Available online www.ejaet.com

European Journal of Advances in Engineering and Technology, 2018, 5(2): 99-105

Research Article ISSN: 2394 - 658X

Modeling and Performance Analysis of Distributed Power Flow Controller on Multi Machine System

Shailendra Shrivastava[1], Vishal Sharma[2] and Dr. Annapurna Bhargava[1]

[1]Department of Electrical Engineering, University College of Engineering, Rajasthan Technical University, India
[2]Department of Electrical Engineering, Jaipur Engineering College and Research Center, Jaipur, India
shailmits@gmail.com

ABSTRACT

In last few decades the demand of electricity grownup drastically. Due to higher demand and aging of networks it is indispensable to control the power flow in transmission systems. The flexible AC Transmission system (FACTS) provides effective control over one or more transmission system parameters to enhance controllability and increase power transfer capability. UPFC is one of the most powerful FACTS devices which can simultaneously control all the parameters of the system i.e., the line impedance, transmission angle and bus voltage. This paper presents a device called Distributed Power Flow Controller (DPFC) which is derived from the UPFC by eliminating common DC link. It is most recent and one of the ultimate device within the FACTS family. The DPFC has control capacities of all the parameters of the transmission network. With DPFC the active power exchange between the shunt and series converter is done through the transmission line by the 3rd harmonic current. It is designed with multiple single phase series converters (D-FACTS) and one three phase shunt converter. The DPFC has more control capability at much reduced cost and improves reliability.

This work presents modelling of a damping controller based on 'Generalized Theory of the Instantaneous Active and Reactive Power' proposed by Akagi commonly known as P-Q theory, the simulation results demonstrate parameters like, compensating current flowing through controllers, and active power flow.

Key words: UPFC, DPFC, D-FACTS Shunt and Series converters, PI Controller etc.

INTRODUCTION

The demand of electricity is growing tremendously but the extension of transmission system and generation is restricted due to various environmental constraints and limited availability of resources. The FACTS devices enhance controllability and optimize the utilization of existing power system capabilities using high speed and reliable power electronic devices. A distributed FACTS (D-FACTS) device has been recently introduced in the FACTS family and gaining significant importance because of several advantages over conventional FACTS devices. The D-FACTS devices parade much lower cost and higher reliability. A Distributed Power Flow Controller (DPFC) has been derived from UPFC and has similar capabilities of simultaneously adjusting all the parameters of the existing system such as impedance of line, transmission angle and degree of bus voltage [1]. The major advantage of DPFC is the abolition of common DC link between shunt and series converters, and utilizes transmission line to exchange active power between these converters at 3rd harmonic frequencies, instead of one large 3 phase converter, it employs several single phase converters as series compensator, and thus the rating of apparatuses reduces and also provides a high reliability [2].

ADVANTAGES OF DPFC OVER CONVENTIONAL FACTS DEVICES

Higher Control Capability

DPFC corrects the line impedance, the power transmission angle, and the bus voltage i.e. all the parameters of the electric power system. There is separate connection of the DPFC converters due to removal of the common DC link. The series and the shunt converters are placed at the most effective location. DPFC can be used to enhance the system stability and to improve the power quality.

High Reliability

Improved reliability is given by redundancy of the series converter. The series and the shunt converters are independent of each other and the damage at one place will not affect the other converters. The converter will be short circuited by bypass protection, when a failure arises in the series converter. If the shunt converter fails to operate then series converter will stop providing active compensation and will acts as the D-FACTS controller.

Lower Cost

In the series converter there is no any requirement of the phase to phase isolation. And each converter has a low power rating and can be simply produced in series production lines.

DISTRIBUTED POWER FLOW CONTROLLER (DPFC)

The purpose of this work is to damp out the oscillations using the distributed power flow controller (DPFC) with proposed current injection model in a power system. DPFC eliminates the common dc link between the shunt and the series converters. It also employs multiple single-phase converters (distributed–FACTS) as the series compensator [3]. The proposed model is tuned to damp power system oscillations with minimum disturbance. Non-linear time domain simulation studies have been carried out for the validation of the purpose of the distributed power flow controller using MATLAB.

The transformation from UPFC to DPFC is as shown in fig.1

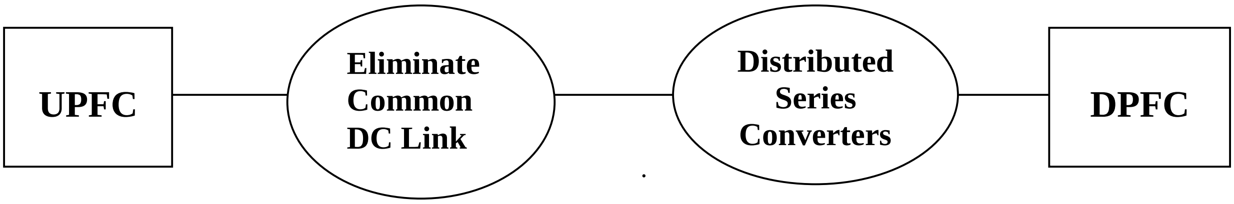

Fig.1 Flow chart from UPFC to DPFC

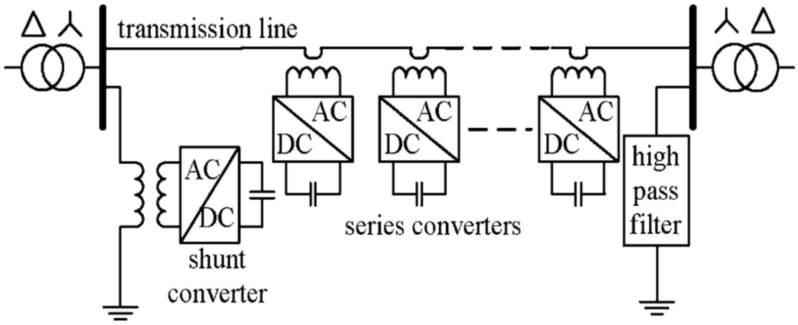

Fig. 2 Basic Module of DPFC

Basic Module of DPFC

The DPFC consists of a several series connected converters and the one shunt converter. The series converter shows the D-FACTS concept while the shunt converter is similar as a STATCOM. Each converter has a separate DC link capacitor to provide the required DC supply. Every converter in the DPFC is independent from each other. Fig. 2 shows the structure of the DPFC that is used in a transformation system with two lines in parallel [6].

Operating Principle of DPFC

In the distributed power flow controller (DPFC), the transmission line introduces a common connection between the AC ports of the series and the shunt converters [5]. However, it is possible to exchange the active power through the AC ports. This method is based on the power theory of the non-sinusoidal components. According to the Fourier analysis, non-sinusoidal current and voltage can be showed as the sum of the sinusoidal function in different frequencies having the different magnitudes. The non-sinusoidal current and voltage results from the active power and is defined as the mean value of the product of current and voltage. Because the integrals of all the cross product of terms with different frequencies are zero, the active power can be shown as:

$$P = \Sigma V_i I_i Cos\text{ø}_i$$

Whereas V_i and I_i are the voltage and the current at the i^{th} harmonic frequency respectively and ø_i is the corresponding angle between the voltage and the current the active power at different frequencies are independent from each other and the voltage or current at one frequency has no any effect on active power at other frequencies. The shunt converter can absorb the active power from the grid at the fundamental frequency and apply the power back at a harmonic frequency. The DPFC series converters generate a voltage at the harmonic frequency, thereby absorbing the active power from the harmonic components. Losses are neglected and generated active power at the fundamental frequency is equal to the power absorbed at the harmonic frequency. Figure 3 shows, how the active power is exchanged between the series and the shunt converter using third harmonic components. Due to the exclusive features of 3rd harmonic frequency components in a three-phase system, the 3rd harmonic is selected for active power exchange in the DPFC [5].

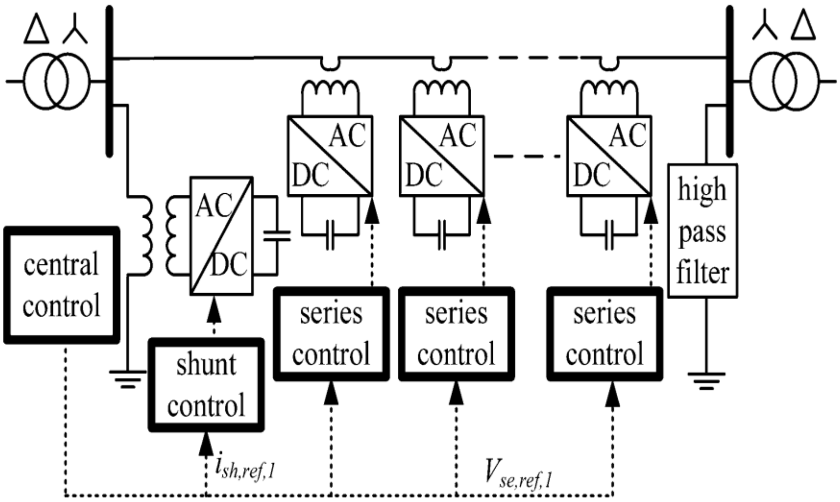

Fig. 3 DPFC Control Block

CONTROLLING AND MODELLING OF DPFC

To control multiple converters, a DPFC consists of three types of controllers: central control, shunt control and series control. The shunt and series control are localized controllers and are accountable for maintaining their own converters' parameters. The central control takes care of the DPFC functions at the power system level [6].

In this paper, attention is focussed in DPFC controller. DPFC is an ultimate device within the FACTS family, which provides much lower cost and higher reliability. It is basically derived from the UPFC and has the same capability of simultaneously adjusting all the parameters of the system such as line impedance, transmission angle and the bus voltage magnitude [7]. The DPFC eliminates the common DC link between the series and the shunt converters, instead of one large three-phase converter. DPFC employs multiple single-phase converters as the series converter. This reduces the rating of the components and provides high reliability because of the redundancy. This instantaneously controls the reactive and the active power flow and the voltage magnitude, it results in power oscillation damping.

The module of the D-FACTS results is low cost and the higher reliability because the D-FACTS units are single phase devices floating on lines and high voltage isolations between the phases are neglected. There is no any requirement of the supporting phase ground isolation. The voltage and power rating of each unit is relatively small, therefore it gives the much higher reliability than any other FACTS device.

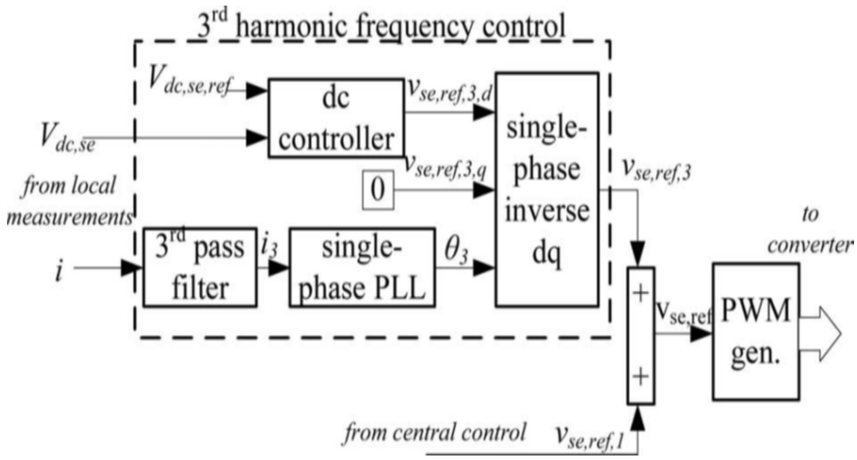

Fig. 4 Block diagram of the series converter control

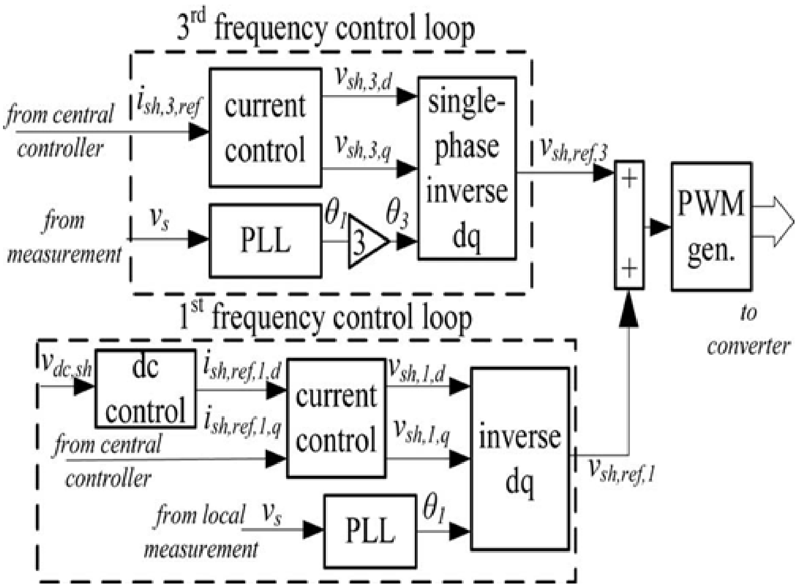

Fig. 5 Block diagram of the shunt converter control

SIMULATIONS AND RESULTS

Simulink setup of a two area system has been built to verify the principle and control of the DPFC. One shunt converter and three single phase series converters are built and tested in a scaled network. Within the setup, multiple series converters are controlled by a central controller. There are basically three control schemes 1. Series control 2. Shunt control 3. Central control. The central controller gives the reference voltage signals for all series converters. The voltages and currents within the setup are measured fundamental and 3rd Harmonic frequency components in MATLAB.

The model is simulated for 0.5 second, at t = 0.01 second a three phase fault is created which cleared at t = 0.15 second. Three phase waveforms of figure 6 shows voltage sag at load bus during the fault without DPFC, similarly waveforms of figure 8 shows the variation in current at load bus for the same duration in above model. Figure 7 shows the variation in voltage when DPFC is applied in above model and all other parameters remain constant, similarly figure 9 shows the variation in current at load bus. Shunt converter injects the power through third harmonic component during fault period. Now the line current has fundamental and harmonics contents, it is necessary to remove third harmonics component. The output of shunt converter is now fed to series converter which removes the third harmonics component of line current and gives the desired output. Figure 10 and 11shows the active and reactive power flow without and with DPFC.

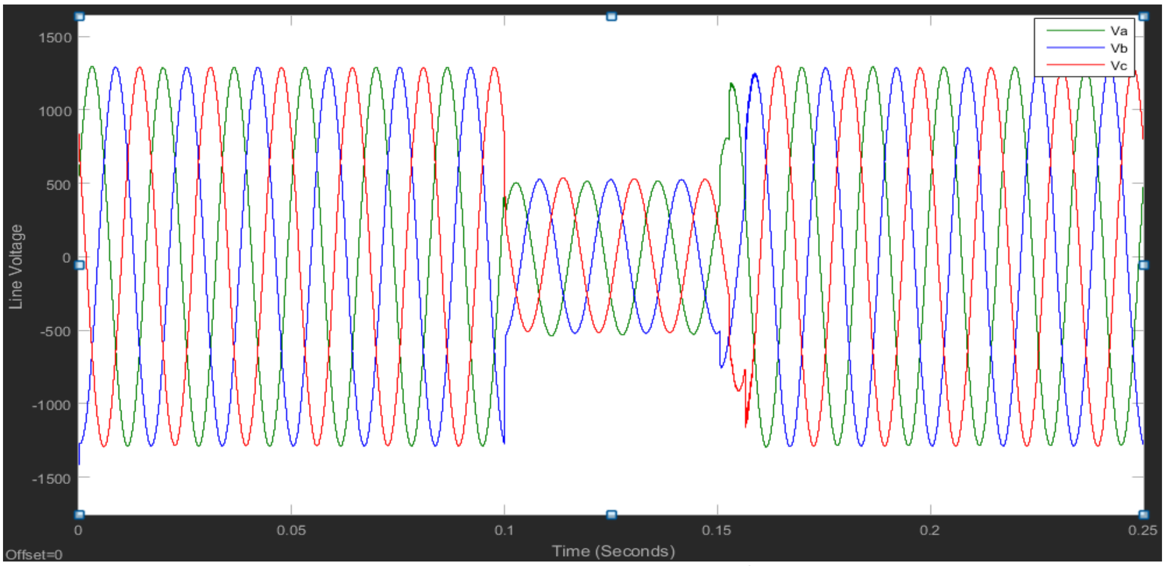

Fig.6 Three-phase load voltage sag waveform

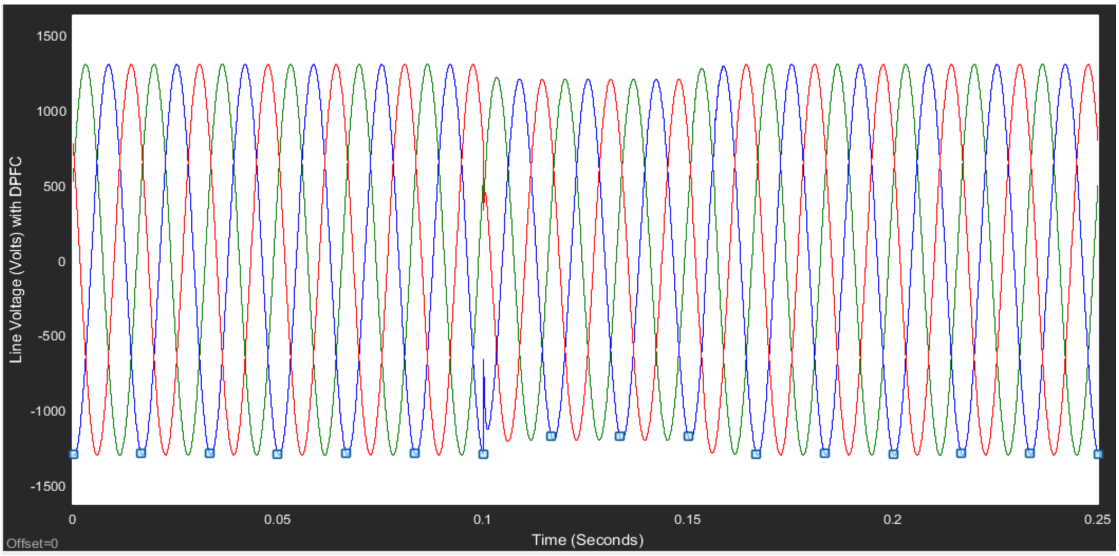

Fig.7 Three-phase load voltage sag with DPFC

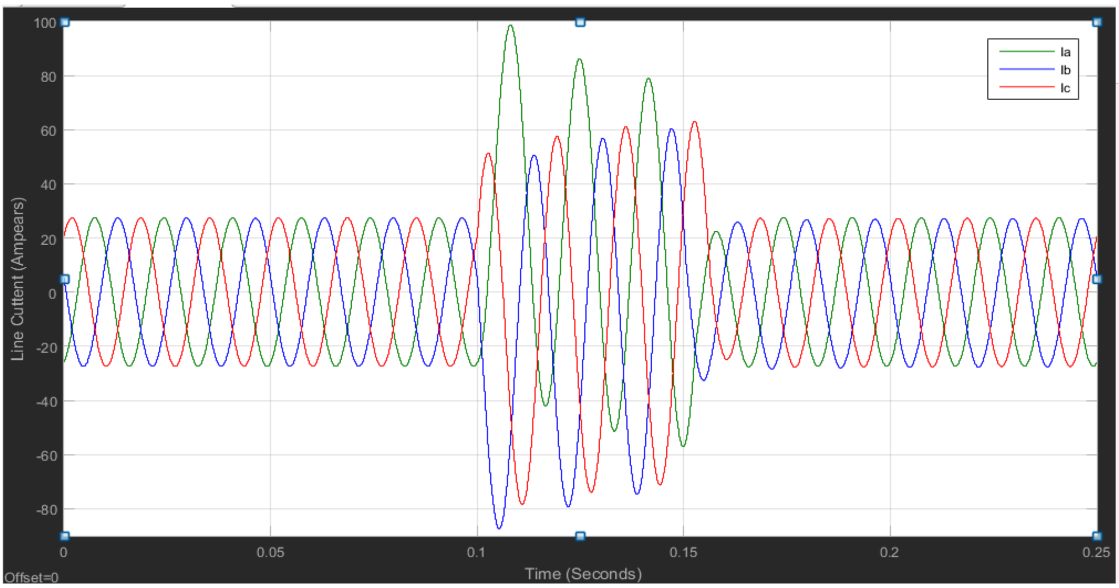

Fig.8 Three-phase load current waveform

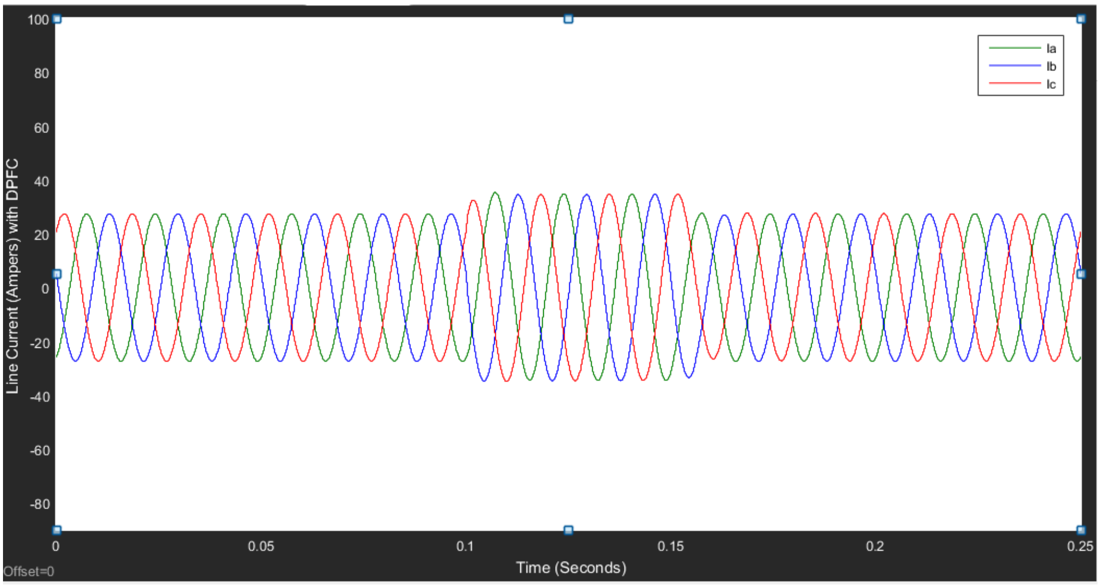

Fig.9 Three-phase load current waveform with DPFC

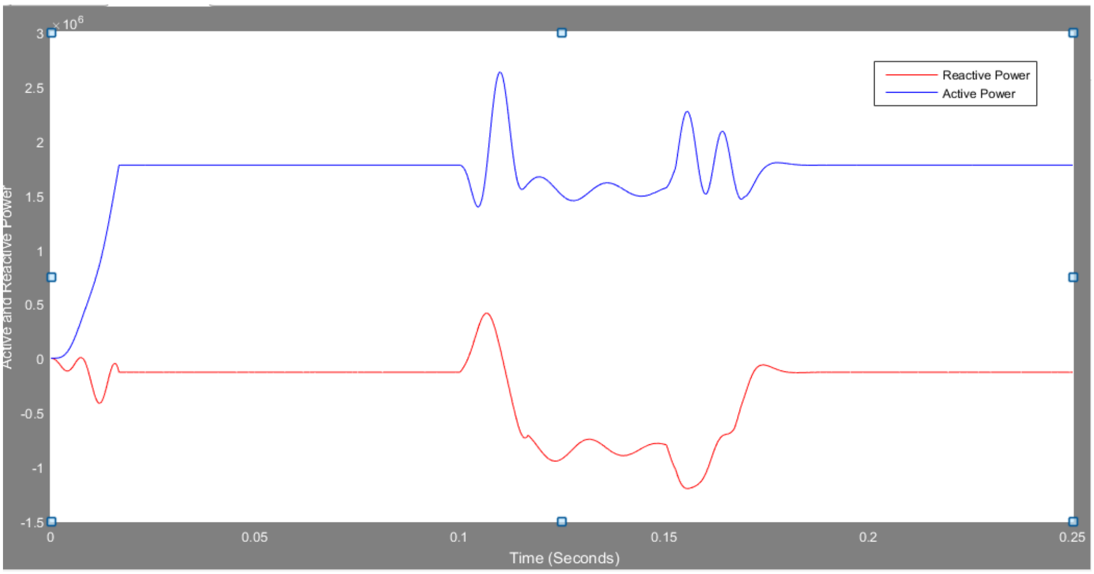

Fig.10 Active and Reactive Power without DPFC

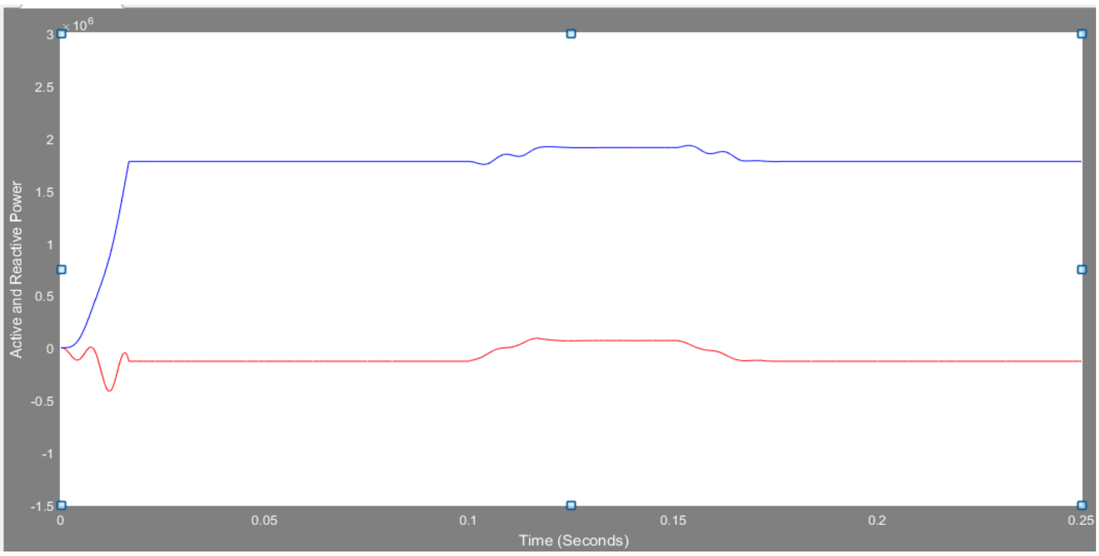

Fig.11 Active and Reactive Power with DPFC

CONCLUSION

Comparative performance of DPFC is better than the UPFC, which is the simultaneous adjustment of the line impedance, the transmission angle, and the bus-voltage magnitude. The common dc link between the shunt and series converters, which is used for exchanging active power in the UPFC, is eliminated. This power is now transmitted through the transmission line at the third-harmonic frequency. The total cost of the DPFC is also much lower than the UPFC, because no high- voltage isolation is required at the series converter part and the rating of the components is low. The simulation results, obtained by MATLAB show the efficiency of DPFC, in controlling line both active and reactive power flow. It is proved that the shunt and series converters in the DPFC can exchange active power at the third- harmonic frequency and the series converters are able to inject controllable active and reactive power at the fundamental frequency and hence enhance the reliability of the transmission line.

REFERENCES

[1] Akhib Khan Bahamani, GV Siva Krishna Rao, AA Powly Thomas and VC Veera Reddy, Modelling and Digital Simulation of DPFC System using Matlab Simulink, *International Journal of Emerging Trends in Electrical and Electronics*, **2013,** 6(1), 1-5.

[2] Amin Safari, Behrouz Soulat and Ali Ajami, Modelling and Unified Tuning of Distributed Power Flow Controller for Damping of Power System Oscillations, *Ain Shams Engineering Journal*, **2013**, 4 (4), 775–782.

[3] N Shanker and B Sampath Kumar, Voltages Sag and Swell Mitigation using DPFC for Multibus System, *International Journal of Engineering Research & Technology,* **2013,** 2(10), 2583-2590.
[4] P Ramesh and M Damodara Reddy, Modeling and Analysis of Distributed Power Flow Controller (DPFC), *International Journal of Engineering Research and Applications,* **2012,** 2(2), 609-615.
[5] Ali Ajami, Behrouz Soulat, and Ali Ajami, A Novel Modelling and controlling of Distributed Power Flow Controller based on PSO Algorithm, *Turkish Journal of Electrical Engineering & Computer Sciences*, **2012**,11, 213-224.
[6] T Santosh Tej, M Ramu, Ch Das Prakash and K Venkateswara Rao, Compensation of Unbalanced Three Phase Currents in a Transmission Line using Distributed Power Flow Controller, *International Journal of Engineering Research and Applications,***2011**, 1(2), 183-189.
[7] CK Panigrahi, PK Mohanty, N Soren and Akhilesh A Nimje, Enhancing Power Quality and Reliability in Deregulated Environment, *International Journal of Electrical Engineering and Technology,* **2011,** 2 (2), 1-11.
[8] Akhilesh A Nimje, CK Panigrahi and AK Mohanty, Enhanced Power Transfer Capability by using SSSC, *Journal of Mechanical Engineering and Research,* **2011,** 3 (2), 48 – 56.
[9] Zhihui Yuan, WH Sjoerd de Haan, Jan Braham Ferreira and Dalibor Cvoric, A Facts Device: Distributed Power-Flow Controller (DPFC), *IEEE Transactions on Power Electronics*, **2010**, 25(10), 2564-2572
[10] NG Hingorani and L Gyugyi, *Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems*, Wiley-IEEE Press New York, **2000.**