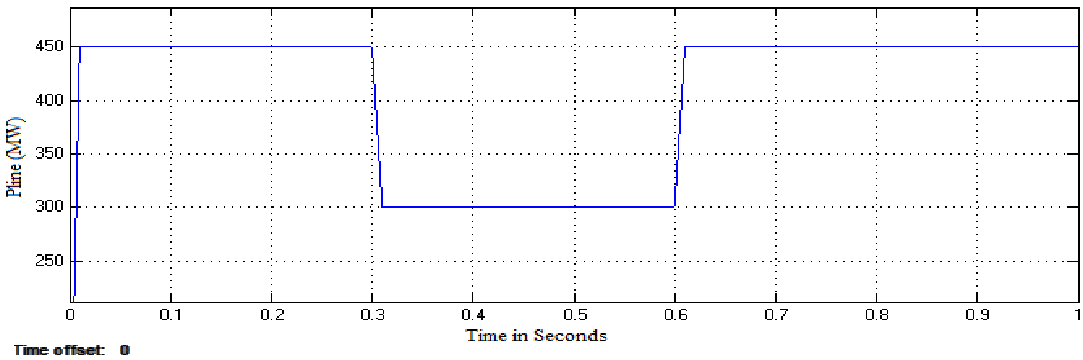

Fig-4. Response of power system to step change in transmission line real power.

5.2 Response of the Power system to Step Changes in Reactive Power Flow Reference

Fig.5.2 (a)shows Fig 5.2(h)the response of the power system (Fig.5.2) to step changes in transmission line reactive power reference (Qref). The initial real and reactive power flow (P_{line}, Q_{line}) in the transmission line are 290 MW and 125 MVAR, respectively. The initial shunt converter reactive power (Qsh) is 80 MVAR. Step changes of 160 MVAR in transmission line reactive power reference are conducted at 0.3 s and 0.6 s. Comparing Fig.5.2. (c), Fig.5.2 (d) with Fig 5.2(g),Fig 5.2(h) respectively, it is seen that the decrease/increase in transmission line reactive power is balanced by an equal decrease/increase in shunt converter reactive power. It is seen from Fig.5.2 (d) that at 0.3 s, the UPFC bus voltage shoots to 1.05 p.u. momentarily for a step decrease of 160 MVAR in transmission line reactive power reference . Similarly at 0.6 s, the UPFC bus voltage drops to 0.95 p.u. momentarily for a step increase of 160 MVAR in transmission line reactive power flow .

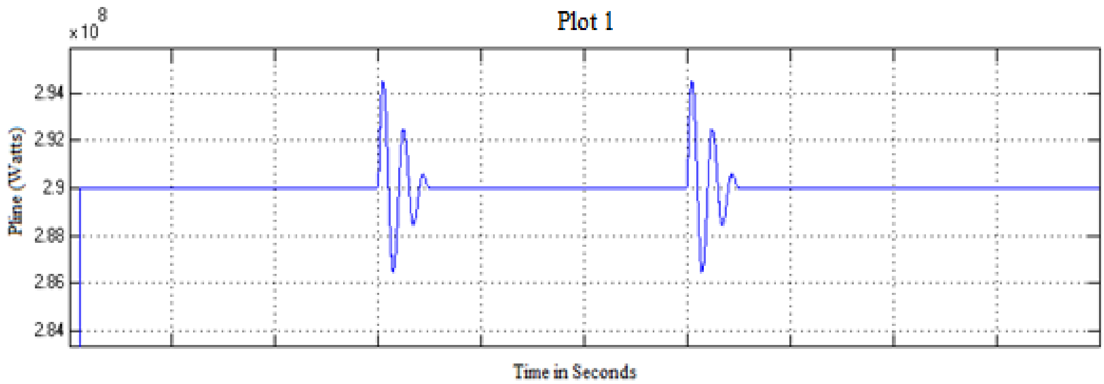

Fig-5.2(a) Transmission line Real Power

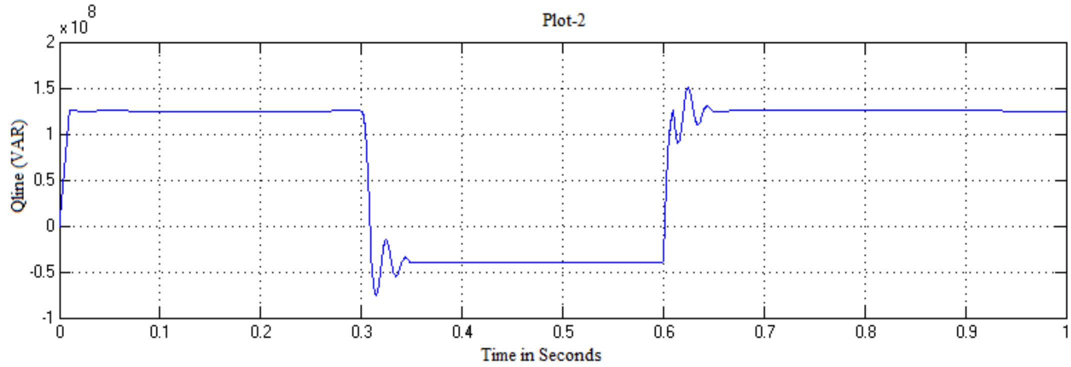

Fig-5.2(b). Transmission line Reactive power

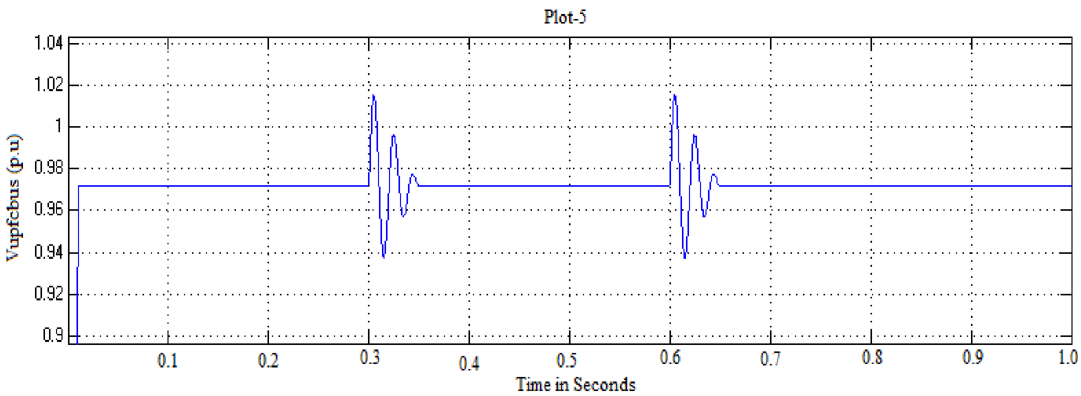

Fig-5.2(c) UPFC Bus Voltage

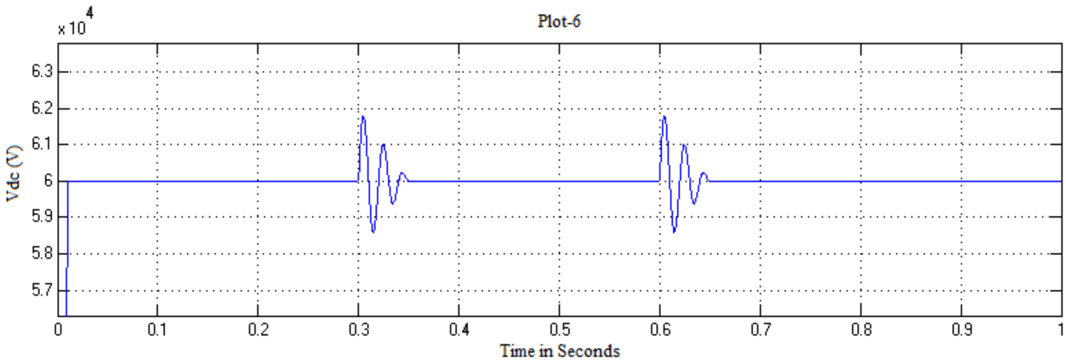

Fig-5.2(d) DC Link Capacitor Voltage

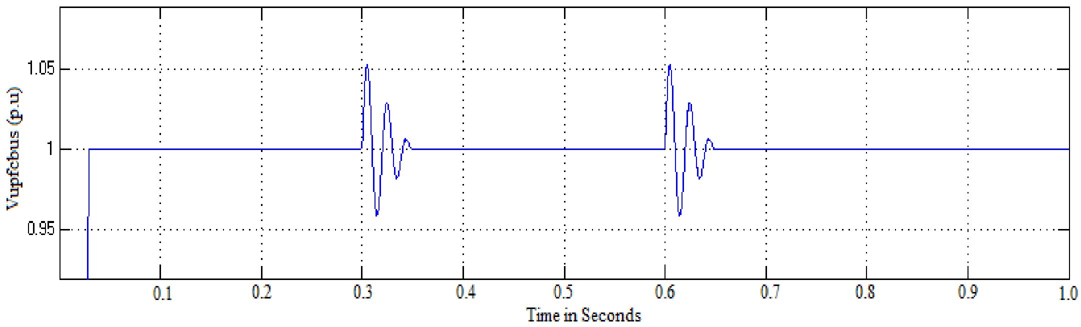

Fig-5.2(e) UPFC Bus Voltage without coordination controller.

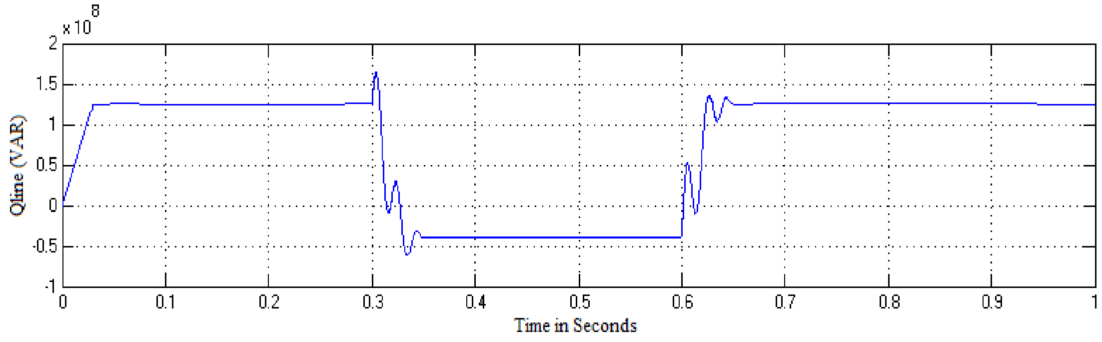

Fig-5.2(f)UPFC Reactive power of transmission line without coordination controller.

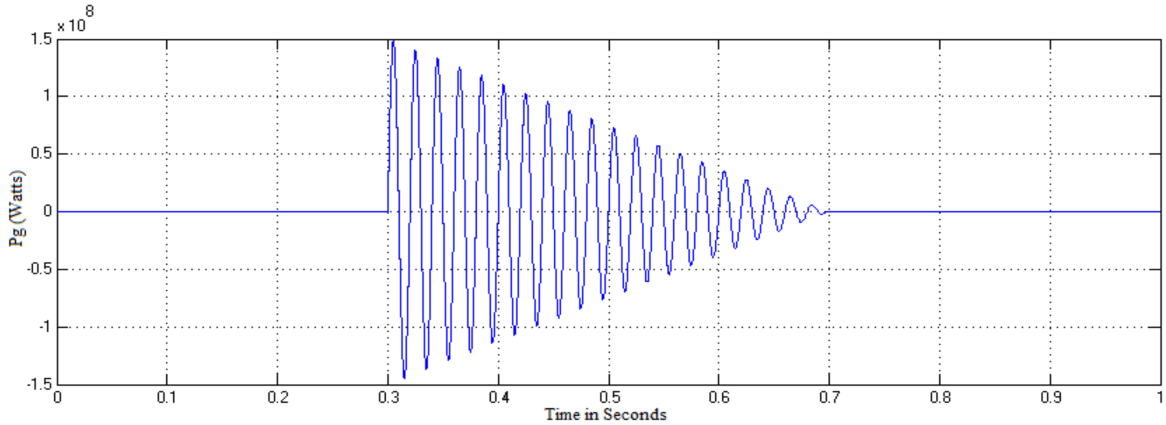

Fig-5.2(g) System Response for three phase fault without UPFC

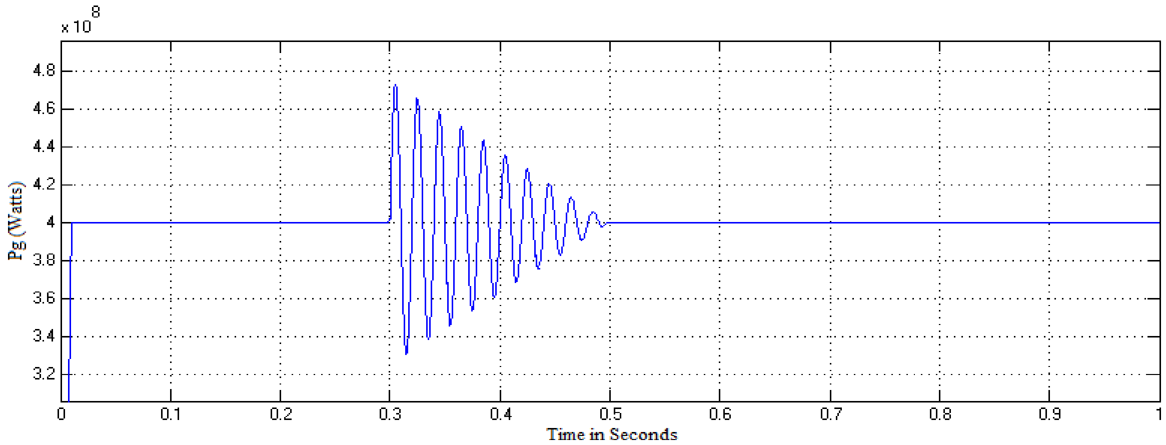

Fig-5.2(h) System Response for three phase fault with UPFC

6. CONCLUSION

Two important coordination problems have been discussed in this paper related to UPFC control. One, the problem of real power coordination between the series and the shunt converter control system. Second, the problem of excessive UPFC bus voltage excursions during reactive power transfers requiring reactive power coordination.

In addition, real power coordination controller in the UPFC control system not only avoids excessive dc link capacitor voltage excursions but also improves its recovery during transient conditions. MATLAB simulations have been conducted to verify the improvement in dc link voltage excursions during transient conditions. Significantly reducing UPFC bus voltage excursions during reactive power transfers. The effect on transmission line reactive power flow is minimal. MATLAB simulations have shown the improvement in power oscillation damping with UPFC.

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