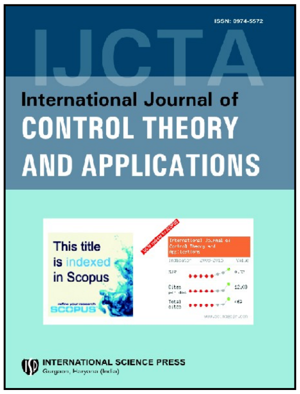

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Closed Loop Hysteretic Controlled DPFC System in Fourteen Bus System

Akhib Khan Bahamani[1], Sreerama Reddy G.M.[2] and Ganesh Vulasala[3]

[1] *Research Scholar, Department of Electrical Engineering, JNT University, Anantapur, Ananthapuramu, Andhra Pradesh, India*
E-mail: akhib71@gmail.com
[2] *Professor and Head, Department of Electronics and Communication Engineering, C.B.I.T, Kolar, Karanataka, India*
E-mail: sreeramareddy90@gmail.com
[3] *Professor, Dept. of Electrical and Electronics Engineering, JNTU College of Engineering, Pulivendula, Andhra Pradesh, India*
E-mail; ganivg@gmail.com

Abstract: Distributed Power Flow Controller (DPFC) is a good choice in multi bus systems for power quality Improvement. This paper deals with comparison of closed loop fourteen bus DPFC systems with and without hysteretic controllers. The objective of this work is to improve the dynamic response of closed loop controlled DPFC system. Data for fourteen bus DPFC system is obtained from the TNEB hand book and closed loop DPFC systems with and without hysteretic controller are modelled, designed and simulated. The results indicate that the dynamic response is improved and current THD is reduced using hysteretic controller. The propose system has advantages like reduced heating, low settling time and limited overshoot.

Keywords: Distributed power flow controller; Total Harmonic distortion; Unified power flow controller.

I. INTRODUCTION

The increasing usage of electricity causes more demand in using the renewable energy sources make it compulsory to control a huge power that enables the power system for a quick switch between the renewable energy sources and the stand-by power generation (1). This demands the availability of stand-by power whenever renewable energy is unable to supply the load. Therefore the need to control the power methods is increased. The parameters used to control voltage value, transmission angle, line impedance are adjusted in order to enhance the power flow. The power flow device is a component that modifies system parameters to control the active power (2). The Distributed Power Flow Controller (DPFC) recently presented in (3), is a powerful device within the family of FACTS devices, which provides a higher reliability than conventional FACTS devices at lower cost. It is derived from the UPFC and has the same capability to simultaneously adjust all the parameters of the power system: line impedance, transmission angle, and bus voltage magnitude (4).

This paper by Haan 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, at the same time, it provides higher reliability and lower cost (5). DPFC control during shunt converter failure is given by Yuan (6). Power quality improvement and mitigation case study using DPFC is given Ahmad Jamshidi (7). Performance of DPFC on system behaviour under balance fault condition is given by vadhera (8).

II. PRINCIPLE OF THE DPFC

Multiple individual converters cooperate together and compose the DPFC, see Fig.1. The series converters consist of multiple units that are connected in series with the transmission lines. They can inject a voltage where the phase angle is controllable over 360° and where the magnitude is controllable as well. Consequently they control the power flow through the line (6). The function of the shunt converter is to compensate reactive power to the grid, and to supply the active power required by the series converter.

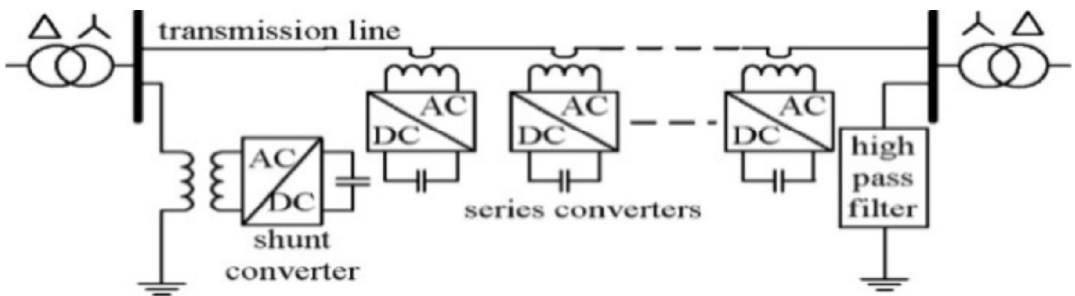

Figure 1: Basic Configuration of DPFC

Since there is no common dc link between the shunt and series converters in the DPFC, the active power is exchanged by harmonics and through the ac network (7). The principle is based on the definition of active power, which is the mean value of the product of voltage and current, where the voltage and current comprise fundamental and harmonics. Since the integrals of all the cross-product of terms with different frequencies are zero, the time average active power can be expressed by

$$P = \Sigma_{i=1}^{\infty} U_i J_i \tag{1}$$

$$V_i = Ri_w + l\frac{di_w}{d_t} + e_w \tag{2}$$

Where U_i and J_i are the voltage and current at the i^{th} harmonic frequency, respectively, and φ_i is the angle between the voltage and current at the same frequency. Equation 1 gives the active powers at different values frequencies.

III. THE DPFC ADVANTAGES

The DPFC in comparison with UPFC has some (8) advantages, as follows:

(A) High control capability

The DPFC similar to UPFC, can control all parameters of transmission network, such as line impedance, transmission angle, and bus voltage magnitude (9).

(B) High Reliability

The series converters redundancy increases the DPFC reliability during converters operation. It means, if one of series converters fails, the others can continue to work.

(C) Low cost

The single-phase series converters rating are lower than one three-phase converter. Furthermore, the series converters do not need any high voltage isolation in transmission line Connecting single-turn transformers can be used to hang the series converters

The above literature does not deal with the improvement in dynamic response of fourteen bus system Distributed power flow controller system using hysteretic controller. This work proposes hysteretic controller for fourteen bus Distributed power flow controller system. The response of fourteen bus distributed power flow controller system with and without hysteretic are compared.

IV. SIMULATION RESULTS

Closed loop DPFC in fourteen bus system without hysteretic controller is shown in Fig. 3.1. The voltage at bus 14 is shown in Fig 3.2 and its peak value is 5600V. The RMS voltage is shown in Fig 3.3 and its value is 3650V. The output current is shown in Fig 3.4 and its peak value is 180A. The real power is shown in Fig 3.5 and its value is 4.1X10^{5}W. The reactive power is shown in Fig 3.6 and its value is 4.2X10^{4}VAR. The current THD is shown in Fig 3.7. The THD is 1.9%.

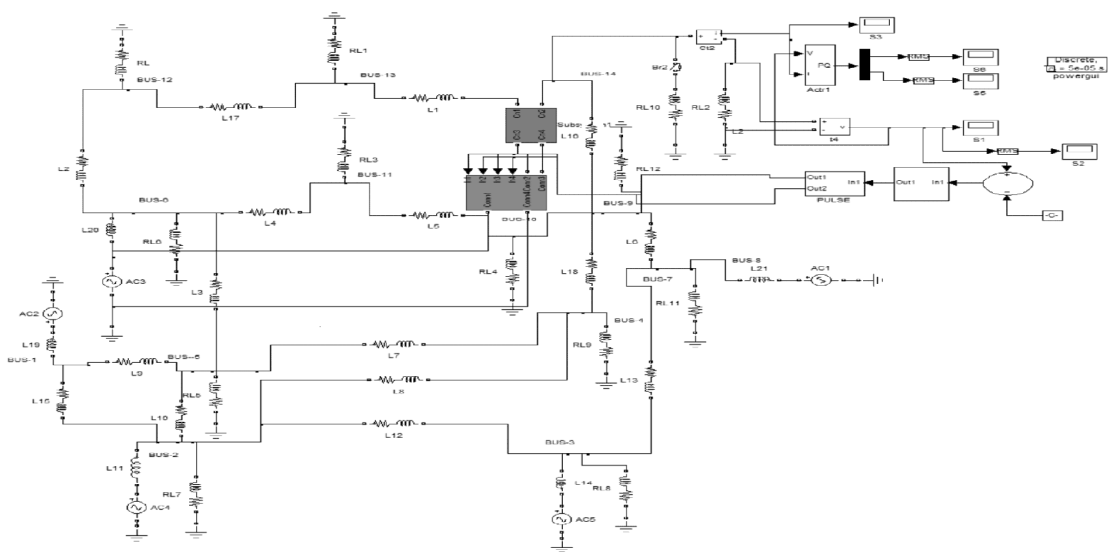

Figure 3.1: Fourteen bus system

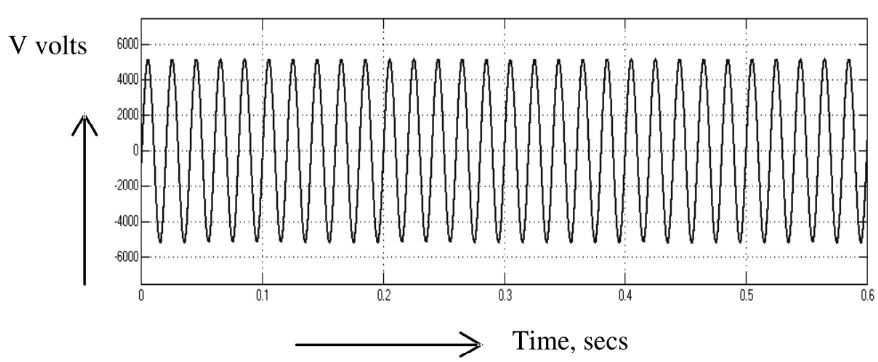

Figure 3.2: Voltage at Bus 14

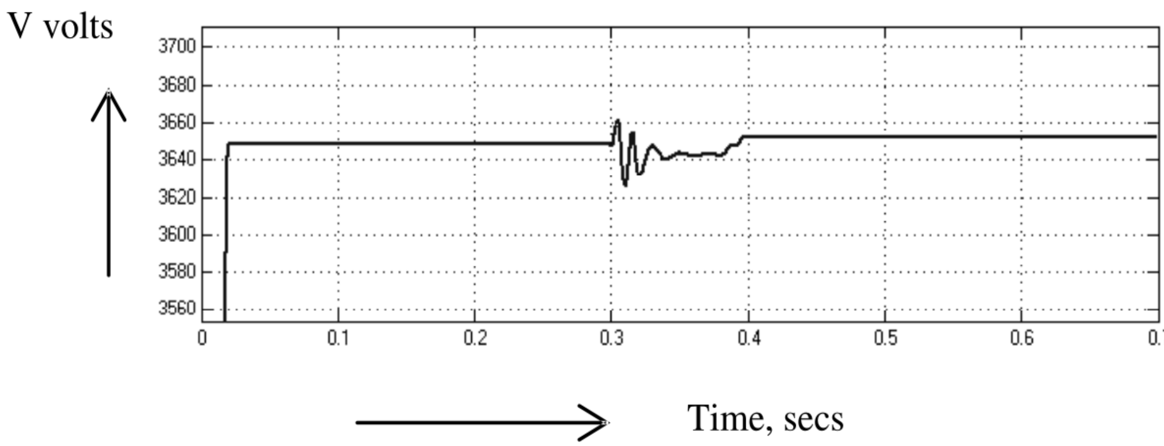

Figure 3.3: RMS voltage

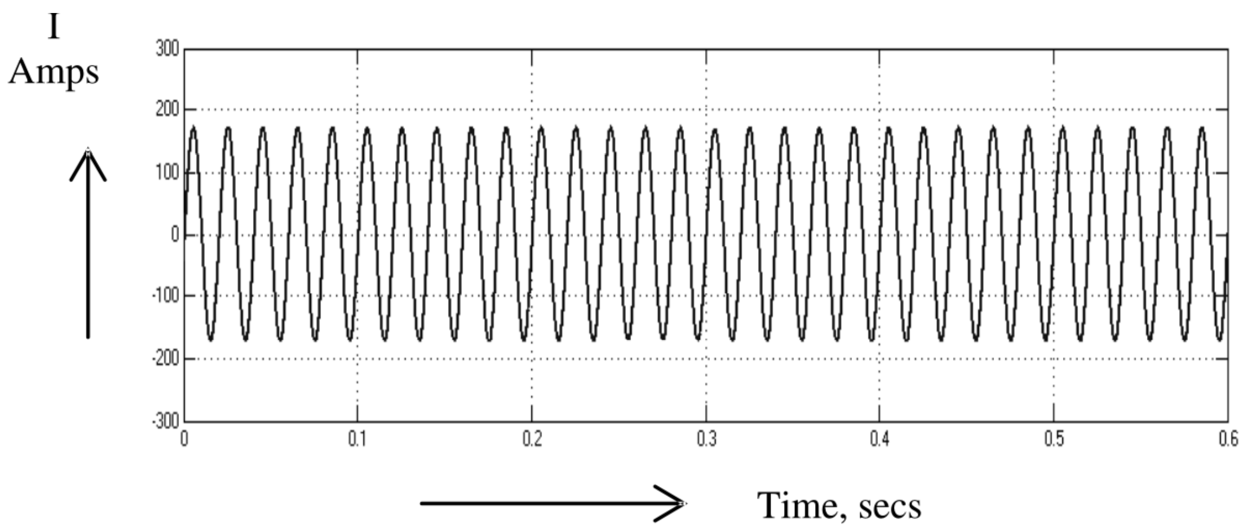

Figure 3.4: output current

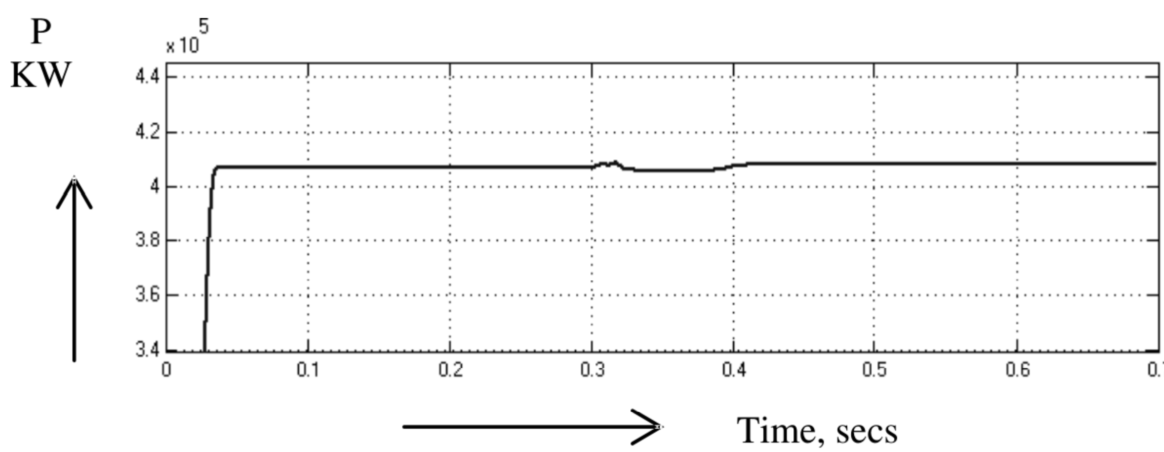

Figure 3.5: Real power at Bus 14

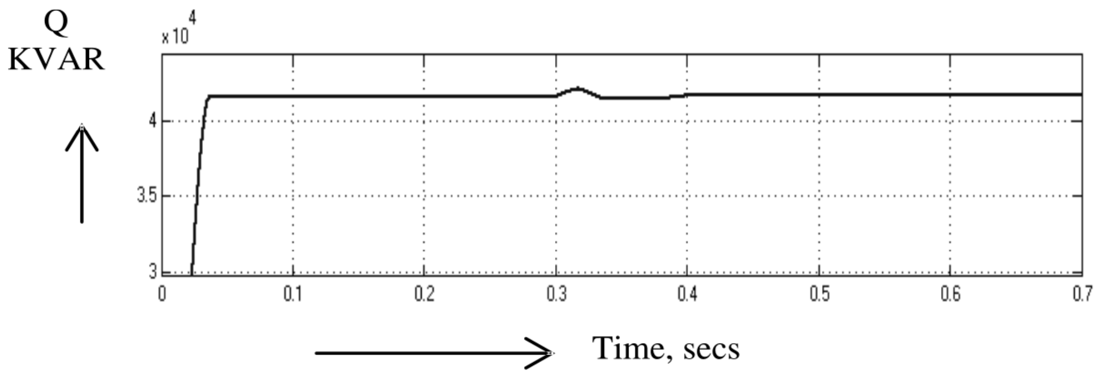

Figure 3.6: Reactive power at Bus 14

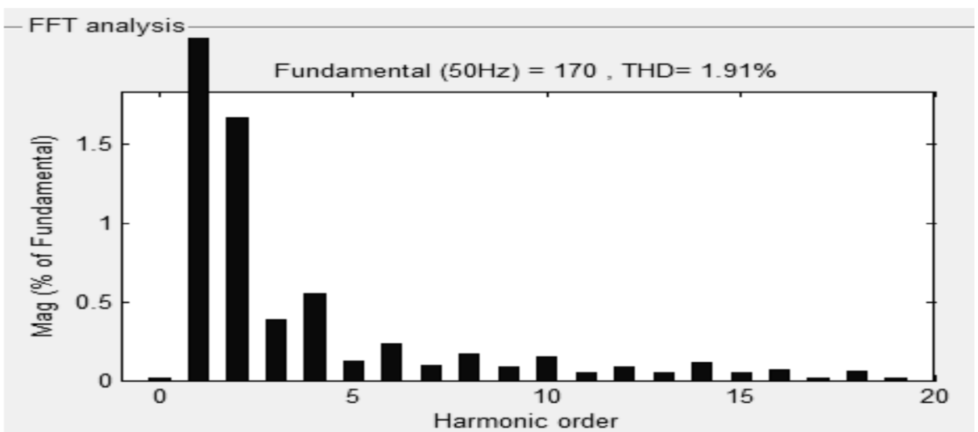

Figure 3.7: Current THD

Closed loop DPFC in fourteen bus system with hysteretic controller is shown in Fig 4.1. The voltage at bus 14 is shown in fig 4.2 and its peak value is 5600V. The RMS voltage is shown in Fig 4.3 and its value is 3650V.

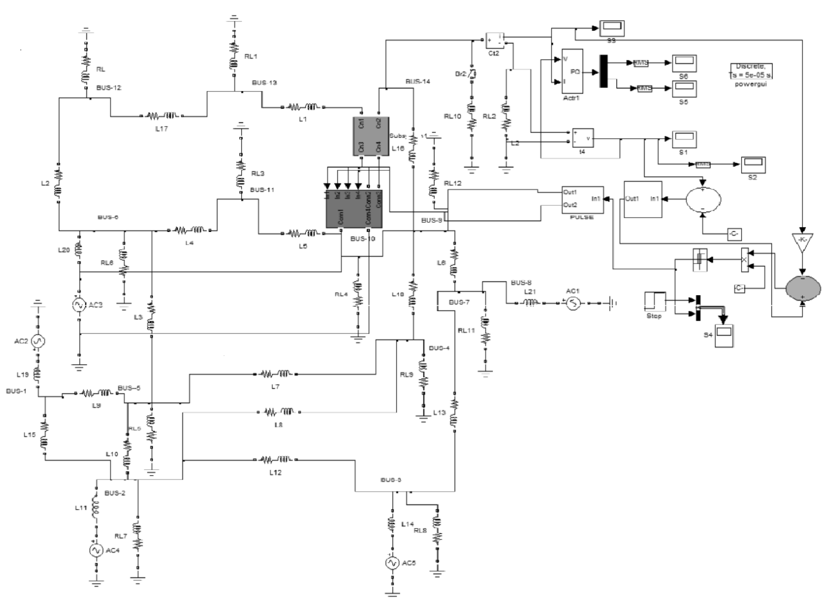

Figure 4.1: Fourteen bus system with hysteretic controller

The output current is shown in Fig .4 and its peak value is 180A. The real power is shown in Fig 4.5 and its value is 4.08X10^{5}W. The reactive power is shown in fig 4.6 and its value is 4.19X10^{4}VAR. The current THD is shown in Fig 4.7. The THD is 0.44%. The summary of time domain parameters is given by Table I.The comparison of THD is shown in Table II. Settling time is reduced by 14% and THD is reduced by 1.5% by using hysteretic controller.

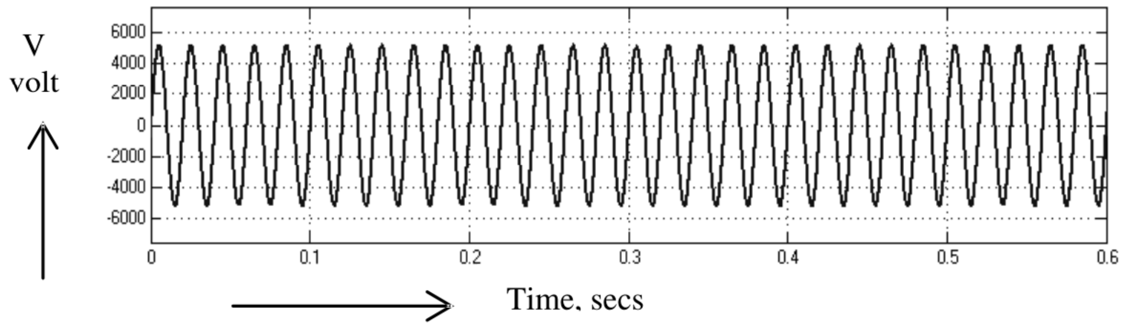

Figure 4.2: Voltage at Bus-14

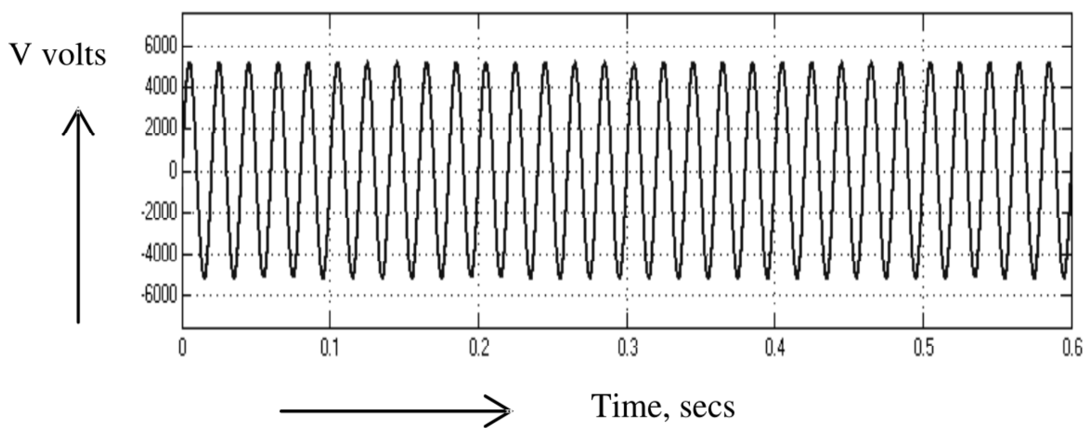

Figure 4.3: RMS voltage

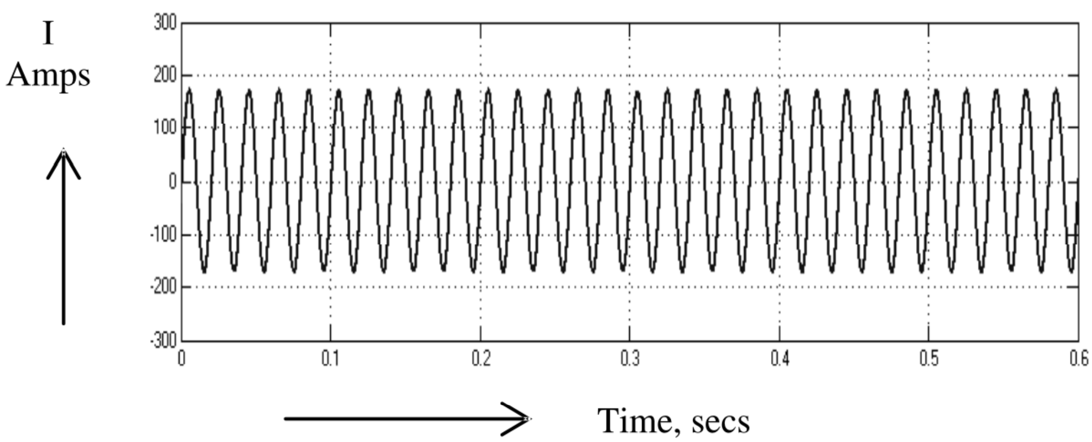

Figure 4.4: Current through load at Bus 14

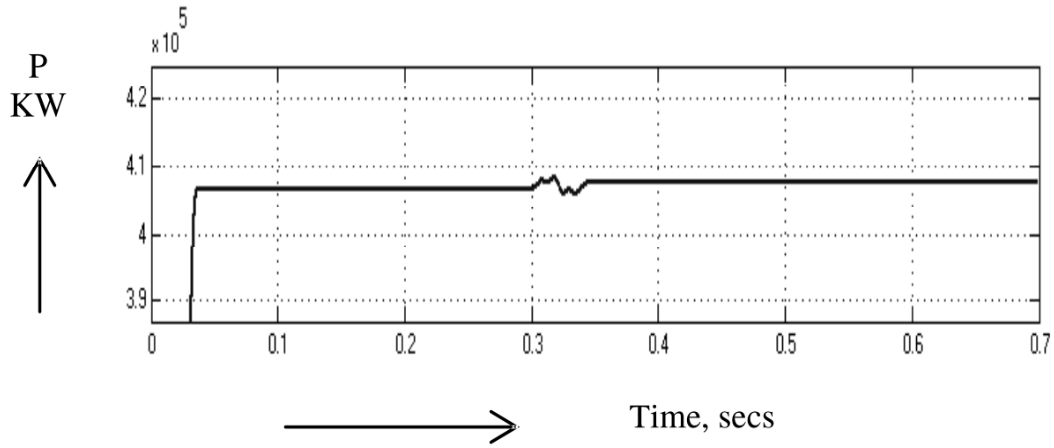

Figure 4.5: Real power

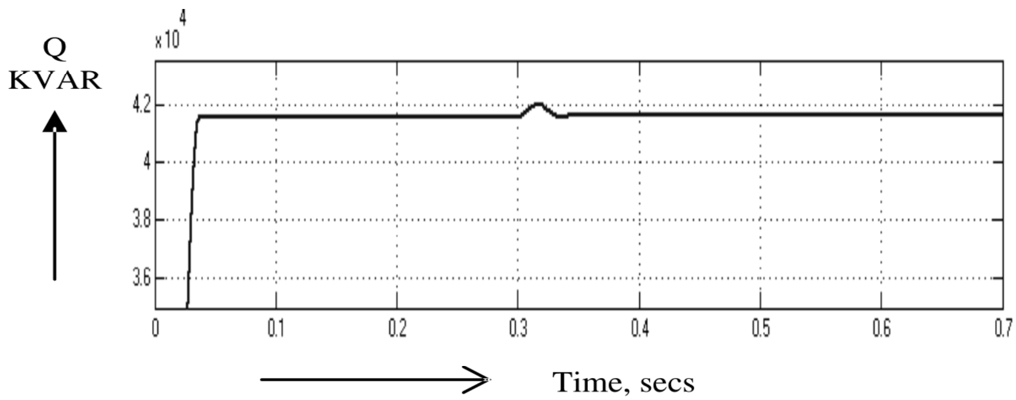

Figure 4.6: Reactive power

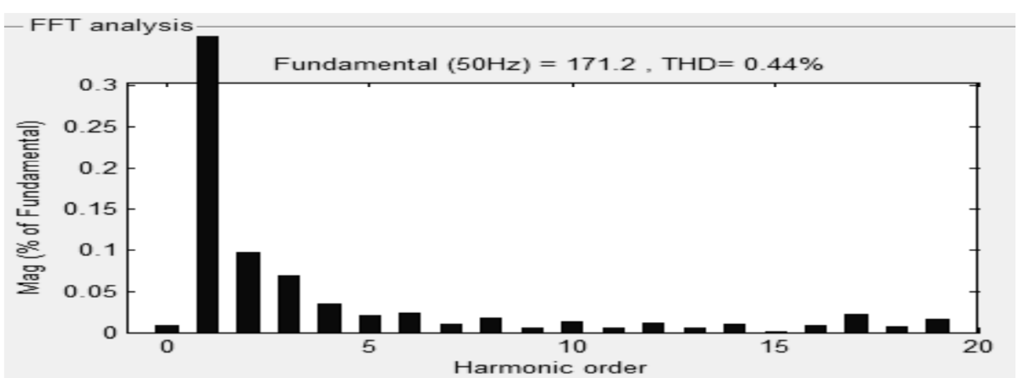

Figure 4.7: Current THD

Table I
Comparison of Time Domain Parameters

Controllers	*Rise time (s)*	*Peak time (s)*	*Settling time (s)*	*Steady state error (V)*
Without hysteresis	0.32	0.36	0.40	6.5
With Hysteresis	0.31	0.32	0.33	4.3

Table II
Comparison of THD

DPFC	*Output Current THD*
Without hysteresis controller	1.91%
With hysteresis controller	0.44%

CONCLUSION

Closed loop DPFC systems in fourteen bus system with and without hysteretic control are modelled and simulated using Simulink. The results with hysteretic controller show robustness for wide range of load impedance values. Hysteretic controller is implemented to update the pulse width for DPFC so that the power quality of fourteen bus system is improved. The results obtained in this work are clear examples of improvement in dynamic response of fourteen bus system.

The scope of the present work is to model and simulate hysteretic controlled DPFC system in fourteen bus system. This concept can be extended to thirty bus system in near future.

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