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A Novel Approach for Reducing the Power Oscillations in Transmission System by using Distributed Power Flow Controller (DPFC)

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ABSTRACT

An innovative control method to improve the system stability by most favorable proposed technique is distributed power flow controller (DPFC) based stabilizer is mentioned in this paper. The paper demonstrates the fundamental module, current injection method,mathematic modelling of DPFC.The function of the effort is to design an power oscillation damping(POD) controller for DPFC to damp out low frequency oscillations and to reduce the oscillations in active power and reactive power and also to improve the transmission voltage and transmission efficiency. The DPFC device is eliminates the common dc link between the shunt and series converters, and uses the transmission line to exchange active power and reactive power between converters at the third-harmonic frequency. Instead of using a large three-phase converter, the DPFC employs multiple single-phase converters (D-FACTS concept).This system was analyzed by using MATLAB/Simulink software.

Keywords: *FACTS, Distribute Power Flow Controller, Power Oscillation Damping.*

I. INTRODUCTION

Generally power demand grows radically, and expansion in transmission and generation is constrained with severe ecological constrains and restricted accessibility of recourse. on the other hand, the ability of long, inter-regional power transmission is frequently restricted, and the main reason is caused by low-frequency power oscillations.In addition, interconnection between power systems ; rise to low frequency oscillations in the range of 0.3–3 Hz. This type of oscillations may results in possibly keep rising in magnitude in anticipation of loss of synchronism, if not healthy damped [1]. And also dangerous oscillation, known as 'Inter-area oscillation', is observed when a mob of generates in a region swings and aligned with group in another region [2]. The conventional result is to use power system stabilizers (PSSs) on generator excitation control systems [3]. On the other hand, PSSs are frequently planned for local oscillation damping, and in large multi-area power systems it capacity be hard to adjust all the PSSs' parameters. FACTS controllers can be engaged for inter-area power oscillation damping (POD), and they are proved to be efficient [4], [5], [6]. The Distributed Power Flow

Controller (DPFC) newly offered in transmission line[7], is a dominant device contained by the FACTS component, in this device is greatly lower cost and high reliability than usual FACTS devices. It is consequential from the UPFC [8] and has similar capability of at the same time adjusting all the parameters, like line impedance, transmission angle, and bus voltage magnitude. The DPFC device is eliminate the common dc link between the series and shunt converters, and also exchange of active and reactive power takes place in transmission line at third-harmonic frequency. As an alternative of one large three-phase

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converter, the DPFC device employs multiple single-phase converters (Distributed-FACTS model [9]).In this paper also investigate the power oscillations in transmission system by using power oscillation damping.

II. DPFC PRINCIPLE

The Distributed Power Flow Controller consists of one shunt converter and a number of series converters. The shunt converter like as a STATCOM, the series converters acts like D-FACTS model. Transformation diagram for DPFC as shown in fig. 1 every converter surrounded by the DPFC is autonomous and has a separate DC link capacitor to provide the essential DC voltage. Several individual converters cooperate together and create the DPFC as shown in Fig.2.all series converters connected in transmission lines. They can inject a convenient voltage at the fundamental frequency and also control the power flow all the way through the line. The shunt converter connected between the line and ground, series converters are Connected between the any two buses.

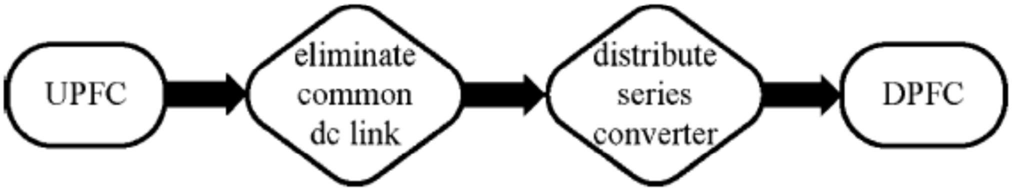


Figure 1: Transformation diagram for DPFC

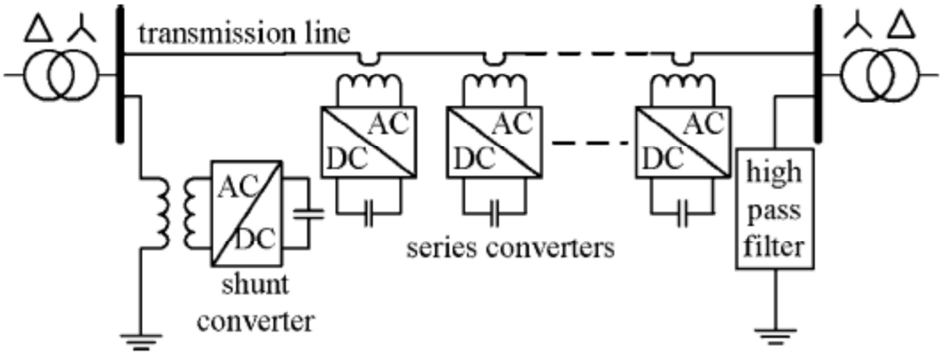


Figure 2: Basic structure of Distributed power flow controller

While there is no common dc link between the series and shunt converters, the exchange of active power takes place through harmonics and ac network. The active power in transmission system is given by integrals of all the cross-product of terms with different frequencies are zero:

$$P = \Sigma V_n I_n \text{Cos}Ø_n \tag{1}$$

Where $Ø_n$ is phase the angle between the current and voltage of the n^{th} harmonic. The third- harmonic is preferred here to exchange the active power in the DPFC, because third harmonic can be easily eliminated by star-delta transformer.

III. MODELLING OF DPFC

(A) DPFC control structure

In this shunt converter supplies active power in support of the series converters by injecting a constant third-harmonic current into the transmission line.

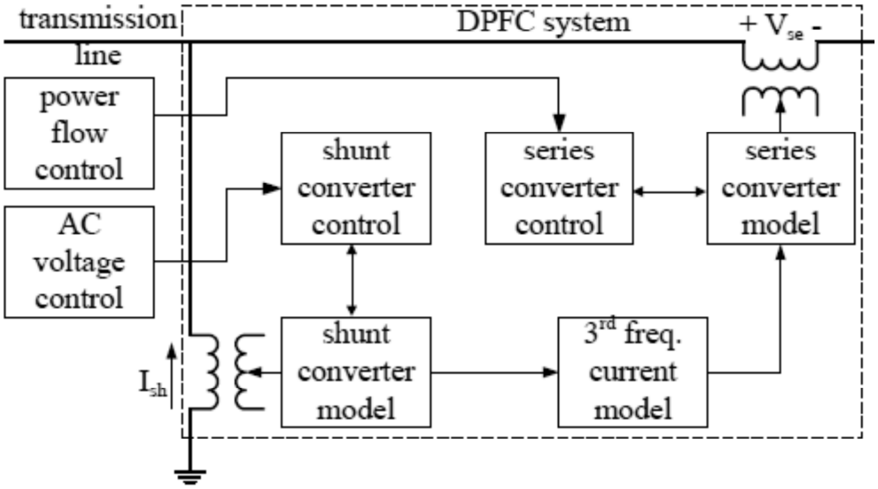


Figure 3: Control structure of DPFC

In this; controller is used to control the dc voltage by the d-component of the fundamental current, and the q-component is utilized for reactive power compensation. The series converters produce a 360^0 rotatable voltage at fundamental frequency; to retain the dc voltages in active power we take help of a voltage at the third harmonic frequency. The control structure of DPFC as shown in Fig. 3.

Given that the third-harmonic frequency components will not control the power system at the fundamental frequency, they can be treated as an inner issue. The MATLAB tool box detailed model in[11].

(B) DPFC current injection model

Generally DPFC structure is analyzed using nodal analysis method with an equivalent circuit and other way by using admittance matrix method. In this case above two methods are very difficult to analyze. In this schoolwork, we suggest current injection model of DPFC to study the effects of it on low frequency oscillations. The proposal of current injected models current source are shunt connected in line replaced by voltage source in series with line. as shown in Fig. 4.

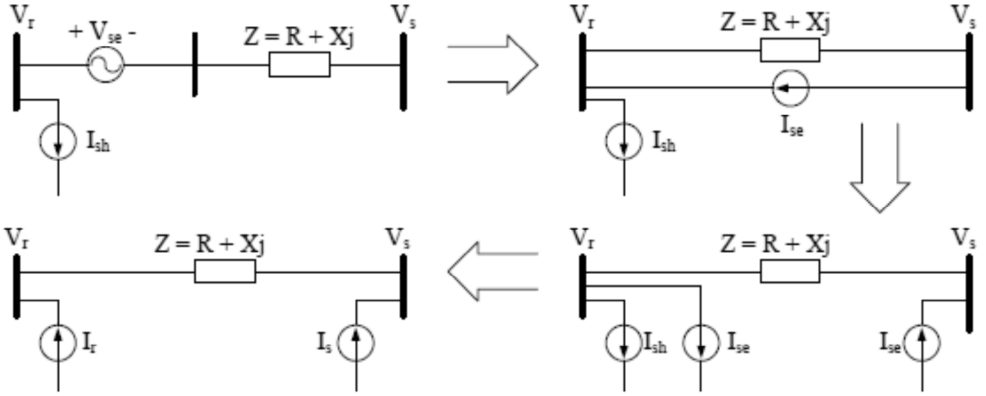


Figure 4: Current injection model of DPFC

Series current $I_{se} = V_{se} / Z$

$$I_r = -I_{sh} - I_{se} \qquad I_s = I_{se}$$

While the currents injected to buses be able to be like as loads.

(C) DPFC-POD Controller

The arrangement of the DPFC POD controller, as shown in Fig.5, is like as the PSS controller [4].

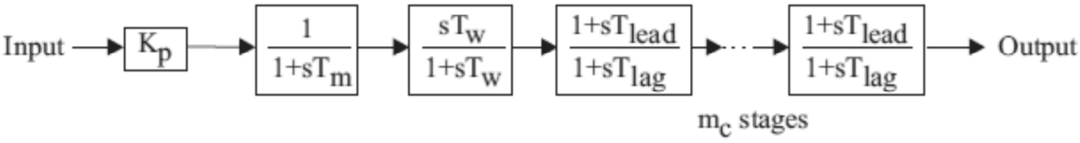


Figure 5: DPFC-POD Controller

It contributes an amplification block, a wash out block and two lead-lag blocks [12].The washout is proposed to remove the dc component of POD controller input signal and has a huge time constant, regularly from 5sec to 10sec, even as the oscillation is at low frequency (less than 2 Hz normally). The time constants of lead-lag blocks T_{lead},T_{lag} and amplification gain K is the POD design parameters. In this case POD controllers are enhancement at the power flow control and ac voltage control blocks in Fig. 3. from the time when the DPFC has three control teqniques ,They are $I_{sh,q}$,$V_{se,d}$ and $V_{se,q}$, the q-component of shunt current and dq-components of the series voltage, correspondingly. The control structure of the possible POD controller location in the DPFC control is as shown in Fig.6.

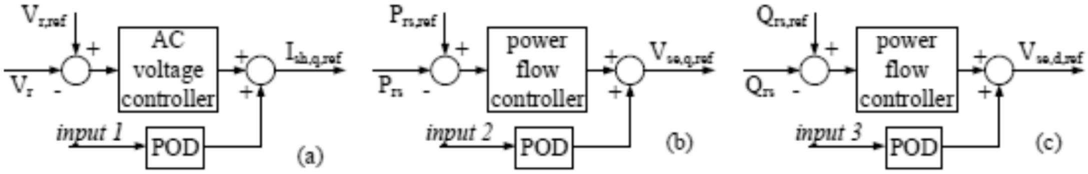


Figure 6: (a) ac voltage controller (b) active power flow controller (c) reactive power flow controller

IV. DESIGN OF DPFC-POD CONTROLLER

(A) System linearization

If design of a POD controller, is analyze to oscillations and to classify the system with DPFC can be represented by the state-space representation:

$$\Delta\dot{x} = A\Delta x + B\Delta u$$

$$\Delta y = C\Delta x + D\Delta u \tag{4}$$

Let $\lambda_i = \sigma_i + j\omega_i$, $\lambda_i = \sigma_i - j\omega_i$ be the i^{th} of the eigen value of the state matrix A. The real part of term consisting is eigen value gives damping, and the complex part gives angular velocity of the oscillation.The relative damping ratio is given by:

$$\zeta_i = - \sigma/(\sigma^2 + \omega^2) \tag{5}$$

In this case eigen value damping ratio less than 3% are considered for critical oscillatory damping[13].To propose the POD controller, the system without the POD controller can be considered as a single input single output (SISO) system, with the open loop transfer function:

$$G(s) = \Delta y/\Delta u = C(SI - A)^{-1}B \tag{6}$$

G(s) can also represent in partial fraction

$$G(s) = \sum_{i=1}^{N} \frac{R_i}{s - \lambda_i} \tag{7}$$

(B) Controller design of DPFC- POD using residue method

In this case using POD controller as the feedback to the SISO system, as shown in Fig.7, eigen values are entire systems are changed. If transfer function of the POD controller is KH(s), the change of the eigen value for the reason that of the POD controller is given by [10]:

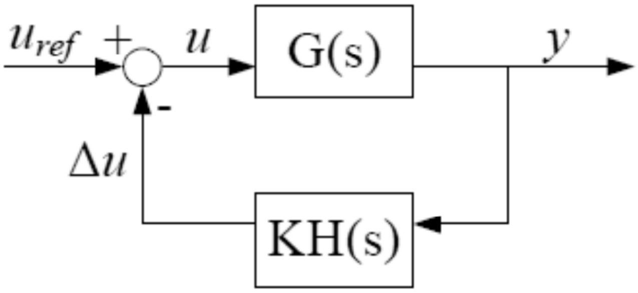


Figure 7: Closed loop system with POD

$$\Delta\lambda_i = R_i KH(\lambda_i) \tag{8}$$

From equation (8) it can be change of the eigen value reason by the POD controller is proportional to the magnitude of the residue. Consequently if input signal of the POD controller is chosen according to magnitude of residue. By increasing the value of residue R_i to damp the oscillation λ_i, for the POD controller. In case by using DPFC-POD to reduces the oscillation of active and reactive power flow through the line, the current, or the bus voltage magnitude. To reduces the oscillation, to move the eigen value towards the left half s- plane, as shown in Fig.8.if angle between the information of the residue and the POD is the reparation angle $Ø_{comp}$, which is achieved by the lead-lag blocks. If the two lead-lag blocks in the POD controller equal, after that the parameters T_{lead} and T_{lag} are resolute by [10]:

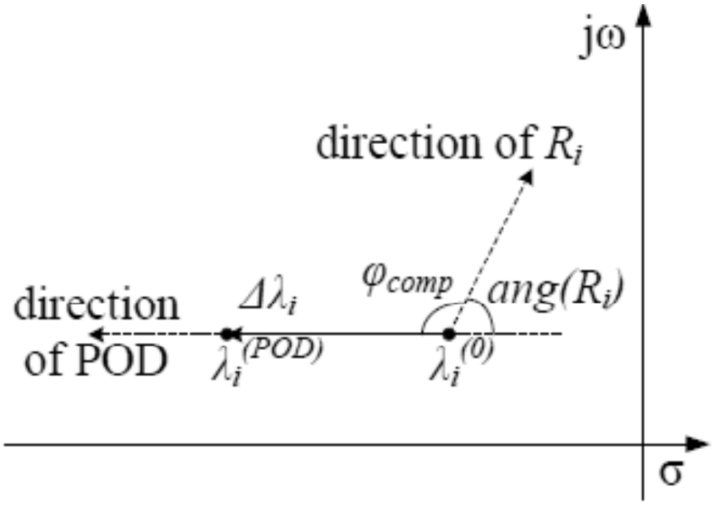


Figure 8: Shift of eigen values with POD controller

$$\begin{gathered} Ø_{comp} = 180^0 - ang(R_i) \\ \alpha_c = T_{lead}/T_{lag} = (1-\sin\varphi_{comp}/m_c)/(1-\sin\varphi_{comp}/m_c) \\ T_{lag} = 1/\omega_i\alpha_c \\ T_{lead} = \alpha_c T_{lag} \end{gathered} \tag{9}$$

Here m_c is the no. of lead-lag blocks and ω_i is the frequency in rad/sec of the oscillation. The amplification gain K can be considered as a function of preferred eigen value location $\lambda_{i,des}$ according to equation (8):

$$K = \text{modules of } (\lambda_{i,des}-\lambda)_i/(R_i H(\lambda_i)) \quad (10)$$

In case POD is added three locations in the DPFC. given that the POD controllers contain manipulate on each other, in this case to calculate very complicate all three sets of POD parameters at one time by using the residue method.

The procedure for manipulative POD controller parameters for a DPFC is described in the subsequent steps:

1. Determine the most significant eigen value of the system as the damping aim of the first POD controller;
2. Evaluate the residue designed for executable of POD locations, and the first POD controller is placed at the location where there is a biggest residue;
3. Evaluate the first POD controller parameters;
4. Evaluate the new eigen values of the system with the first POD controller, and find out the most critical eigen values one as the second POD controller damping objects;
5. Repeat the above procedure for calculating the rest POD controller parameters.

V. CASE STUDY OF DPFC-POD

If POD ability of the DPFC is simulated in a simple two-area system [2]as shown in Fig.9. In this system consists of two areas which are associated by a weak tie, and each area consisting of two coupled generators. These generators are self-excited by dc exciters, and PSSs is not included in them. later than the linearization of the system without DPFC, a pair of eigen values are present in the positive plane with an oscillation frequency of approximately 0.4Hz.The DPFC is present in between the buses 8 and 9 used to monitor the power flow during the tie, and also to damp out the oscillations at the same time. Bus 8 is a perfect location for placing the shunt converter, because voltage swings are very high at bus 8.

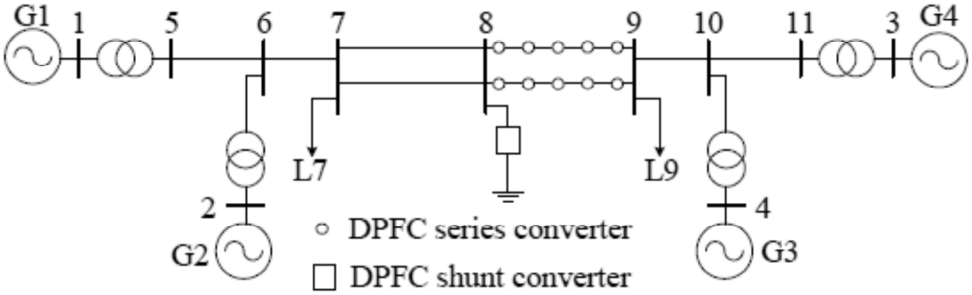


Figure 9: Two-Area system with DPFC

As mentioned earlier, the drawback with a set of fixed controller parameters i.e.tuned by conventional method, arises when the topology of the system is changed. In such cases, the re-tuning of POD parameters is required.To overcome this problem; based on a complete set of the model parameters,we have to re-tune the controller parameters for every new operating condition . In following Figures, dynamic responses obtained by this approach are denoted as “re-tuned POD”, i.e. POD is re-tuned for appropriate operating condition, e.g. with the line out of service, whereas “fixed POD” means POD controller which is tuned well by residue based method, but for nominal condition.

By placing DPFC without POD controller causes the unstable eigen values; these values will be shifted a little bit towards left side ; however the eigen values are still present at the right half plane and the system is unstable. By enhancing the control dynamic of DPFC, the eigen value can be further shifted to left, but the shifting is not very large. The critical oscillatory mode is characterized by eigen value $\lambda_1 = 0.0216 + j2.021$ and $\lambda_1^1 = 0.0216 - j2.021$ with the damping ratio $\zeta 1 = -0.044\%$. It is found that the DPFC control parameter Vse,d has the largest residue $R = 11.2058$ and therefore the most efficient to apply the POD controller to that variable. The input signal given to the POD controller is the active power and reactive power flow from bus 8 to bus 9. Using above method, the transfer function of the first POD controller is obtained as:

$$H_1(s)= 0.2505*5s/(1+5s)*(1+0.1456s/1+0.2589s)^2$$

By using single POD controller, the critical eigen values are shifted from right to left ,it is nothing but a stable location. However, as a side effect, the controller also brings a stable eigen value on the way to the critical damping, as shown in Fig.9.In fig.9 illustrates the eigen values of the system, where only the eigen values are close to the critical damping is shown. Three cases are mentioned below: without POD, with single and double POD controllers. To eliminate this side-effect, the second POD controller is employed to damp out the oscillatory mode $\lambda_2 = -0.1090+j0.4590$ and $\lambda\text{-}_2^1 = -0.1090+j0.4590$ with the damping ratio $\zeta_2 = -0.190\%$. The DPFC control parameter Vse, q is selected to apply the second POD controller and using input signal as reactive power flow . The second POD controller transfer function are obtained as:

$$H_2(s) = 0.2001*5s/(1+5s)*(1+0.1245s/1+0.0519s)^2$$

After applying two POD controllers, all the Eigen values are away from the critical damping line; therefore it is not necessary to use the third POD controller in this case. when a fault occurs, the power oscillation phenomenon can be observed . To test the capacity DPFC POD , a fault is created in between the lines 7-8 at t =1s, and it is cleared after 0.1s. Fig. 11 shows the active power and reactive power flow from bus 8 to bus 9 in the three cases. When POD controller is not included ,There is no such a huge difference between with one POD and two POD controllers, for the reason that the damping aim of the second POD controller is at a standstill under the critical damping line. In this simple 2-area system, only two POD controllers can achieve necessary stability. In case use of three possible POD controllers are in use, the DPFC can further stabilize a complex system ,because of to calculate the multiple critical eigen values are difficult.

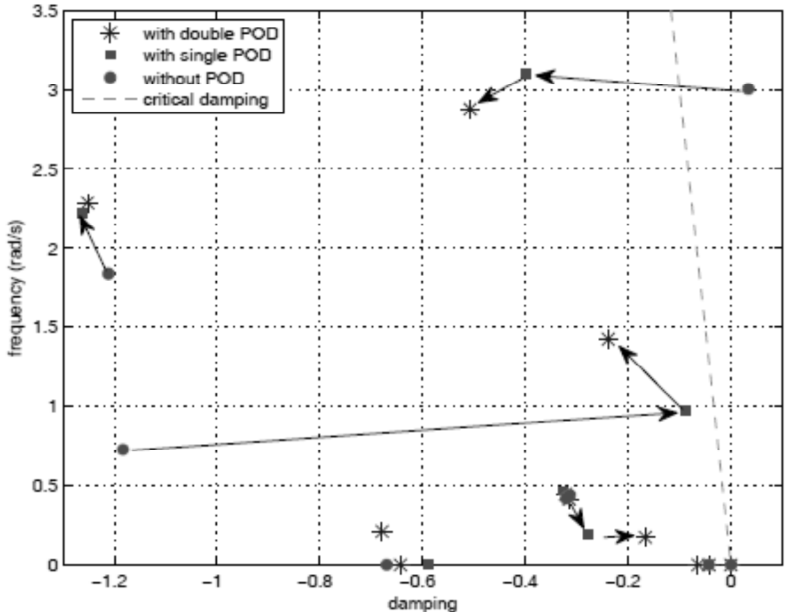
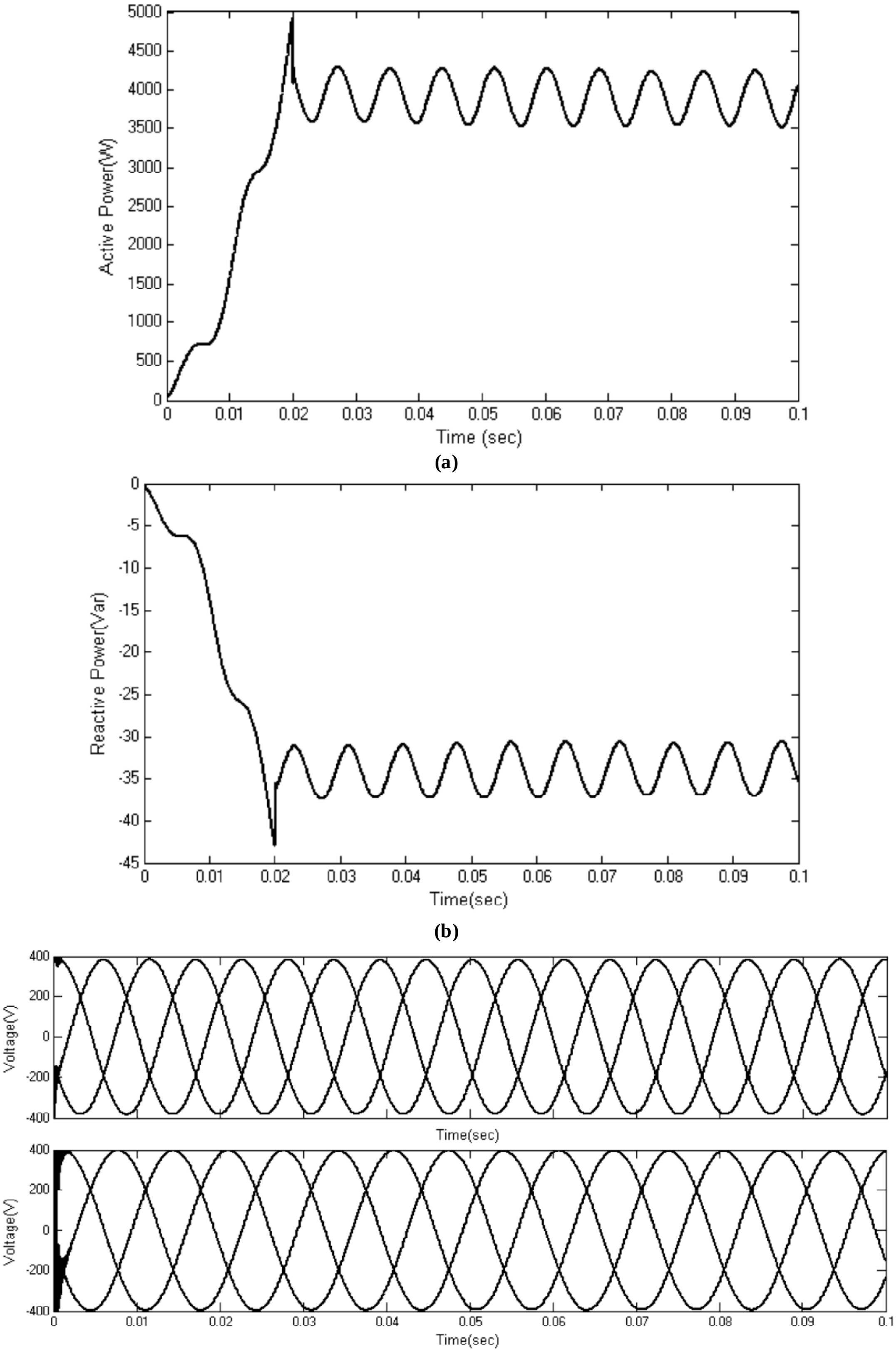


Figure 10: Location of eigen value in two-area system

VI. SIMULATION RESULTS

The simulation is done by using MATLAB/ SIMULINK software to analyze the active power and reactive power flow, bus voltages without DPFC-POD controller as shown in fig. 11.



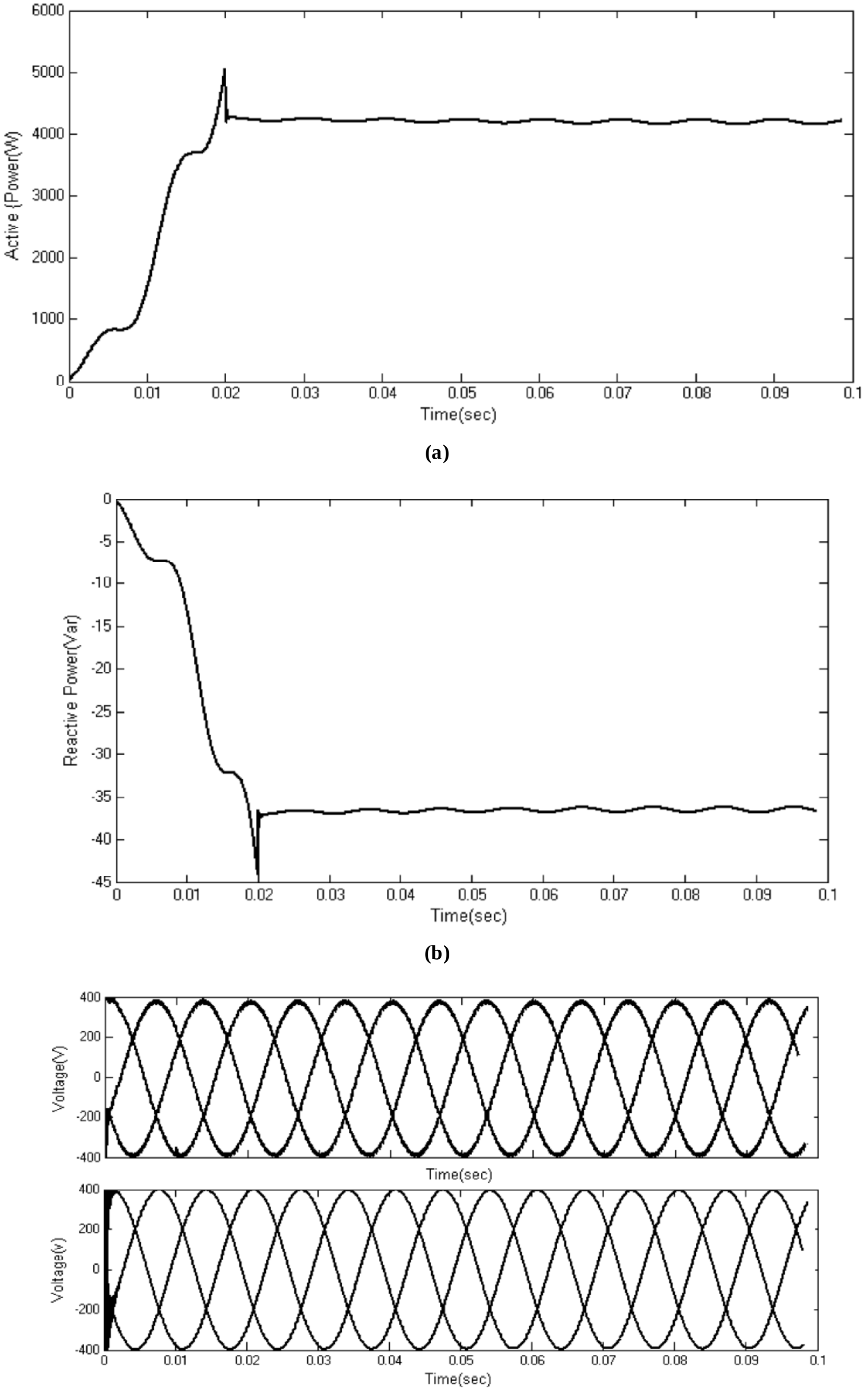
(a)

(b)

(c)

Figure 11: Without DPFC-POD (a) Active power (b) Reactive power (c) Bus voltage

It can be seen that the proposed model based optimized DPFC-POD damping controller has good performance in damping low frequency oscillations and active power and reactive power flow, bus voltages as shown in fig 12.



(a)

(b)

(c)

Figure 12: With DPFC-POD (a)Active power (b) Reactive power (c) Bus voltage

VII. CONCLUSION

DPFC is a new control technique in transmission system; it can control the active power and reactive power flow in transmission line. Here in this paper Power Oscillations Damping Controller is provided to damp low-frequency and multiple frequency power oscillations at the same time. Here POD control parameters are calculated by using residue method.

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