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Transients Improvement in Electrical Power System Using Digital Control of UPFC Controller

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***Abstract*— To overcome the transients caused by change in voltage and frequency of the power supply in the electrical power system due to fault occurrence, power oscillation damping controller (POD) are being used. Many power controllers are developed for transients' detection and control as well, flexible AC transmission system (FACTS) are playing important role in this regard. But the question is that how effectively the power controller is performing? This is totally dependent upon the circuitry of the power electronic controller and control technique used for it to operate effectively in the power system. In this paper unified power flow controller (UPFC) is considered as FACTS controller and the auxiliary controller is a digital controller used for effective control of UPFC. In this work a digital POD controller is proposed to and implemented in MATLAB. Effectiveness of the technique used is justified and performing well as compare to state-of-the-art existing methods.**

***Keywords* - Flexible AC Transmission System (FACTS), Unified Power Flow Controller (UPFC), Power System, Voltage Source Inverters (VSIs), POD controller.**

I. INTRODUCTION

Signals Electrical power systems are the most complex systems that have great importance in modern life. They directly affect the social, political, economic, and modernization aspects. The electrical industry is undergoing unprecedented changes in its structure worldwide. With the advent of an open market space and competition in the industry, new issues in power system operation and planning are inevitable. One of the important consequences of this new electrical space is the greater emphasis on the stability and reliability operation of the power system. The transmission networks of modern power systems are increasingly stressed under the effect of growing demands and the current limitations on the construction of new lines. One of the results of such a stressed condition is the continuous menace of losing system stability when there is exposure to a severe disturbance. Flexible AC Transmission System (FACTS) devices are very efficient in reducing this stress. Though acceptable results have been achieved in these studies, responses under large disturbances could not be entirely obtained by this liberalized system method.

A. Basic Structure of Pi Based UPFC

Figure 1 depicts the UPFC, which consists of a converter1–shunt converter operation, a converter2–shunt converter operation, Measurement block, Settings block, shunt converter output voltage computation block, series converter output voltage computation block, dc voltage computation block, PI based controller STATCOM and series controller SSSC, Measurement block, Settings block, shunt converter output voltage computation block, series converter output voltage computation block, dc voltage computation block. Under stable operating condition the power flows from sending end to receiving end and transmission line parameters like voltage, line impedance, line reactive power, real power remains stable.

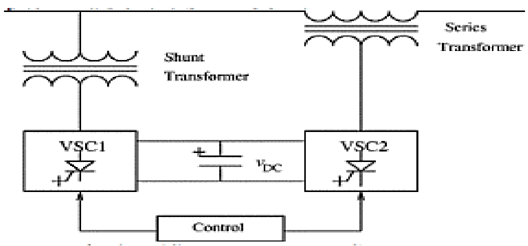

Fig 1. Simplified model of PI based UPF

The transmission line parameters received from the measurement block are compared to specified nominal rating values by the controller block. If the difference between predefined line parameters and that of sent from measurement block is zero then controller will send signal to setting block to stop giving pulses to series and shunt converter for shunt and series compensation. If predefined This error signal is processed by PI controller block and controller sends signal to setting block to generate appropriate pulses that has to be sent to shunt and series converter. Once the predefined line parameters get synchronized with that of sent form measurement block the controller block sends signal to setting block to stop pulses being given to series and shunt converters. Shunt converter output voltage computation block compute the output ac voltage of shunt converter and series converter output voltage computation block computes the series injected voltage. DC voltage computation block computes the common dc link voltage.

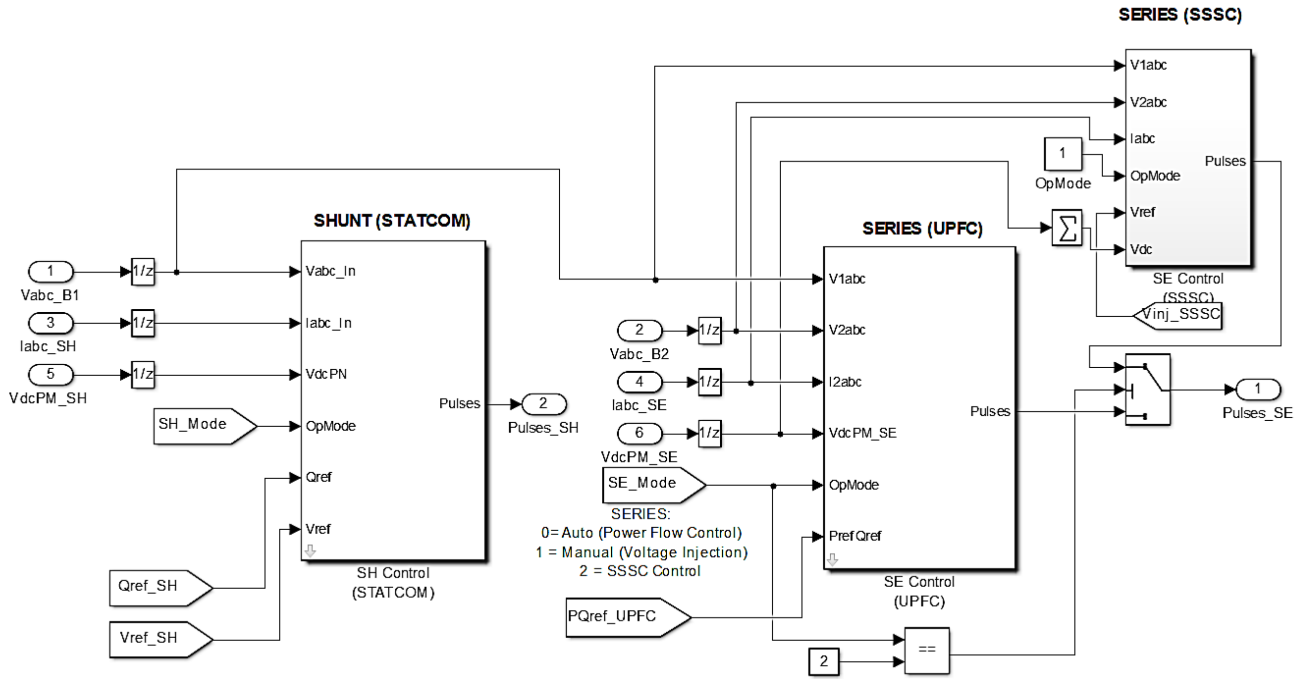

Fig 2. Detailed architecture of UPFC

II. UPFC SHUNT AND SERIES CONTROLLERS

A. *Control scheme of shunt controller*

The STATCOM shunt controller consist of ac voltage controller (ac voltage regulator), dc voltage controller (dc voltage regulator), current controller (current regulator), current limiter and Iqref selection block. controls the active power of transmission line. AC voltage regulator compares the predefined value of line voltage with measured value of line voltage sent from measurement block and generates the error signal. This error signal is processed by PI controller of AC regulator and PI controller generates the reference value for reactive component of line current. This reference value is further processed by Iqref selection block and current limiter block. Iqref selection block will either select the reference value generated from ac regulator or it will select the refence value corresponding to predefined reactive power commanded to the controller and later on this reference value will give to current limiter to keep it within predefined limits.

DC voltage controller compares the actual value of dc link voltage measured by measurement block and predefined value of dc link voltage and generate an error signal.

$$\begin{bmatrix} Vd \\ Vq \\ V0 \end{bmatrix} = \frac{2}{3} \begin{bmatrix} \cos wt & \cos(wt - \frac{2\pi}{3}) & \cos(wt + \frac{2\pi}{3}) \\ -\sin wt & -\sin(wt - \frac{2\pi}{3}) & -\sin(wt + \frac{2\pi}{3}) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \times \begin{bmatrix} Va \\ Vb \\ Vc \end{bmatrix} \quad (1)$$

PI controller generates reference value for active component of line current, Idref. When the active and reactive components of line current are compared to these reference values, the current regulator generates an error signal, which is processed by the current regulator's PI controller to generate reference values for the active and reactive components of line voltage, Vd* and Vq*. The park transformation, whose equations are provided below, can be used to find the real(active) and reactive components of line current/voltage:

UPFC Shunt and Series Controllers

A. Control scheme For Series Converter

The Series converter controller consist of converter voltage regulator, VdVq selection block. Voltage regulator compares the predefined value of active and reactive power with that of actual values measured by measurement block and generates an error signal. This error signal is further processed by PI controller of regulator to generate a reference value for active and reactive component of voltage to be injected in series with line. VdVq selection block either selects the reference value generated by regulator or it can select the value commanded to it.

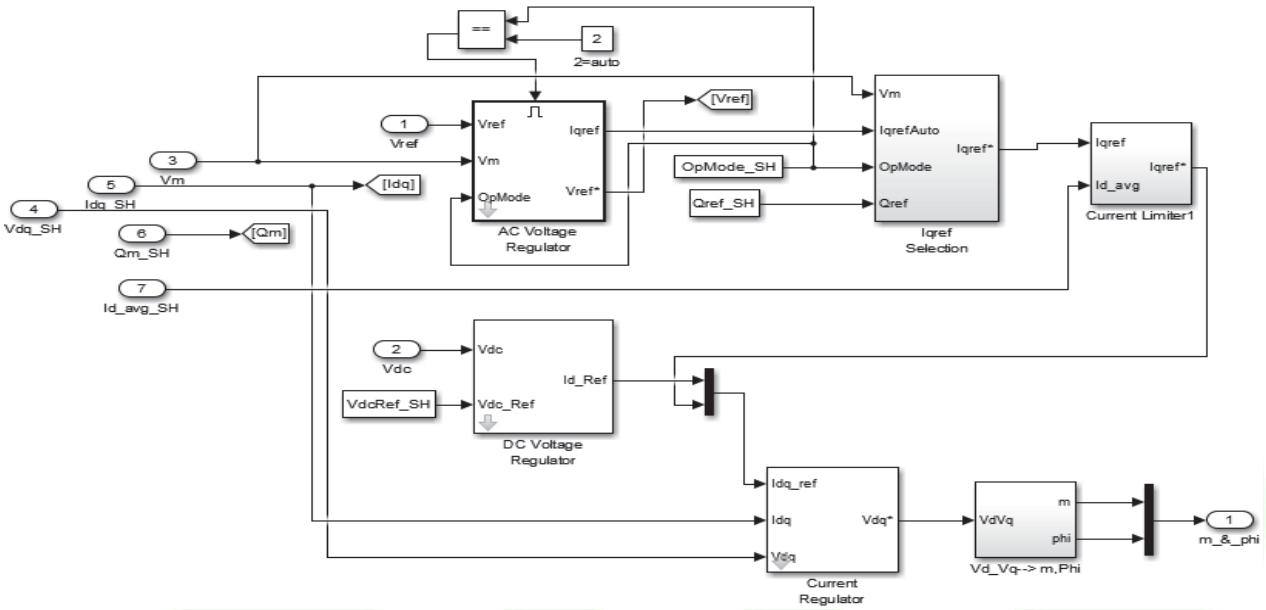

Fig. 3. Shunt controller for UPFC

B. Control scheme For Series Converter

The Series converter controller consist of converter voltage regulator, VdVq selection block. Voltage regulator compares the predefined value of active and reactive power with that of actual values measured by measurement block and generates an error signal. This error signal is further processed by PI controller of regulator to generate a reference value for active and reactive component of voltage to be injected in series with line. VdVq selection block either selects the reference value generated by regulator or it can select the value commanded to it.

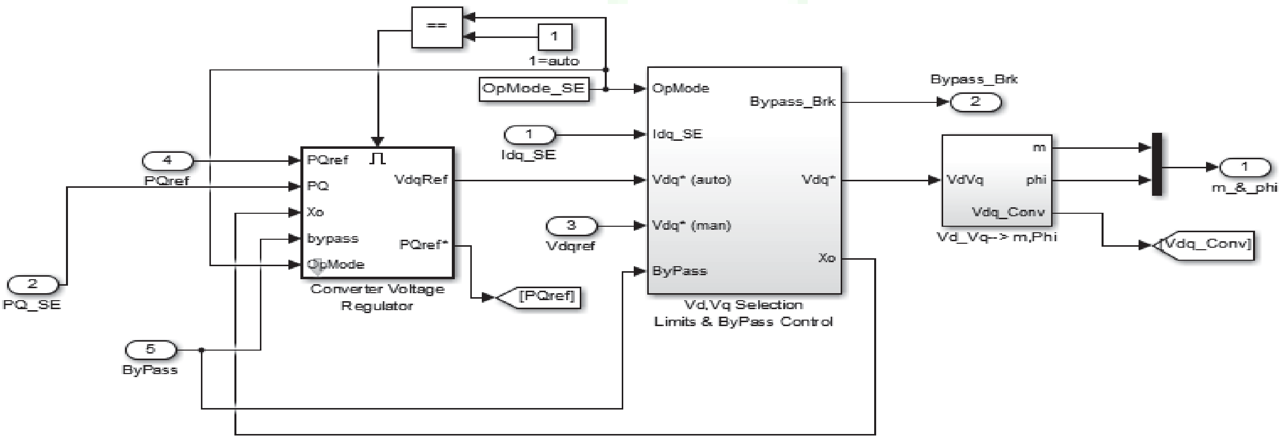

Fig. 4. Series controller for UPFC

C. General POD controller

The The SSSC can made to vary the series-compensation level dynamically in response to the controller-input signal so the resulting changes in the power flow improve the system damping. The traditional type of controller for Power Oscillations Damping (POD) purposes uses cascade-connected washout filters and linear lead-lag compensators to generate the desired reactance modulation signal. The purpose of the washout filter is to eliminate the average and extract the oscillating part of the input signal [3, 4]. Structure of general POD is shown in figure 2. Fig.5 Structure of simple POD controll

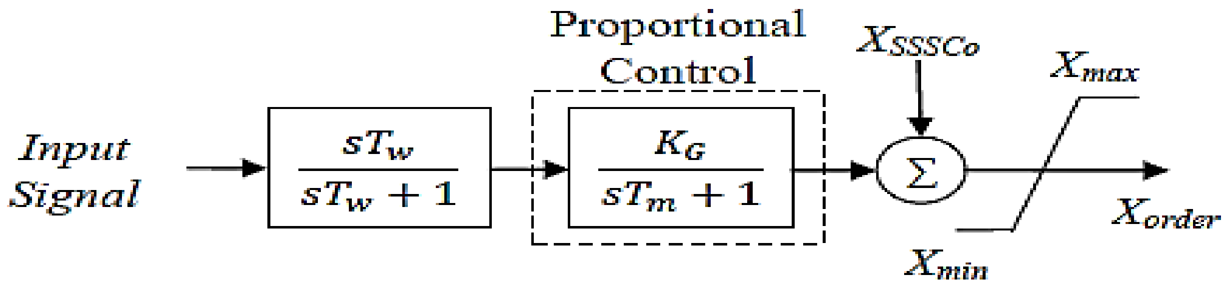

Fig.5 Structure of simple POD controller

D. Digital POD controller

To achieve acceptable performances, in modern power systems, additional control loops are generally added to the systems. For instance, to improve the damping of the inter-area modes, Power Oscillation Damping (POD) controller is added to the systems [2,4,5]. The washout filters smooth the input when there are changes in the input signal. Additionally, the filter rejects the entries of steady state, letting the transient oscillations get through to the POD. The lead-lag compensators are used to improve the frequency enters to the POD [2]. Depending on the system and the input and output variables of the POD, it may be required a phase lead or a phase lag, or both actions in different frequency ranges. The component of the POD is described below.

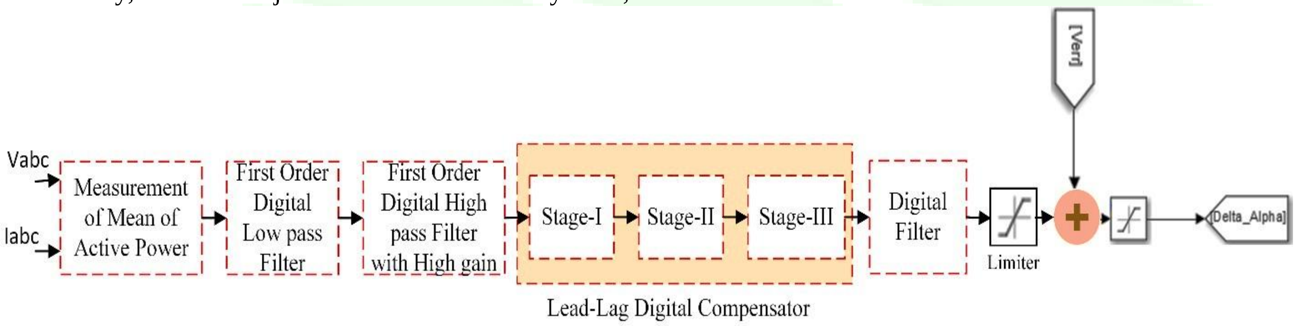

Fig.6 Block diagram of proposed digital POD controller

The transfer function of lead lag filter-

$$K(s) = \frac{1+STlead}{1-STlag} \quad (1)$$

$$T_{lag} = \frac{1}{\omega_i\sqrt{\alpha_c}} \quad (2)$$

$$T_{lead} = \alpha_c T_{lag} \quad (3)$$

$$\alpha_c = \frac{1-\sin \emptyset comp/m}{1+\sin \emptyset comp/m} \quad (4)$$

$$C(z) = \frac{(z-1)^2+2\gamma_d\delta_d\Omega_n(z^2-1)+\Omega_n{}^2(z+1)^2}{(z-1)^2+2\gamma_d\Omega_n(z^2-1)+\Omega_n{}^2(z+1)^2} \quad (5)$$

Where, γ_d, Ω_n and δ_d are real and positive. Since

$$\frac{e^{j\omega T}-1}{e^{j\omega T}+1} = j\Omega(\omega) \quad (6)$$

$$where\ \Omega(\omega) = tan\,\frac{\omega T}{2}$$

the frequency response of equation (5) for $\omega \in [0, \pi T]$ can be written as:

$$C(\omega,T) = C(e^{j\omega T}) = \frac{1+jX(\omega,T)}{1+jY(\omega,T)} \quad (7)$$

Where, T is the sampling period and

$$X(\omega,T) = \frac{2\gamma_d\delta_d\Omega_n\Omega(\omega)}{\Omega_n{}^2-\Omega(\omega)^2} \quad (8)$$

$$Y(\omega,T) = \frac{2\delta_d\Omega_n\Omega(\omega)}{\Omega_n{}^2-\Omega(\omega)^2} \quad (9)$$

The steady-state gain of a discrete compensator is $\gamma_{d0} = \lim_{z\to 1}C(z) = 1$. From (7) and (8) it follows that

$$\gamma_d = C(e^{j\omega T})\Big|_{\omega=\frac{2}{T}arctan\Omega_n} = \frac{X(\omega,T)}{Y(\omega,T)} \quad (10)$$

III. RESULTS AND DISCUSSION

The simulation results of the UPFC with and without digital controller are discussed here and the effectiveness of the proposed technique is verified with these results.

A. UPFC Response without Digital Controller

By the varying of magnitude of the secondary voltage Vs generated shunt converter control the reactive power is obtained with keeping in phase with bus B1 voltage Vs and Vp in Fig. 7 started to show at t = 0.6 sec due to changing into the value of reactive power.

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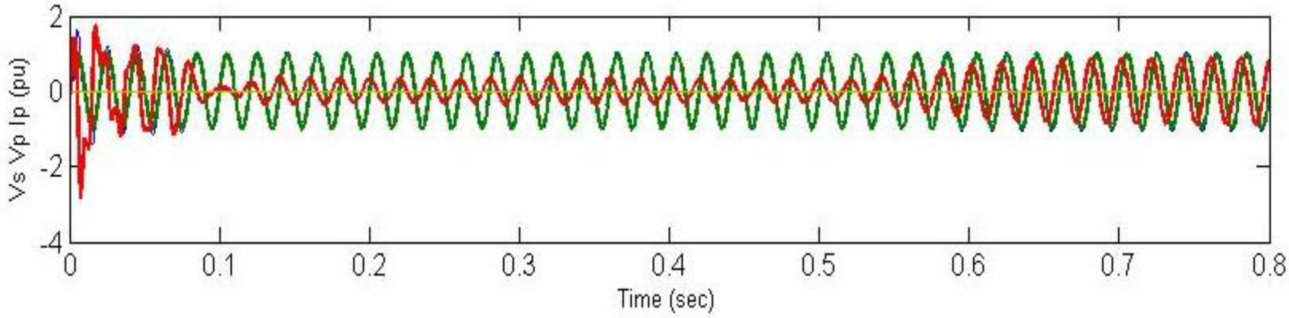

Fig. 7 Series and parallel injected voltage

The P (L1, L2, L3) is the active power shown in fig. 8 And it is observed that resulting changes in active power flow in the 3 transmission lines. The blue line shows the UPFC response.

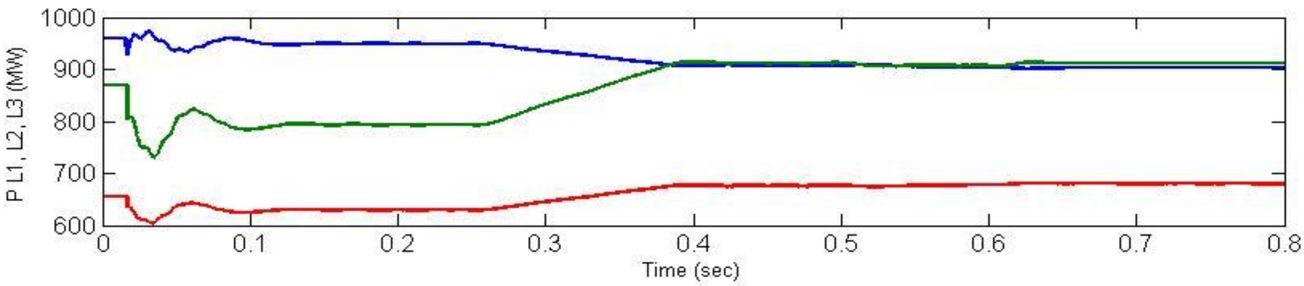

Fig .8 Active power response in 3 transmission line

The Q (L1, L2, L3) is the reactive power shown in fig. 9. And it is observed that resulting changes in reactive power flow in the 3 transmission lines. The blue line shows the UPFC response.

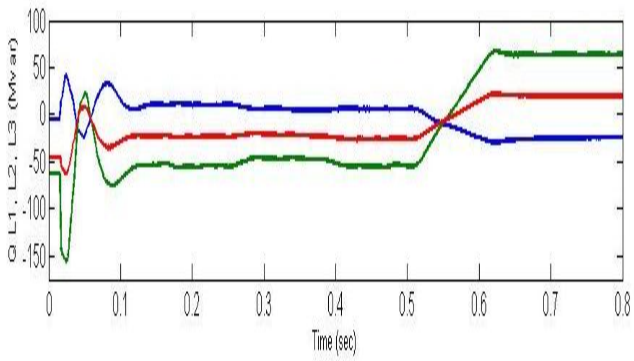

Fig .9 Reactive power response in 3 transmission line

B. UPFC Response with Proposed Controller

Current and voltage in the bus B1 with digital POD controller shown in fig. 10 is more stabilized and the transients are less as compare to without digital POD controller shown in figure 4.

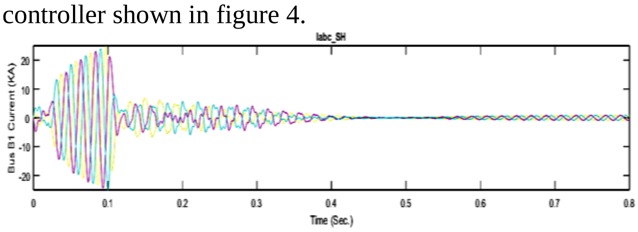

Figure .10 Series and parallel injected voltage with digital POD

The P (L1, L2, L3) is the active power shown in fig. 11 And it is observed that resulting changes in active power flow in the 3 transmission lines is fast stabilized as compare to without digital POD controller. The blue line shows the UPFC response.

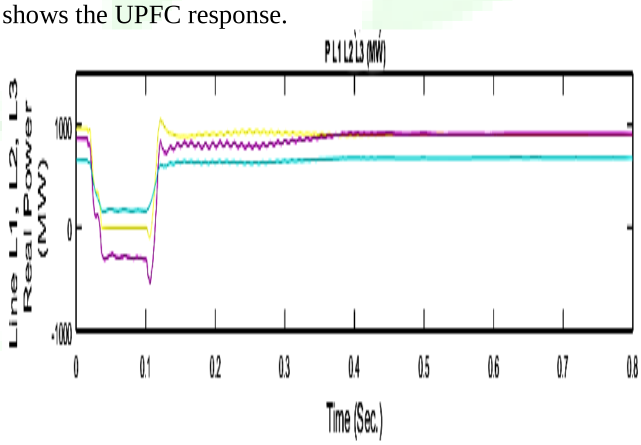

Fig .11 Reactive power response in 3 transmission line with digital POD

The Q (L1, L2, L3) is the reactive power shown in fig. 12 And it is observed that resulting changes in reactive power flow in the 3 transmission lines is fast stabilized as compare to without digital POD controller. The blue line shows the UPFC response.

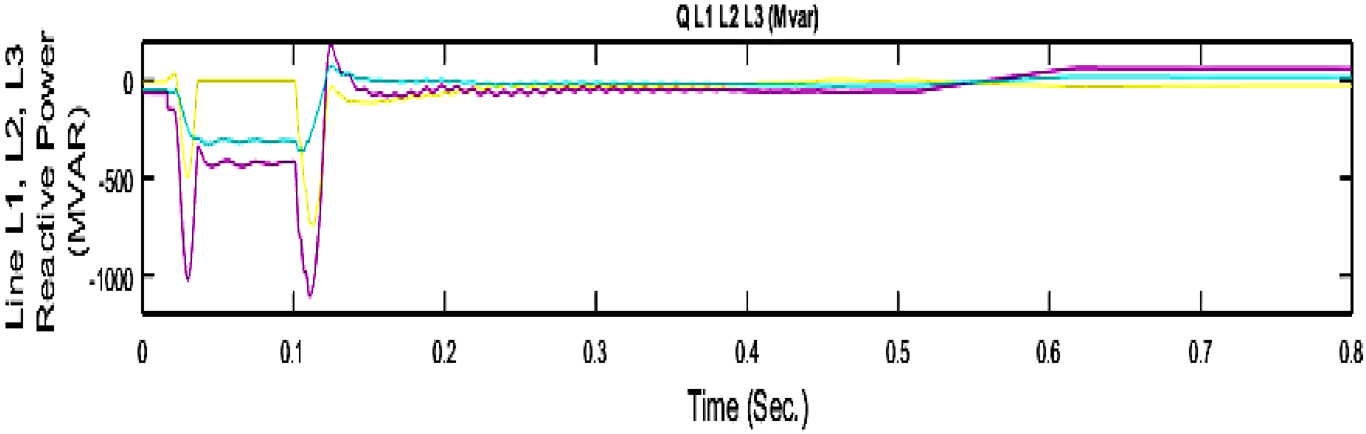

Figure .12 Reactive power response in 3 transmission line with digital POD

Comparison of real and reactive power with and without POD is shown in Fig. 13, this clear that the proposed technique is more effective as compare to the others techniques. The proposed technique is responding faster, which is the need to control oscillation in short duration.

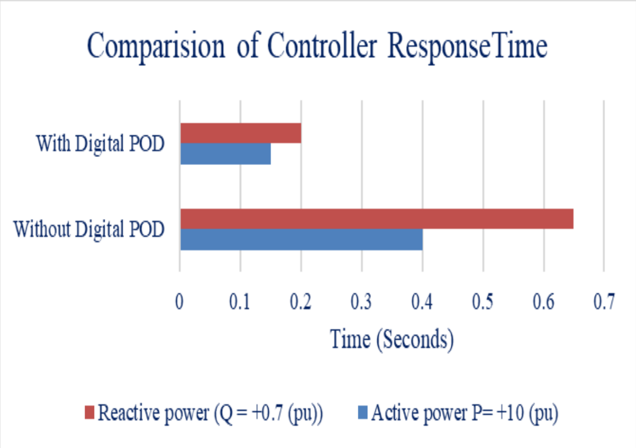

Fig.13 Comparing results of UPFC response with digital POD and without digital POD controller

IV. CONCLUSION

It is found that there is an improvement in the real and reactive powers, through the transmission line when POD is introduced. Performance of UPFC with advanced controlling methods is also analyzed. By using effective controllers real and reactive powers are more effectively controlled. The Simulation results approve that Voltage and Power Oscillation can be damped appropriately utilizing the proposed POD controlled UPFC. This study is planned to exhibit the viability of the proposed scheme in damping power system oscillations resulting from clearing system faults.

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