Indonesian Journal of Electrical Engineering and Computer Science
Vol. 4, No. 3, December 2016, pp. 499 ~ 507
DOI: 10.11591/ijeecs.v4.i3.pp499-507

Power Quality Improvement in Fourteen Bus System using Non-Conventional Source Based ANN Controlled DPFC System

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Abstract

DPFC can be used to improve receiving end voltage of fourteen bus system. This paper shows the conception and simulation of wind and solar based distribution power flow controller for sag compensation and ohmic loss reduction. The objectives of this work are to improve the voltage and reduce the line losses. Fourteen bus systems with DPFC in open loop is simulated. Fourteen bus system with DPFC in closed loop using PI and ANN are also simulated and the results are presented. The comparative study is presented to demonstrate the improvement in dynamic response of ANN controlled DPFC system. ANN is observed to provide better control than has other controllers and improved damping characterises.

Keywords*: artificial neural network, power quality improvement distributed power flow controller, proportional integration, total harmonic reduction.*

1. Introduction

Design of distributed FACTS controller and consideration for transient characteristics is given by GaidiNing [1]. Control of distributed power flow controllers using active power from homo polar line current is given by Martins [2]. Performance of distributed power flow controller on system, behaviour under balance fault condition is given by Santosh Kumar [3]. DPFC design procedure a case study using the KEPCO UPFC as an example is given by Zhihai [4]. Utilizing distributed power flow controller (DPFC) for power oscillation damping is given by Sjoerd [5]. A New FACTS component: Distributed Power Flow Controller (DPFC) is given by Yuan [6]. Distributed FACTS-A New Concept for Realizing Grid Power Flow Control in power Electronics specialists' conference is given by Divan [7]. Impact of Distributed Power Flow Controller to Improve Power Quality Based on Synchronous Reference Frame Method is given by Ahmad Jamshidi [8]. Performance Analysis of DPFC under Different Load Conditions is given by Siva Kumar [9]. DPFC control during shunt converter failure is given by Yuan [10]. Utilizing distributed power flow controller (DPFC) for power oscillation damping is given by Haan [11]. Distributed facts-A new concept for realizing grid power flow controller is given by De Haan [12].

To knowledge, the literature does not deal with fourteen bus system employing DPFC. This work proposes DPFC to improve power Quality of fourteen buses System. Voltage sag is compensated using DPFC. The above literature does not deal with MLI based DPFC. This work proposes five level inverter based DPFC for power quality improvement. The above papers do not deal with enhancement of dynamic response using ANN. Matlab package uses state space method to obtain solution. The paper deals with the comparison of responses of PI and Ann controlled MLI based DPFC systems. The scheme of the DPFC in a simple two-bus system is illustrated in Figure 1.

Received September 13, 2016; Revised November 2, 2016; Accepted November 16, 2016

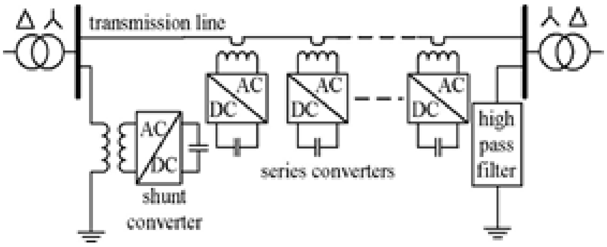

Figure 1. Basic Configuration of DPFC

2. Structure of DPFC

The basic issues in DPFC principle are DC-link elimination and using 3rd-harmonic current to active power exchange. In the following subsection DPFC basic concepts are explained.

2.1. Eliminate DC-Link and Power Exchange

Within the DPFC, the transmission line is used as a connection between shunt converter and AC port of series converters, instead of using DC-link for power exchange between converters. The method of power exchange in DPFC is based on power theory of non-sinusoidal components [9]. Non-sinusoidal voltage and current can be presented as the sum of sinusoidal components at different frequencies. It is the main result of Fourier analysis. The product of voltage and current components provides the active power. Since the integral of some terms with different frequencies are zero, so the active power equation is as follows:

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

where $V_i$and $I_i$are the voltage and current at the i^{th}harmonic frequency, respectively, and $\varphi_i$is the angle between the voltage and current at the same frequency. Equation1 expresses the active powers at different frequencies are independent from each other’s. Thus, the converter can absorb the active power in one frequency and generates output power in another frequency. The configuration of the DPFC is shown in Figure 1.

The real and reactive powers are calculated with the following formulae:

$$\mathrm{P} = \frac{\mathrm{VsVr}}{\mathrm{X}} \sin\delta \tag{2}$$

$$\mathrm{Q} = \frac{\mathrm{Vr}}{\mathrm{X}} (\mathrm{Vs} - \mathrm{Vr}) \tag{3}$$

3. Control of DPFC

The DPFC has three control strategies [10]. They are central control, series control and shut control as shown in Figure 2.

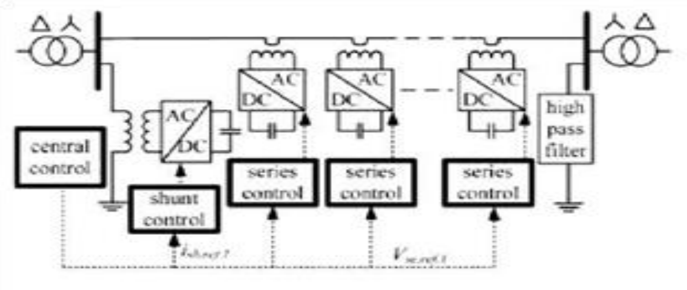

Figure 2. Block Diagram of a Control System

Block diagram of proposed system is shown in Figure 3. Three level based VSI is replaced by five level based MLI. ANN controller is used to handle the non-linearity.

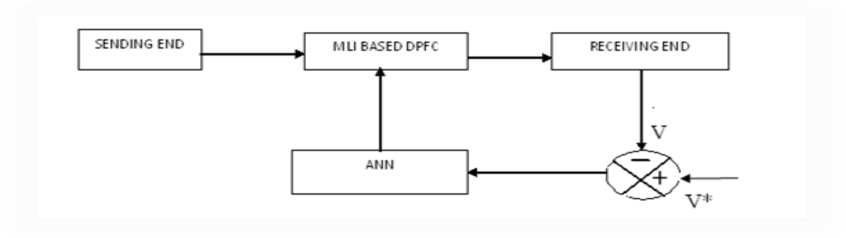

Figure 3. Block Diagram of Proposed System

4. Simulation Result

Fourteen bus systems with wind and solar based DPFC is shown in Figure 4. Measurement of power in solar system is shown in Figure 5. The output voltage of solar system is shown in Figure 6. The output voltage is 100V. The output voltage of wind generator is shown in Figure 7. The peak value is 600V. The five level inverter circuits is shown in Figure 8 and the five level inverter output voltage output voltage is shown in Figure 9. The peak value is 100V. Voltage across load 1 and load 2 are shown in Figure 10. The peak value is 5800V. Real and Reactive power are shown in Figures 11 and 12 respectively. The real power is 2.2x10^{5}W and the reactive power is 3.5x10^{5}VAR. The THD in the output five level inverter is shown in Figure 13 and the THD is 5.09%.

The fourteen bus system employing DPFC with PI controller is shown in Figure 14. Voltage across load 1 and load 2 are shown in Figure 15 and current wave form is shown in Figure 16. The fourteen bus system employing DPFC with ANN is shown in Figure 17. The PI controller is replaced with ANN controller. The voltage across load 1 and load 2 are shown in Figure 18. The current wave form is shown in Figure 19. The voltage reaches normal value very smoothly. The summary of time domain parameters is given in Table 1. This table indicates that response with ANN superior to the PI controlled system. The Real and Reactive power with DPFC 14-bus system with and without non-conventional sources is given in Table 2. The settling time is reduced by 0.31sec. Steady state error in voltage is reduced by 19V.The real and reactive powers are increased by 5% after adding the non-conventional sources. The THD content is reduced by 0.8% by adding PV and wind sources.

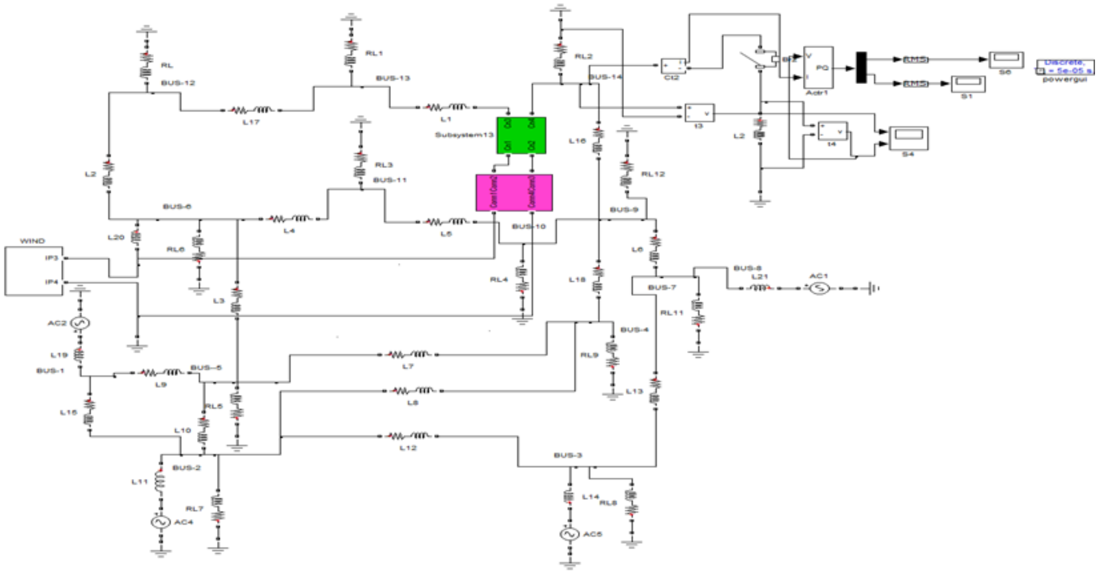

Figure 4. Fourteen Bus System DPFC with Wind and Solar

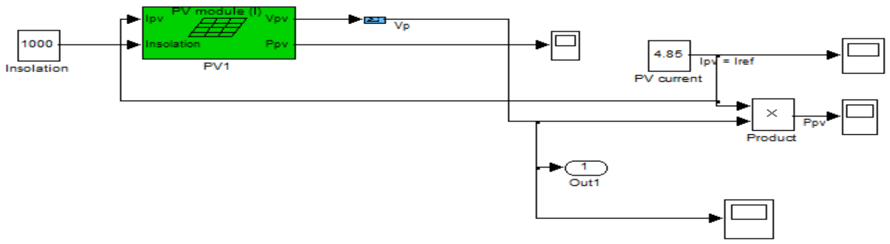

Figure 5. Measurement of Power

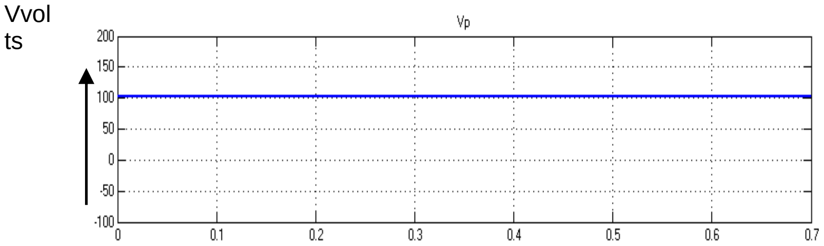

Figure 6. Output Voltage of Solar System

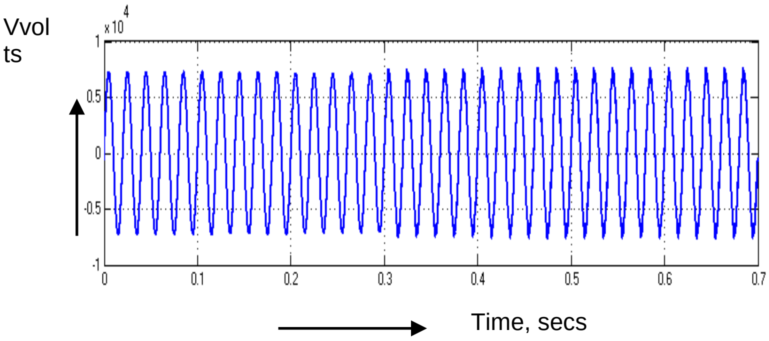

Figure 7. Output Voltage of Wind System

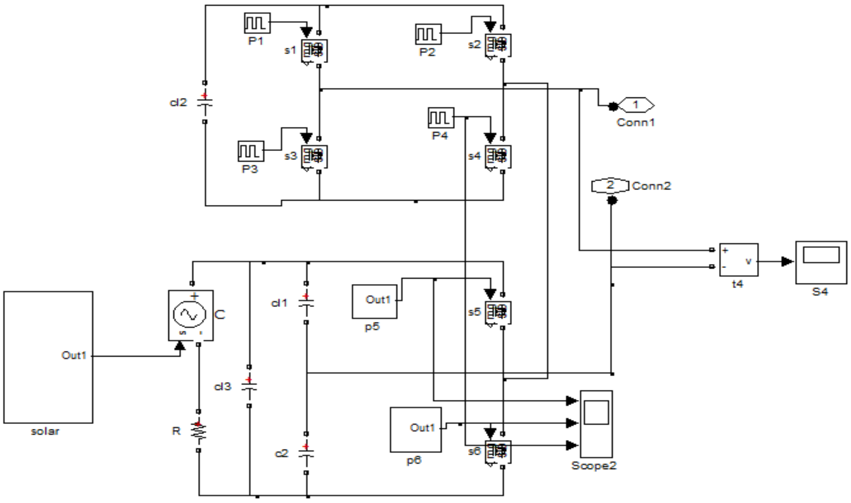

Figure 8. Five Level Inverter Circuit

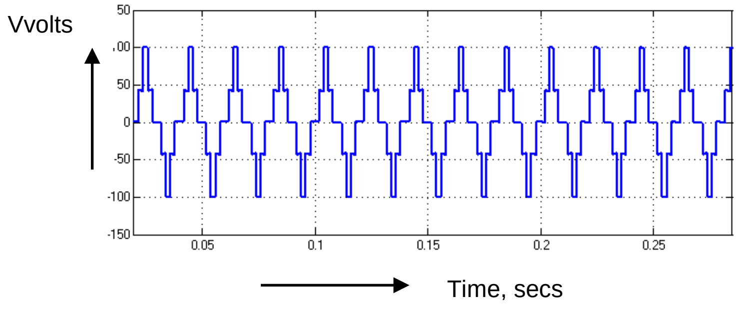

Figure 9. Output Voltage of Inverter

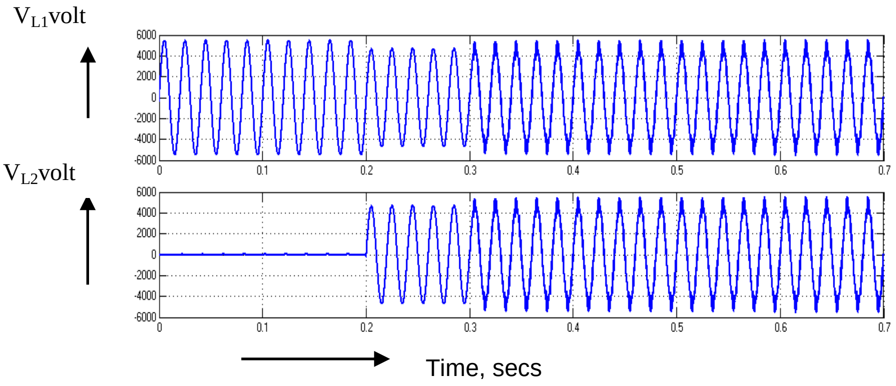

Figure 10. Voltage across load 1 and load 2

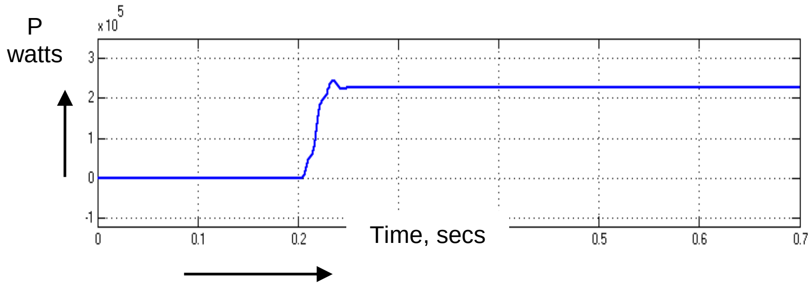

Figure 11. Real Power

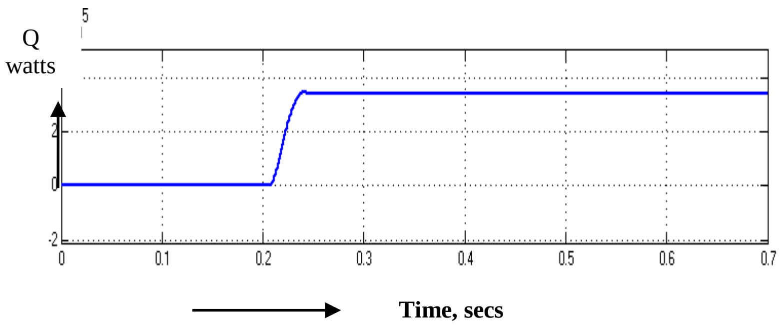

Figure 12. Reactive Power

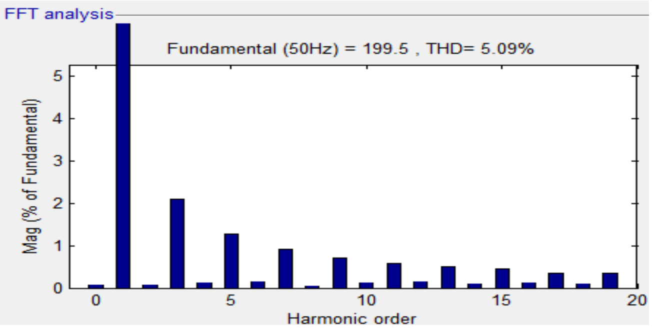

Figure 13. THD

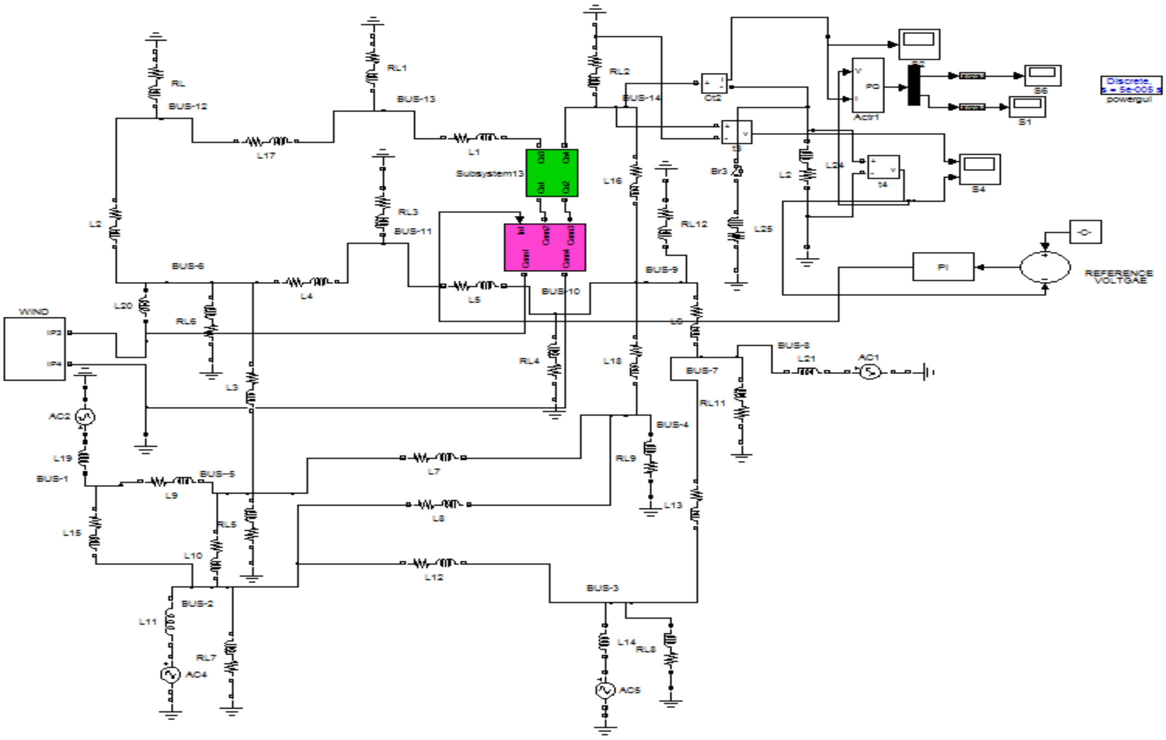

Figure 14. Simulink Model with PI Controller

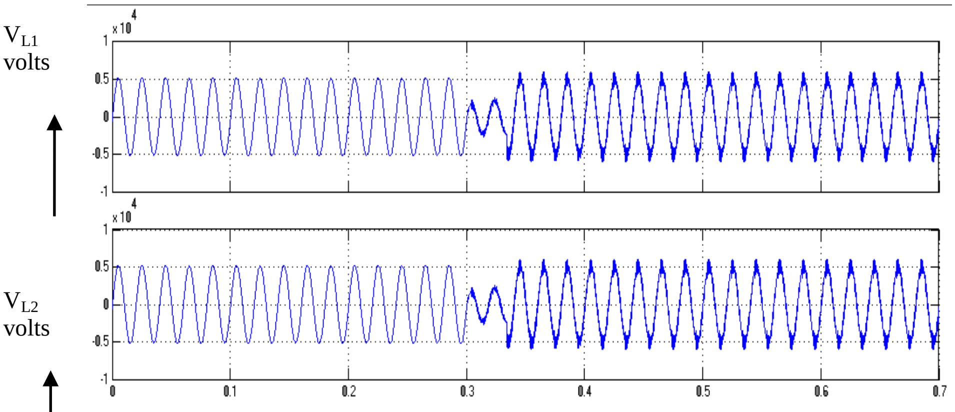

Figure 15. Voltage Waveform

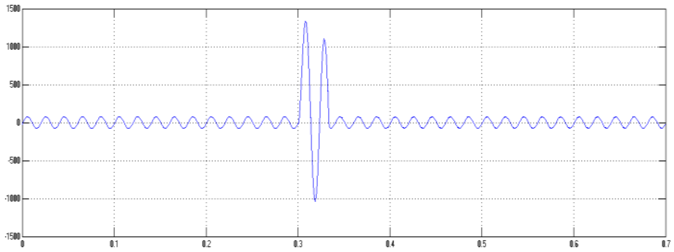

Figure 16. Current Waveform

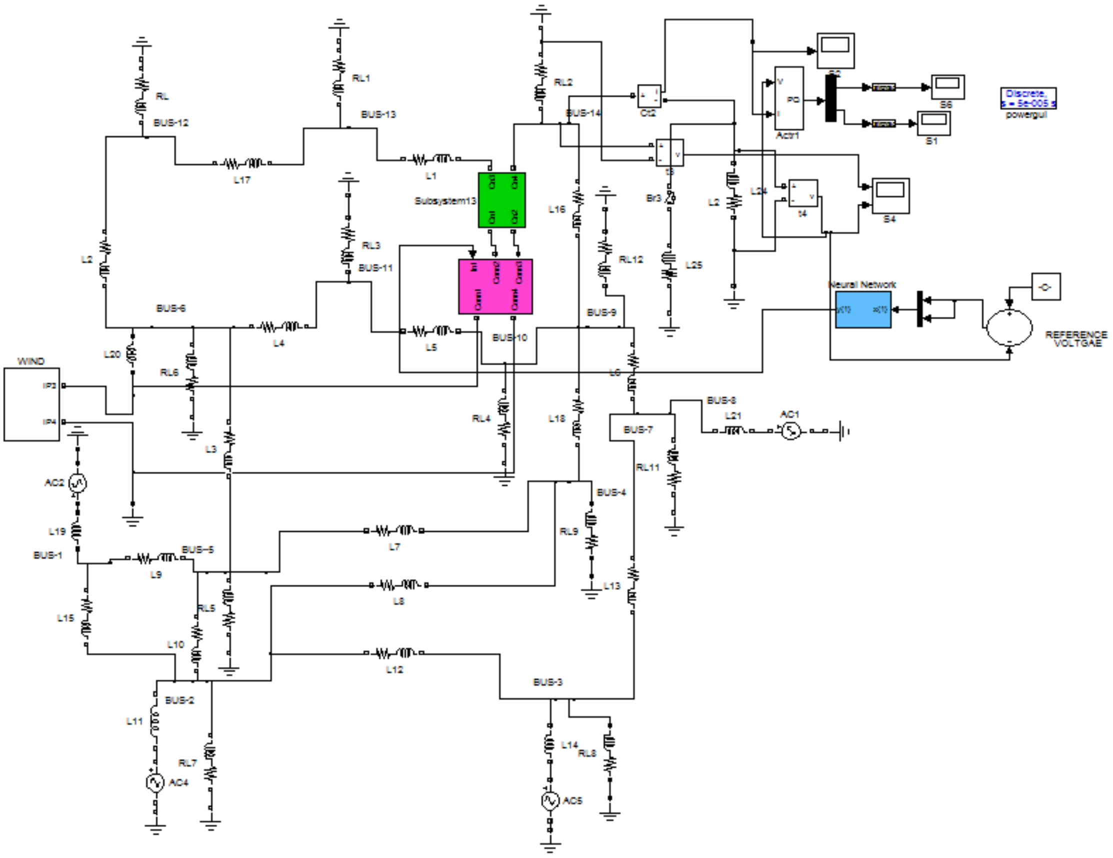

Figure 17.Simulink Model Model of Fourteen Bus System with ANN

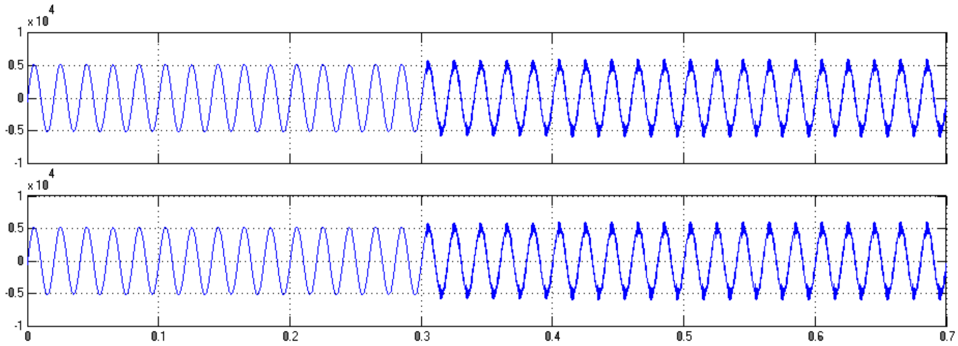

Figure 18. Voltage Waveforms

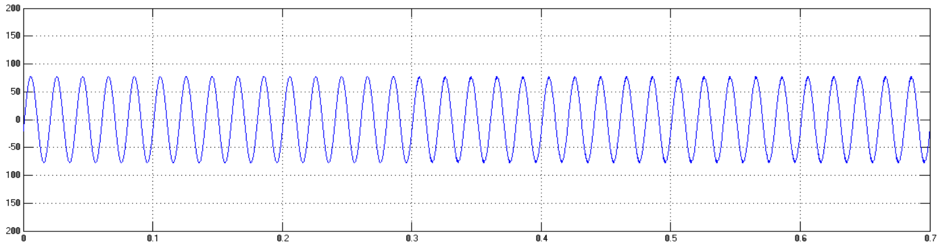

Figure 19. Current Waveform

Table 1. Summary of Time Domain Parameters

Controllers	Rise time (s)	Peak time (s)	Settling time (s)	Steady state error (V)
PI controller	0.31	0.32	0.33	20
ANN	0.01	0.02	0.025	1

Table 2. The Real and Reactive power with DPFC in 14-bus System with and without Non-Conventional Sources

DPFC-14-bus	Real power (MW)	Reactive power (MVAR)	THD
Without wind & solar	0.195	0.267	5.89%
With wind & solar	0.234	0.348	5.09%

5. Conclusion

The open loop response of fourteen bus systems with DPFC employing wind and solar systems were presented. Also the closed loop response with PI and ANN controllers was studied. The results indicate that the response of ANN based system is smoother. The settling time is reduced from 0.33to 0.025secs. The steady state error in bus voltage is reduced from 20V to 1V. The simulation results of this work are clear indication of improved dynamic response. The proposed system has advantages like low maintenance cost, high transmission efficiency and good voltage stability. The disadvantages of proposed system are high initial cost and requirement of more series converters.

The scope of the present work is to compare PI and ANN controlled DPFC systems. The comparison between ANN and hysteresis control will be done in near future.

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Akhib Khan Bahamani has done his B.E and M.tech from VTU, Belgaum, in the years 2005 and 2007 respectively. He is presently a research scholar at JNTU, Ananthapuramu, Andhra Pradesh. His research area is on power quality improvement using DPFC.

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Dr. Ganesh Vualsala is graduated B. Tech in 1998 from JNTU University, Hyderabad, Masters from S.V. University, Tirupathi, and Ph.D from J.N.T.University, Anantapur Andhra Pradesh, INDIA. He is presently working as Professor for the Department of Electrical and Electronics Engineering, J.N.T.University, Pulivendula, Andhra Pradesh, INDIA. His areas of interest are Genetic Algorithms, FACTS and its applications to Electrical distribution systems and its automation. He is also doing research in smart grid, design of controllers for renewable energy sources etc.