Reduction of THD in multi bus system using MLI based DPFC with PI and FOPID

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***Abstract :** This paper proposes "Reduction of THD in multi bus system using MLI based DPFC with PI and FOPID" Which is composed of a Distributed Power Flow Controller is a new device within the family of FACTS. The DPFC has the same control capability as the UPFC, but with much lower cost and higher reliability. This project addresses one of the applications of the DPFC to Compensate Voltage sag in Transmissions Systems. Thirty bus system with normal VSI with five level MLI based DPFC systems are simulated and their results are presented. The comparison indicates that the THD is reduced with MLI based DPFC system. Closed loop Thirty bus system(TBS) with PI and FOPID controllers are simulated and the dynamic response indicates that FOPID Produces better response when compared to PI controller.*

***IndexTerms -** DPFC: Distributed Power Flow Controller, MLI: Multi level inverter, TBS: Thirty bus system*

I. INTRODUCTION

Growing demand and aging of network makes it desirable to better control the power flow in power transmission systems. FACTS devices, specially UPFC, provide a fast, smooth control of power system parameters. However, for cost and reliability reasons, the application is limited. UPFC which is a combination of STATCOM and SSSC as shown in Fig.-1, it can also be termed as combined series-shunt controller. Improvement in bus voltage and power factor is done by STATCOM whereas the line impedance drop is compensated by SSSC. Coupling of Static Synchronous Compensator (STATCOM) and Static Synchronous Series Compensator (SSSC) via a common DC link is to allow bidirectional flow of real power between the series and shunt output terminals of the SSSC & STATCOM, in order to provide concurrent real and reactive series line compensation without an external electric energy source. Control of transmission line parameters is done selectively by unconstrained voltage injected in series by UPFC. The UPFC may also provide independently controllable shunt reactive compensation.

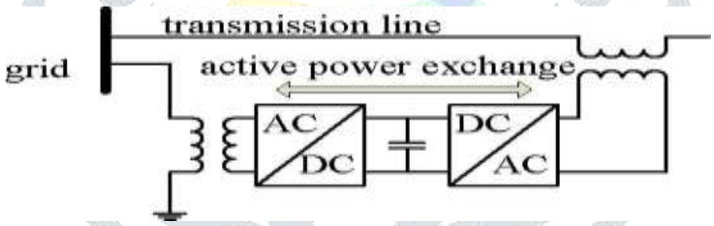

Figure 1 Simplified representation of UPFC

However, such solid state power flow controllers are not widely applied because of the following reasons: the high cost due to the high voltage isolation, high power rating and the relative low reliability. The reliability of UPFC depends on the power electronics. A single component failure will cause the whole system shut down. This paper introduces a new concept of distributed power flow controller (DPFC) that combines conventional FACTS and D-FACTS devices. The DPFC gives the possibility of control all system parameters, such as line impedance and power angle. At the same time, it provides higher reliability and lower cost.

II. NEW CONCEPT OF DISTRIBUTED POWER FLOW CONTROLLER

The same as the DPFC, The Distributed Power Flow Controller (DPFC) recently presented in is a power flow device within the FACTS family, which provides much lower cost and higher reliability than the conventional FACTS devices. It is derived from the UPFC and has the same capability of simultaneously adjusting all the parameters of power system like line impedances, transmission angle and bus voltage magnitude. The DPFC configuration and flow chart is as shown in Fig. 2 and Fig.3. The DPFC eliminates the common DC link between the shunt and series converters and uses the transmission line to exchange active power between converters at the 3rd harmonic frequencies. Instead of one large 3 phase converter, the DPFC employ multiple single phase converters as the series compensator. This concept not only reduces the rating of the component but also provides a high reliability because of the redundancy.

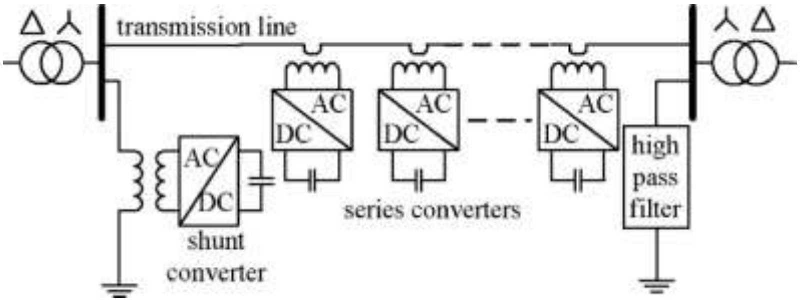

Figure 2 Configuration of DPFC

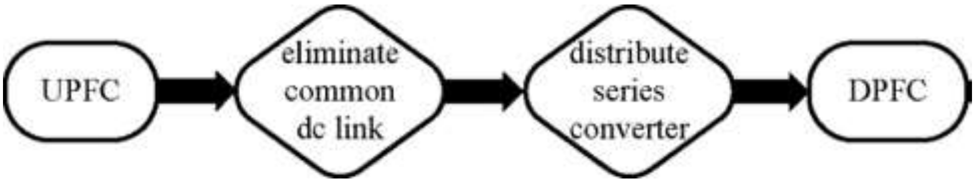

Figure 3 Flow chart from UPFC to DPFC

III. WORKING PRINCIPLE

Within the DPFC, transmission line is the common connection between the ac terminal of the shunt and series converters. Therefore it is possible to exchange the active power though the terminals of the converters. The method is based on power theory of non sinusoidal components. According to the Fourier analysis, a non sinusoidal voltage and current can be expressed by the sum of sinusoidal functions in different frequencies wit different amplitudes. The active power resulting from this non sinusoidal voltage and current is defined as the mean value of the product of voltage and current. Since the integral of all the cross product of terms with different frequencies are zero, the power can be expressed by

$$P = \sum_{i=1}^{\infty} V_i I_i cos\varphi_i \qquad 1.1$$

Where V_i and I_i are the voltages and current at the ith harmonic respectively. φ_i is the corresponding angle between voltage and current. From this equation active power at different frequencies is isolated from each other and voltage or current in one frequency has no influence on active power at other frequencies. The independency of the active power at different frequencies gives the possibility that a converter without power source can generate active power at one frequency and absorb this power from other frequencies. By applying this method to the DPFC the shunt converter can absorb the active power from the grid at the fundamental frequency and inject the current back into the grid at a harmonic frequency.

Due to unique features of 3rd harmonic frequency components in a three phase system, the 3rd harmonic is selected for active power exchange In the DPFC. In a three phase system the 3rd harmonic each phase is identical, which means they are zero sequence components. Because the zero sequence harmonic can be naturally blocked by star delta transformers and these are widely incorporated in power systems, there is no extra filter required to prevent harmonic leakage.

IV. CONTROL PRINCIPLE OF DPFC

The DPFC system consists of two types of converters, and each type of converter requires a different control scheme. The block diagram of the DPFC and its control is shown in Fig.4. To supply active power for series converters, the shunt converters is controlled for injection of a constant third harmonic current. Extraction of some active power from the grid by the shunt converter is necessary to maintain its DC voltage. DC voltage is by means of'd' component of the current at fundamental frequency, whereas the 'q' component is used for compensation of reactive power. Generation of voltage using the third harmonic frequency for absorbing active power to maintain a constant DC voltage value is achieved by series control. Realization of the power flow control is possible by an outer control loop and the power flow control block. Through wireless or PLC communication method, the power flow block sends remotely the reference signals and the control signals for DPFC series converters.

●Power flow control:

Generating the voltage reference signals for series converter of the DPFC is possible by means of power flow control and the control function is dependent on the specifications of the DPFC used for particular application.

●Series converter control:

Generation of switching signals according to the received data with stabilized DC voltage is achieved by using third harmonic frequency components as each series converter has its own series control.

●AC voltage control:

For compensation of reactive power at the fundamental frequency, AC voltage control fixes the set points to shunt converter and generates the reference signals for the shunt converter of the DPFC. DPFC application specifications determine the control function of AC voltage control and its control function provides the reference signals for reactive current signal for the shunt converter at the power system level for low frequency power oscillation damping and balancing of asymmetrical components.

●Shunt converter control:

Injection of third harmonic current constantly to supply the active power for the series converters is done by shunt converter control. By stabilizing the DC voltage and injecting the reactive current at the fundamental frequency, maintenance of capacitor DC voltage of the shunt converter at a constant value by absorption of active power is achieved.

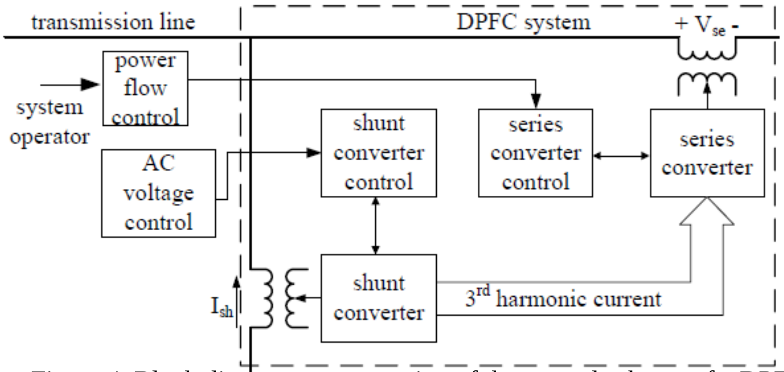

Figure.4. Block diagram representation of the control scheme of a DPFC

V. SIMULATION RESULTS

A. CLOSED LOOP SYSTEM WITH PI CONTROLLER BASED DPFC USING SEVEN LEVEL INVERTER IN 30-BUS SYSTEM

Closed loop system with PI controller based DPFC using seven level inverter in 30- bus system is shown in Fig 5.1. The Output voltage is shown in Fig 5.2 and its value is 4300 V. The RMS voltage is shown in Fig 5.3 and its value is 3100 V. The load current is shown in Fig.5.4 and its value is 130 A. The real power is appeared in Fig 5.5 and its value is 1.2 $*10^5$ W. The reactive power is shown in Fig 5.6 and its value is $14*10^4$ VAR. Load current THD is shown in Fig 5.7 and its value is 2.71%.

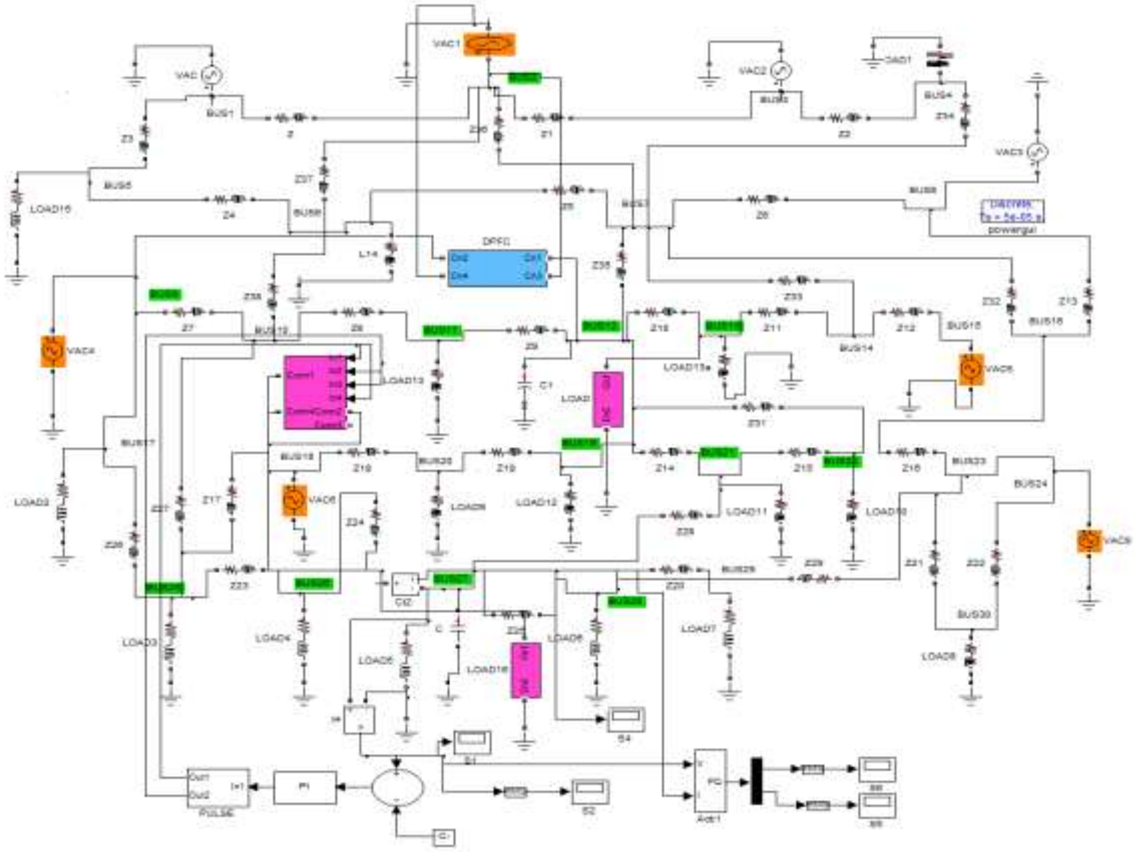

Figure 5.1 Closed loop system with PI controller based DPFC using seven level inverter in 30-bus system

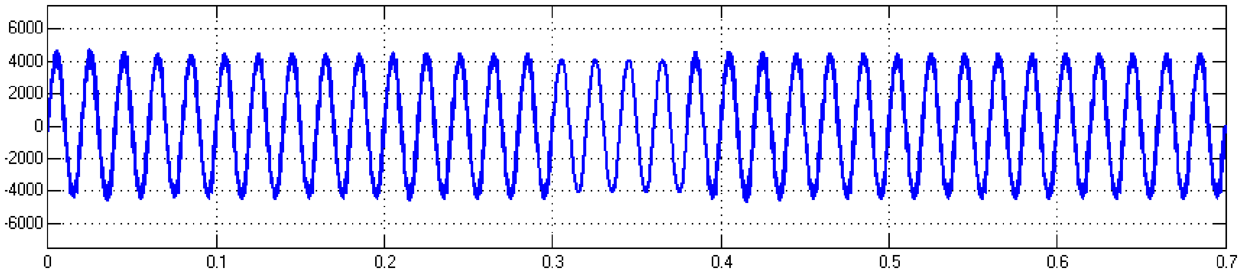

Figure 5.2 Voltage at bus 28

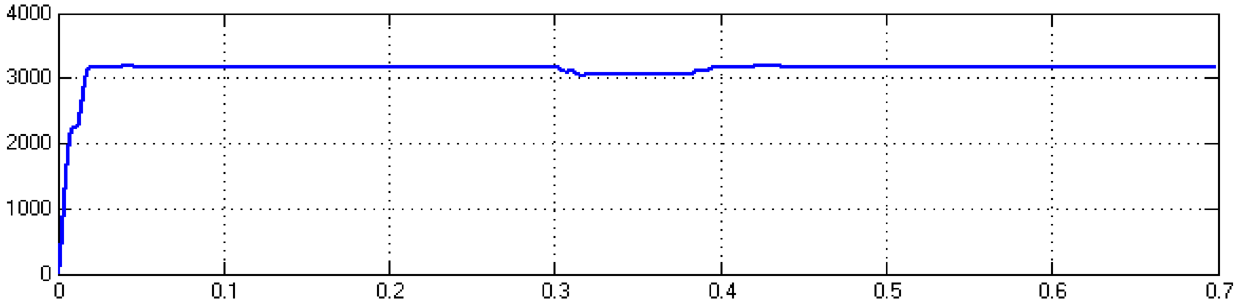

Figure 5.3 RMS voltage at bus 28

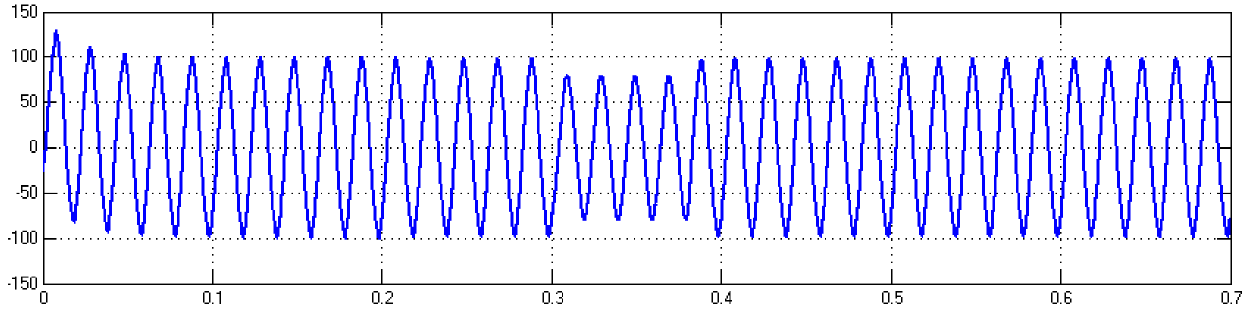

Figure 5.4 Load current at bus 28

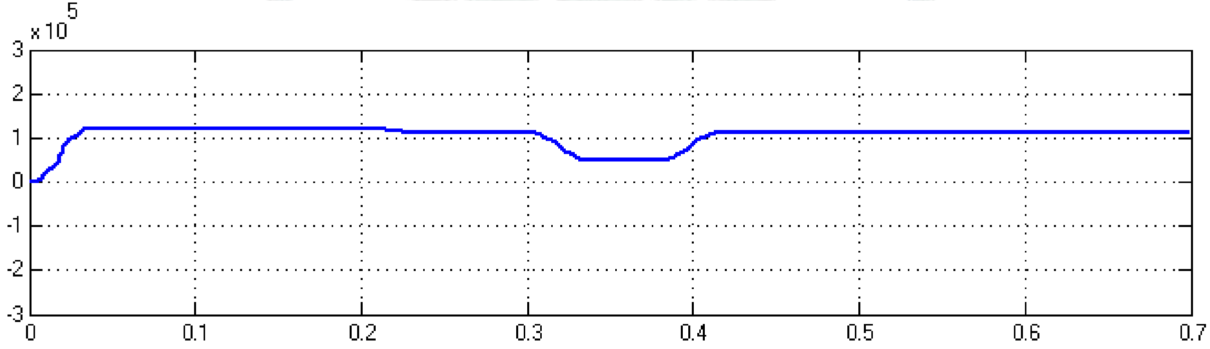

Figure 5.5 Real power at bus 28

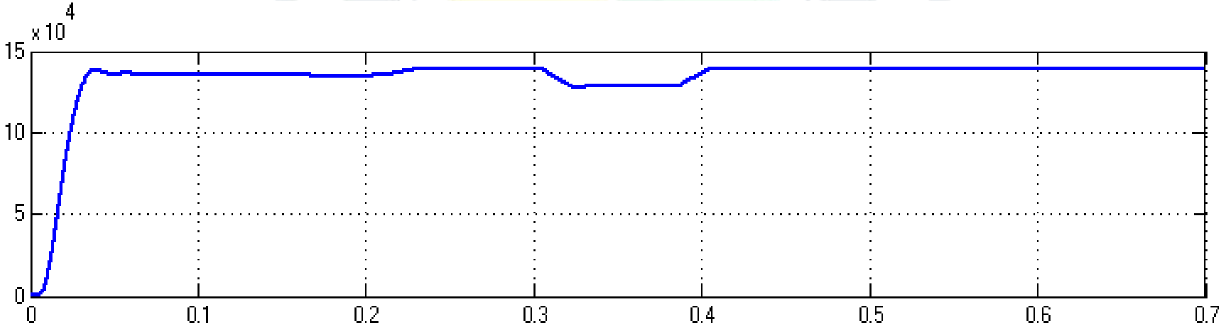

Figure 5.6 Reactive power at bus 28

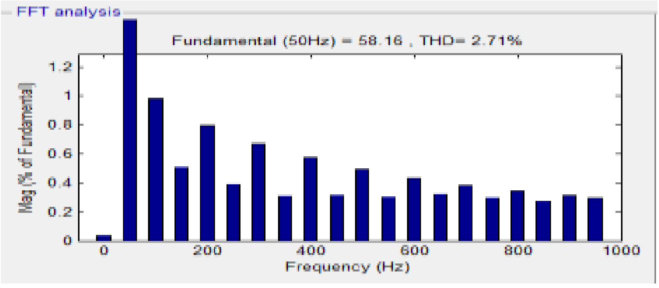

Fig. 5.7 Load current THD

B. CLOSED LOOP SYSTEM WITH FOPID CONTROLLER BASED DPFC USING SEVEN LEVEL INVERTER IN 30-BUS SYSTEM

Closed loop system with FOPID controller based DPFC using seven level inverter in 30-bus system is shown in Fig 5.7. The voltage at bus 28 is appeared in Fig 5.8 and its value is 5000 V. The RMS voltage is shown in Fig 5.9 and its value is 3200 V. The load current is shown in Fig 5.10 and its value is 150 A. The real power is appeared in Fig 5.11 and its value is 1.2 $*10^5$ W. The reactive power is shown in Fig 5.12 and its value is $14*10^4$VAR. Load current THD is shown in Fig 5.13 and its value is 0.15%.

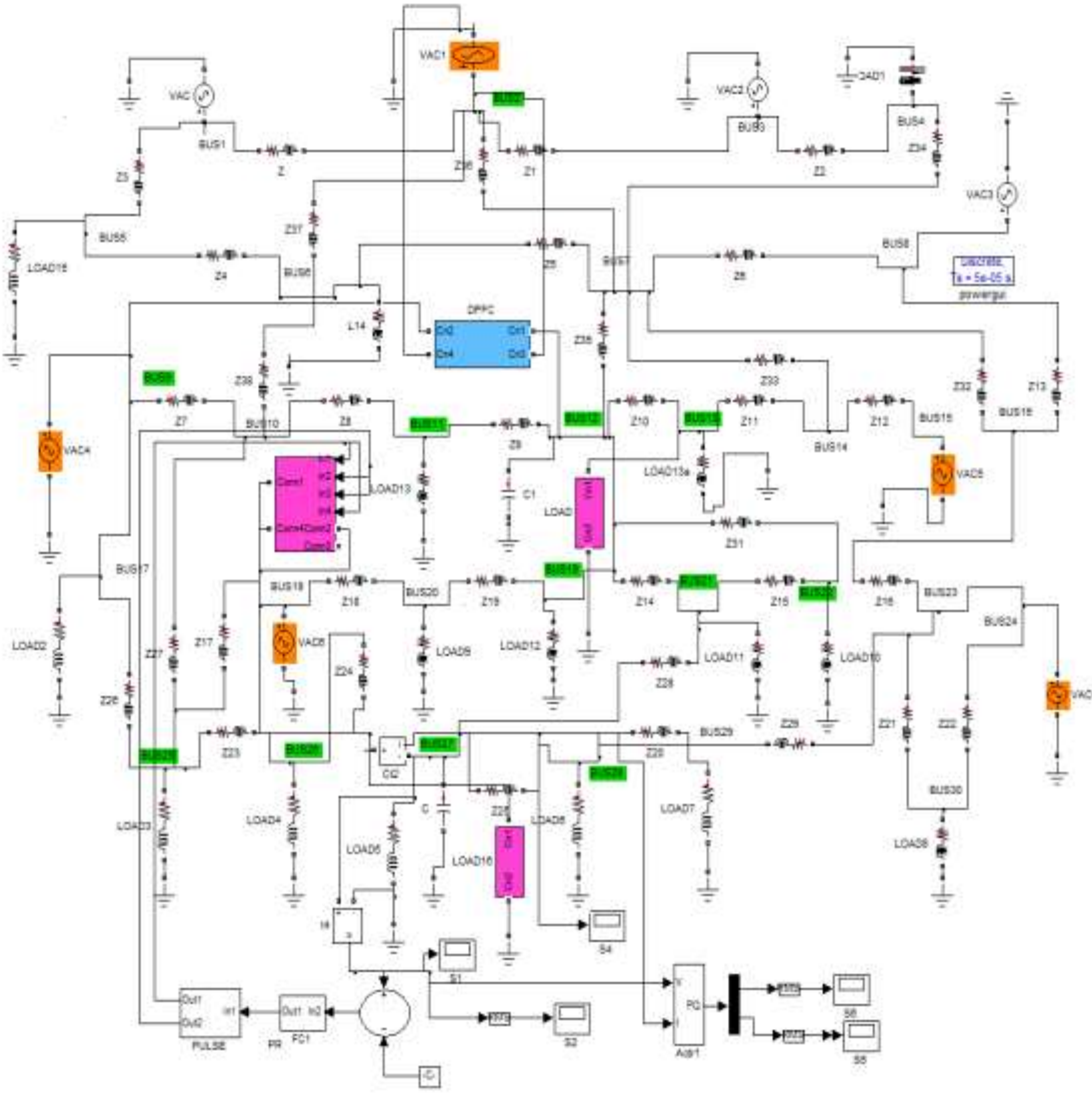

Figure 5.7 Closed loop system with FOPID controller based DPFC using seven level inverter in 30-bus system

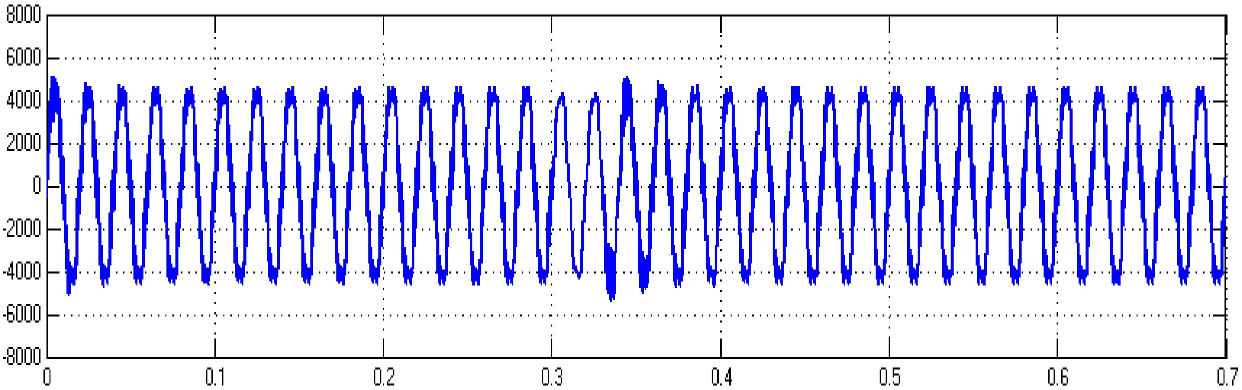

Figure 5.8 voltage at bus 28

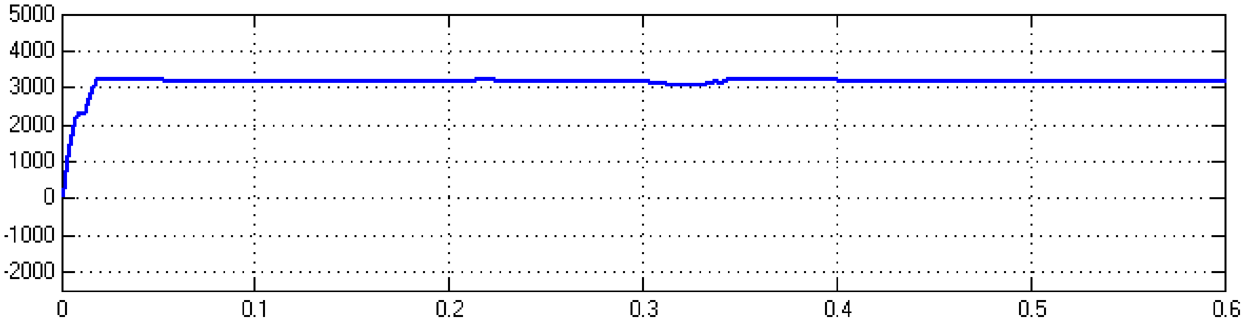

Figure 5.9 RMS voltage at bus 28

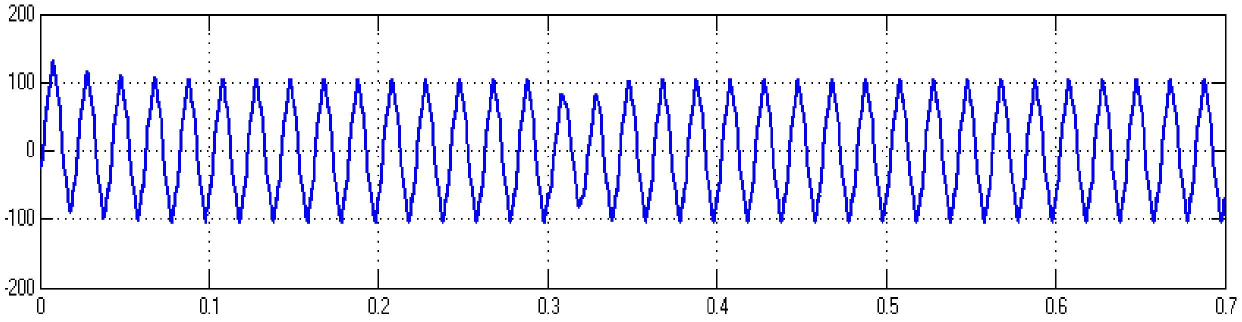

Figure 5.10 Load current at bus 28

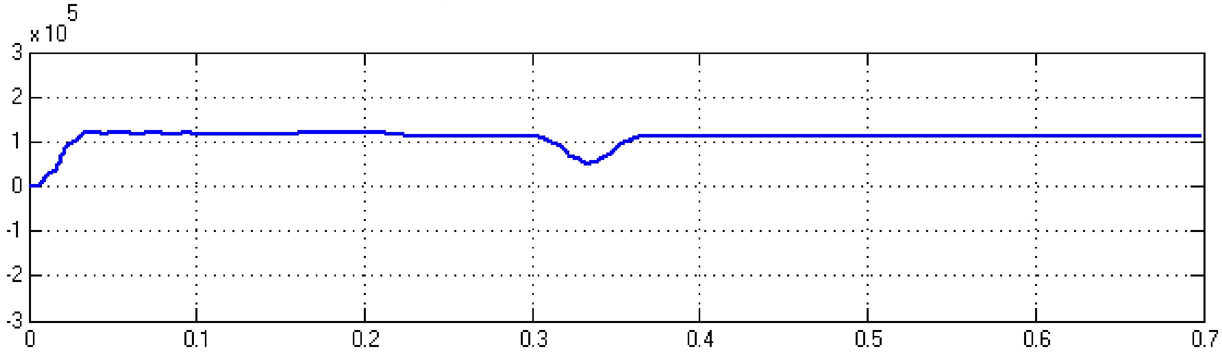

Figure 5.11 Real power at bus 28

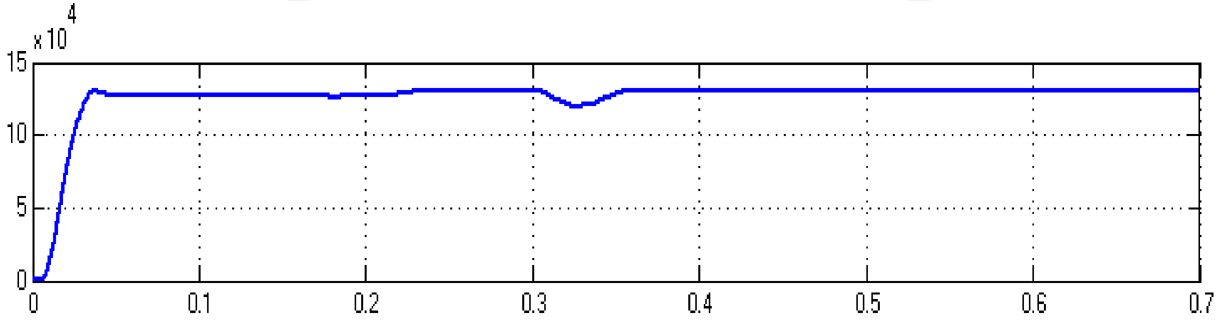

Figure 5.12 Reactive power at bus 28

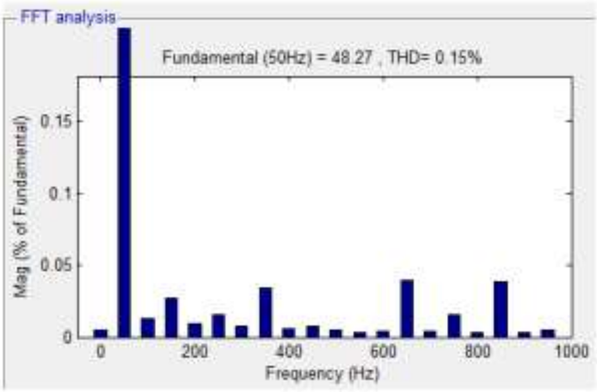

Figure 5.13 load current THD

Table-5.1 Comparison of time domain parameters

Controllers	Rise time (s)	Peak time (s)	Settling time (s)	Steady state error (V)
PI	0.33	0.38	0.42	6.7
FOPID	0.31	0.34	0.35	4.3

From table 5.1 rise time is reduced from 0.33 to 0.31, peak time is reduced from 0.38 to 0.34 settling time is reduced from 0.42 to 0.35 and steady state error is reduced from 6.7% to 4.3%.

VI. CONCLUSION

DPFC systems controlled by PI and FOPID Controllers were designed, modeled and simulated using Matlab Simulink. The proposed reactive power loop was successfully employed to maintain constant reactive power. The response of FOPID Controller controlled system was found to be superior to the PI controlled system. This was due to reduction in the peak time, the peak overshoot and the steady state error. The advantages of DPFC are improved voltage and reactive power profiles. The disadvantage of DPFC is the requirement of about six inverters, six driver circuits and injection transformers.

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