International Journal of Electrical Engineering.
ISSN 0974-2158 Volume 8, Number 4 (2015), pp. 419-431

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Power Quality Improvement in Fourteen Bus System using UPQC

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Abstract

This paper deals with line loss and THD reduction in Fourteen Bus system employing Unified Power Quality Conditioner (UPQC). The UPQC system combines the abilities of the Dynamic Voltage Regulator (DVR) and the Active Filter (AF). The Eight Bus systems with and without UPQC are modeled and simulated using the blocks of MATLAB/SIMULINK and reduction in the losses and the THD are presented. It is noted that the introduction of UPQC reduces the line losses and improves the transmission efficiency. The UPQC system has advantages like voltage sag compensation ability and loss reduction. The UPQC is proposed in the present work to improve Power Quality of fourteen bus system.

Key words: Real power, Reactive power, Dynamic Voltage Regulator, Active Filter, Total Harmonic Distortion, Line Losses, Power Quality

List of Abbreviations:

UPQC	-	Unified Power Quality Conditioner
FACTS	-	Flexible AC Transmission Systems
VAR	-	Volt Ampere Reactive
DVR	-	Dynamic Voltage Regulator
AF	-	Active Filter
THD	-	Total Harmonic Distortion
FFT	-	Fast Fourier Transform

1. INTRODUCTION

It is the objective of the electric utility to supply its customers with a sinusoidal voltage of fairly constant magnitude and frequency. The generators that produce the electric power generate a very close approximation to a sinusoidal signal. The planning, design, and operation of industrial and commercial power systems require several studies to assist in the evaluation of the initial and future system performance, system reliability, safety and the ability to grow with production and operating requirements. The conventional AC electric power systems are designed to operate with sinusoidal voltages and currents. The quality power supply is essential for proper operation of industrial processes which contain critical and sensitive loads. However nonlinear loads and electronically switched loads will distort steady state AC voltage and current waveforms. Periodically distorted waveforms can be studied by examining the harmonic components of the wave-forms. Reducing voltage and current waveform distortions to acceptable levels has been a problem in power system design from the early days of alternating current. The quality power supply is essential for proper operation of industrial processes which contain critical and sensitive loads.

However there are loads and devices on the system which have nonlinear characteristics and result in harmonic distortion of both the voltage and current signals. As more nonlinear loads are introduced within a facility, these waveforms get more distorted. In a modern power system due to wide use of nonlinear loads such as adjustable speed drives, electric arc welders, and furnaces it has become necessary to establish criteria for limiting power quality problems. These problems cause reduction in system efficiency, poor power factor, maloperation of electronic equipment's and reduction in equipment mean life time. The nonlinear load injects the harmonic current into the networks and consequently distorts the voltage waveform. This distorted voltage waveform affects other loads connected. To avoid this problem and to protect the loads from distortion, the harmonic components of the voltage and current must be compensated.The numbers of loads which are very sensitive to PQ problems have increased in the modern power system and at the same time the number of PQ polluting factors has also escalated. The increased penetration of distributed generation sources in to the power system has further contributed to existing PQ complexities. These distributed generation sites are often fueled by renewable energy sources such as wind and solar. The random nature of these energy sources poses a reliability threat to the power system.

By use of Passive filters, the problem reduces, but these have many disadvantages such as fixed compensation, large size, and resonance problems. To overcome the above problem, the shunt active filters were used with passive filters [1]-[2], but this method does not reduce the voltage harmonics. In order to deal voltage and current harmonic problems simultaneously, the most sophisticated device i.e., unified power quality conditioner has been developed [2]-[3]. In section 2, structure of UPQC is presented. In section 3, an eight bus system without UPQC, with UPQC and their comparative analysis are presented. Finally, section 4 concludes the results.

2. STRUCTURE OF UPQC

UPQC is a series combination of series and shunt active power filters sharing a common DC link. The two active power filters have different functions. Series filters is operated as a controlled voltage source to suppress and isolate voltage harmonics, same time shunt filters acts as a controlled current source to compensate the current harmonics. This paper presents complete simulation of UPQC system. The basic configuration of the UPQC is presented in Figure-1.

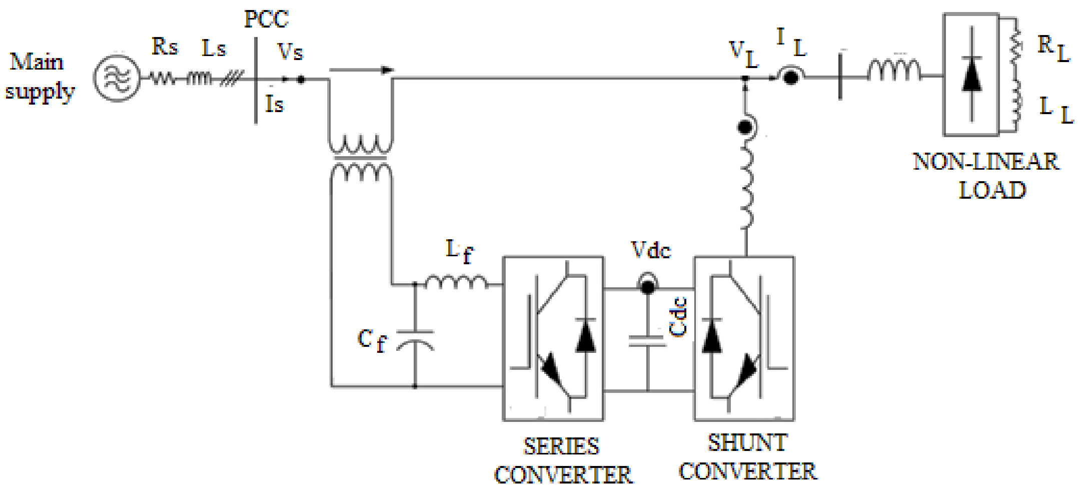

Fig.1: Basic Configuration of UPQC

Figure 1 shows a basic configuration of general UPQC consisting of two voltage source inverters: one act as a series APF and the other as shunt APF, which are connected back to back through dc link capacitor. The series APF which is connected between the source and PCC using three single phase series transformers has the capability of compensating the voltage harmonics, voltage flicker and improving voltage regulation [4]. The shunt APF is connected through a small rated capacity inductive filter in order to eliminate the high switching ripple content in the shunt APF injected current. Direct control strategy for UPQC in 3 phases, 4 wire system is given by Yong [5]. Enhancing Electric Power Quality using UPQC is given by Khadkikar [6]. Control scheme for three phase four wire UPQC in a three phase stationary frame is given by Chen [7]. Series active power filter compensates current harmonics and voltage unbalance simultaneously is given by Wallace [8]. UPQC for simultaneous voltage and current compensation is given by Ledwich [9]. Harmonic modeling of residential and commercial loads with unified power quality conditioner is given by Tulasiram [10]. Unified power quality conditioner for power quality improvement with advanced control strategy is given by Kamble, S.Y [11].

The above literature does not deal with the Power Quality Improvement in fourteen bus system using UPQC. This work proposes UPQC in fourteen bus system for improving Power Quality. A new Simulink model for Fourteen bus system with UPQC is presented in this paper.

3. SIMULATION RESULTS

The model for fourteen bus system is developed using the elements of MATLAB and SIMULINK. The results of simulation with and without UPQC are presented in this section. The Simulink model for fourteen bus system with linear and nonlinear loads is shown in Figure 3.1. PQ power measurement blocks are connected to measure real power and reactive power. The output voltage of wind generator is shown in Figure 3.2. Voltage across load-1 and load-2 are shown in Figure 3.3. The voltage decreases at time equal to 0.2 sec due to the addition of second load. Real and Reactive power at buses five and nine are shown in figures 3.4 and 3.5 respectively. The FFT analysis is done for the current and the T.H.D is 9.3%.

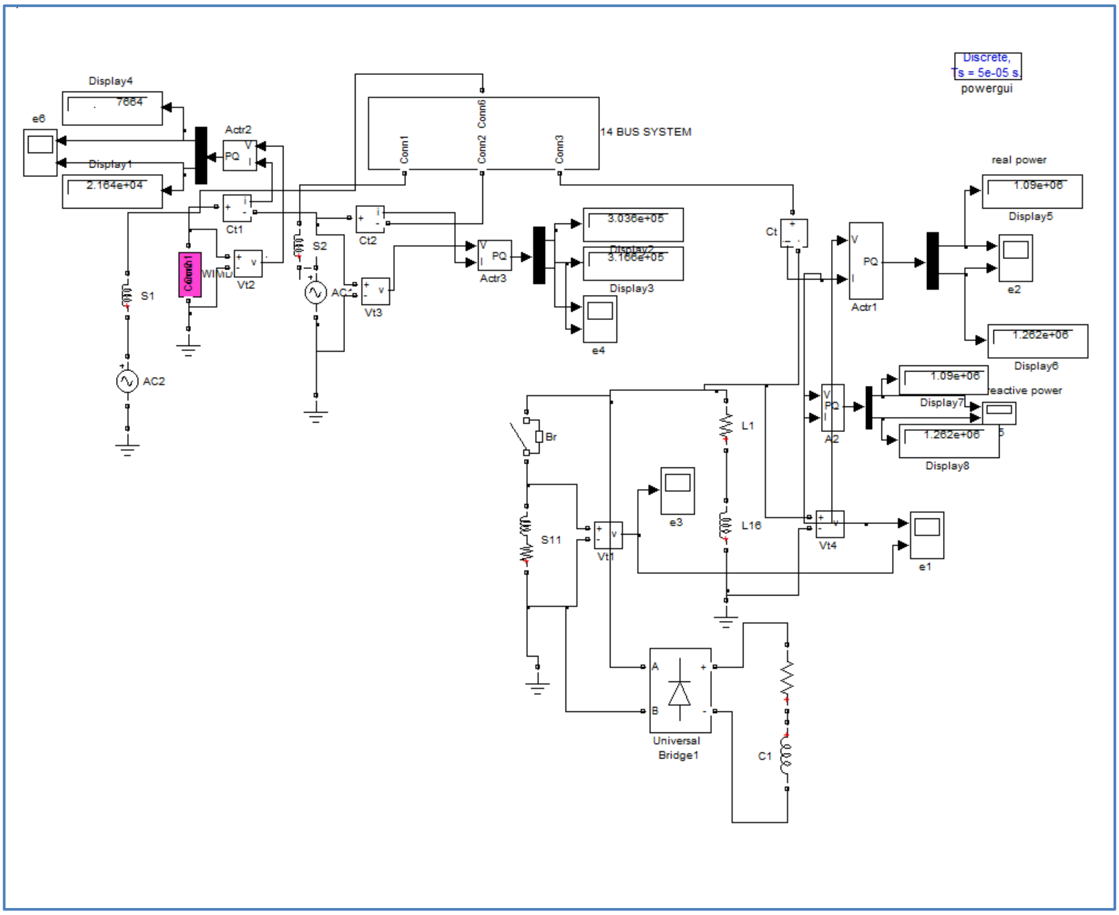

Fig.3.1: 14 Bus system without UPQC

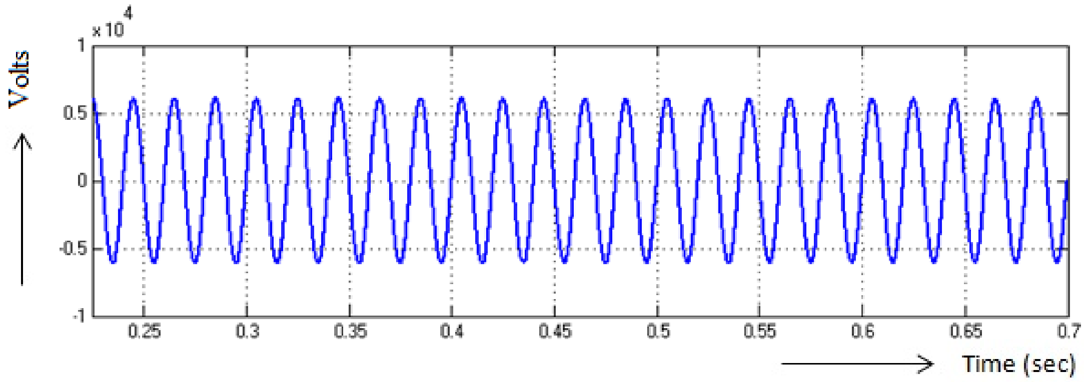

Fig.3.2: Output Voltage of Wind Generator

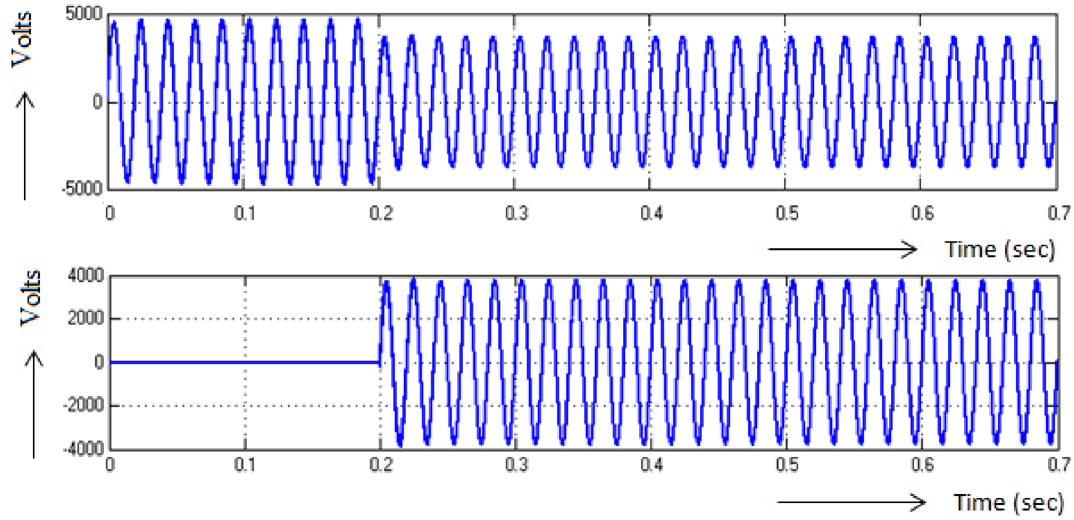

Fig.3.3: Voltage across load-1 and load-2

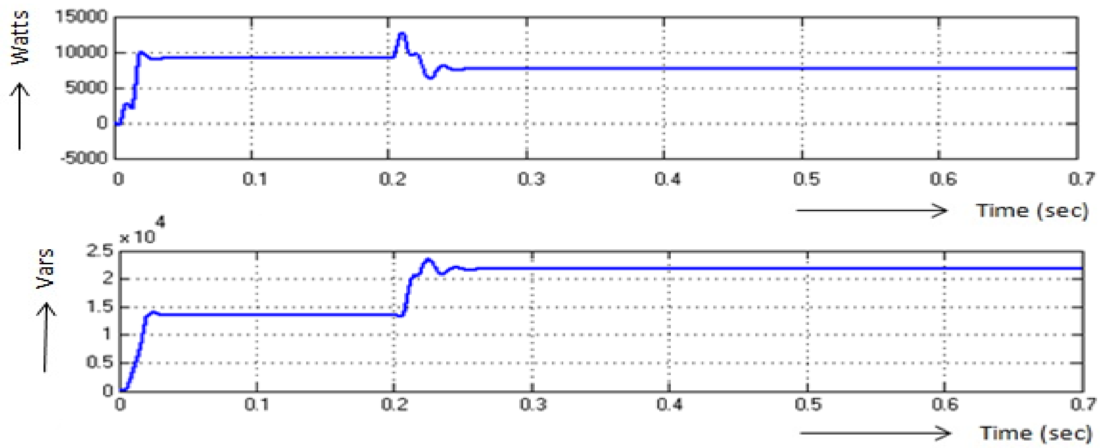

Fig.3.4: Real and Reactive power at Bus-5

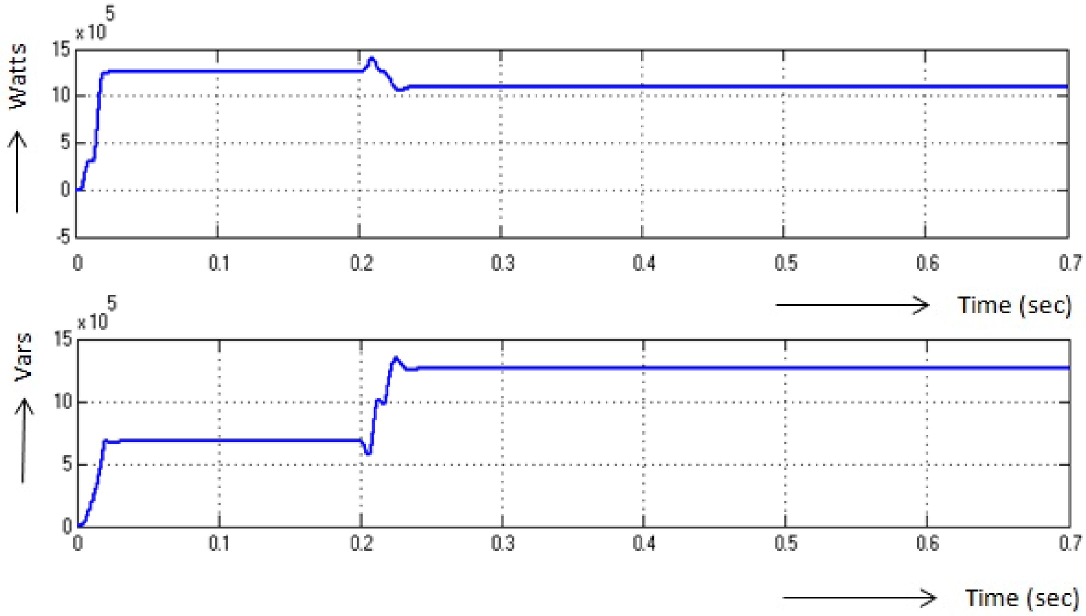

Fig.3.5: Real and Reactive power at Bus-9

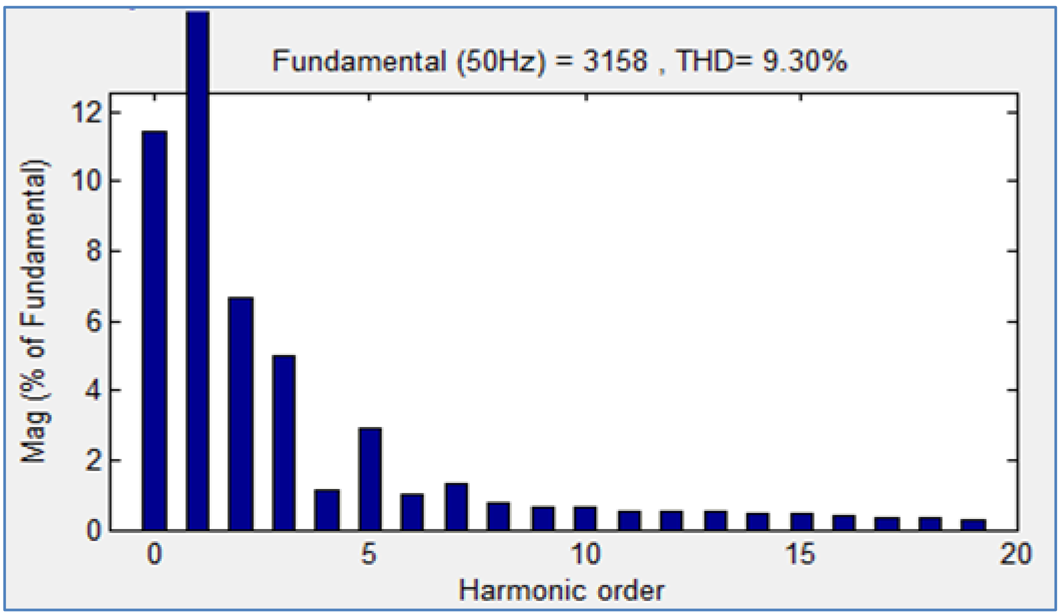

Fig.3.6: FFT Analysis for current

4. Fourteen Bus System with UPQC Implementation

The SIMULINK model of fourteen bus system with UPQC is shown in figure 4.1. The UPQC is introduced to improve the voltage profile and reduce the T.H.D. The subsystem containing 14-bus network is shown in figure 4.2. Line impedances are represented as series combination of resistance and reactance. Load impedances are

represented as series resistance and reactance between bus and neutral. The output voltage of wind generator is shown in figure 4.3. The voltage across load-1 & load-2 are shown in figure 4.4. The voltage profile is improved by the addition of UPQC at time equal to 0.4 sec. The real and reactive powers at bus five, bus nine, bus eleven and bus thirteen are shown in figures 4.5, 4.6, 4.7 and 4.8 respectively. FFT analysis for the current is shown in Figure 4.9 and T.H.D is 5.8%. Summary of real and reactive powers with and without UPQC are presented in Table-1. The summary of line losses is given in Table-2. The average line losses are reduced from 1.27 kW to 1.22 kW. The comparison of Average Real power loss, Reactive power losses and THD are summarized in Table-3.
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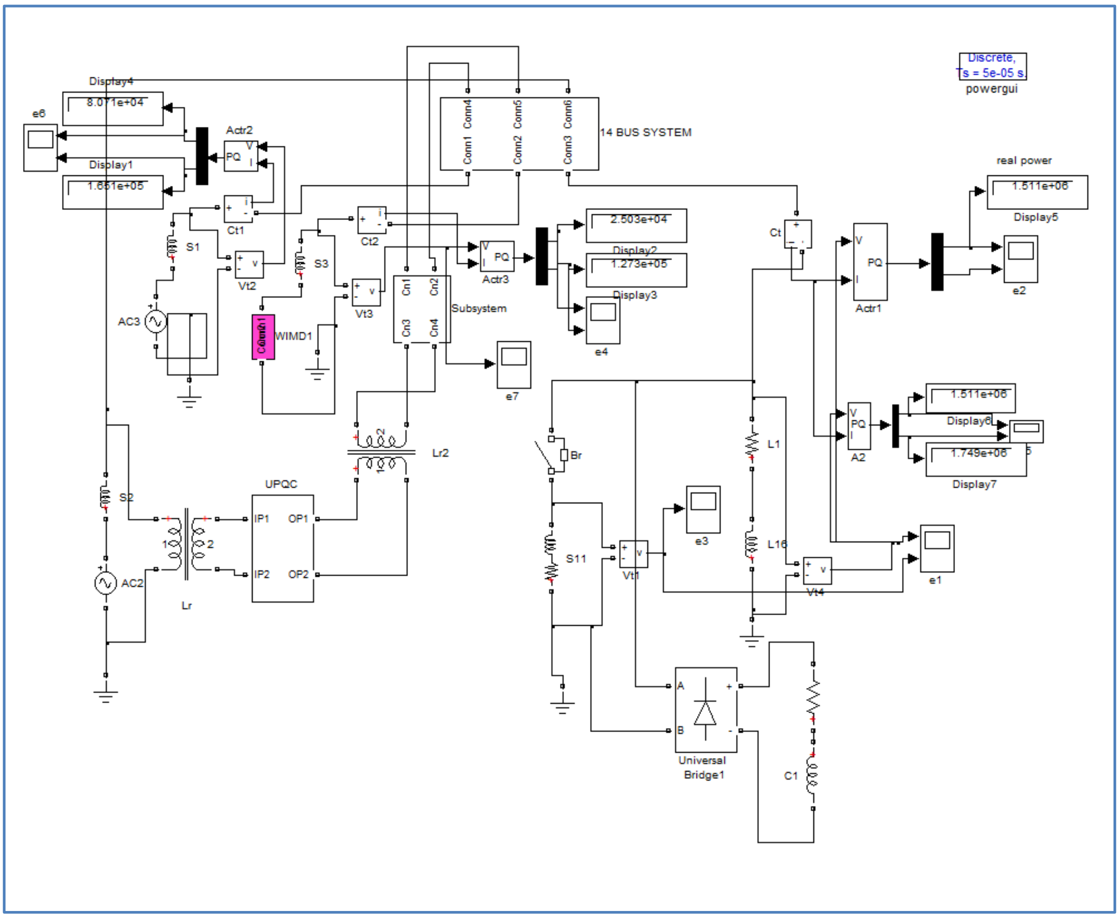

Fig.4.1: 14 Bus system with UPQC

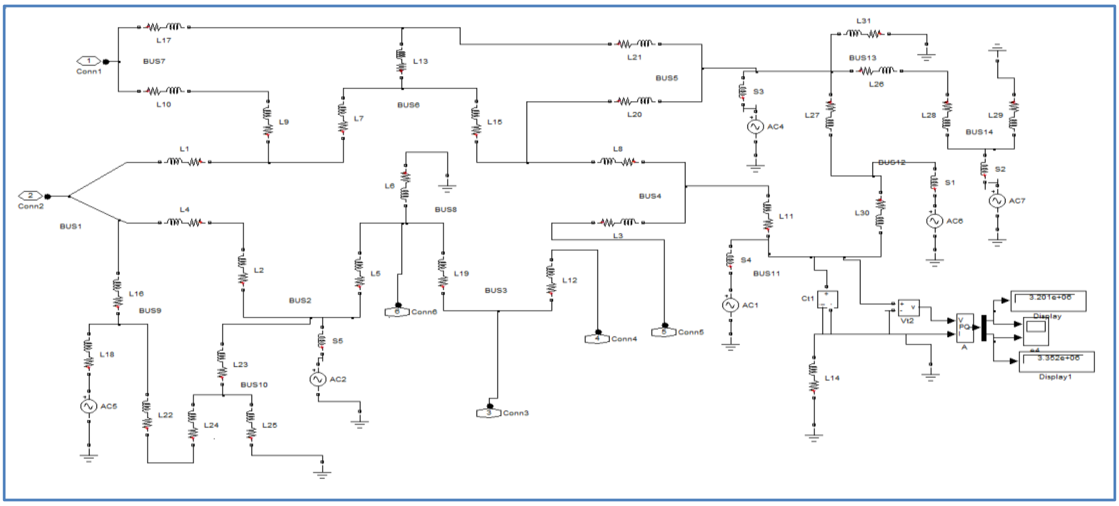

Fig.4.2: 14 Bus Network

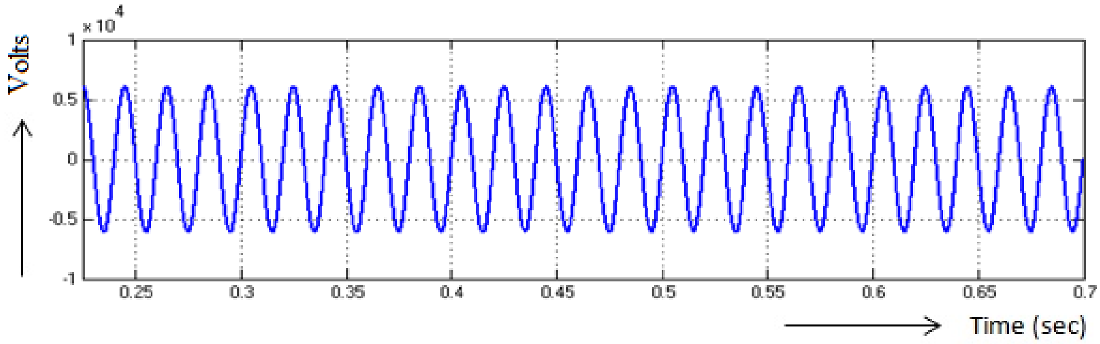

Fig.4.3: Output Voltage of Wind Generator

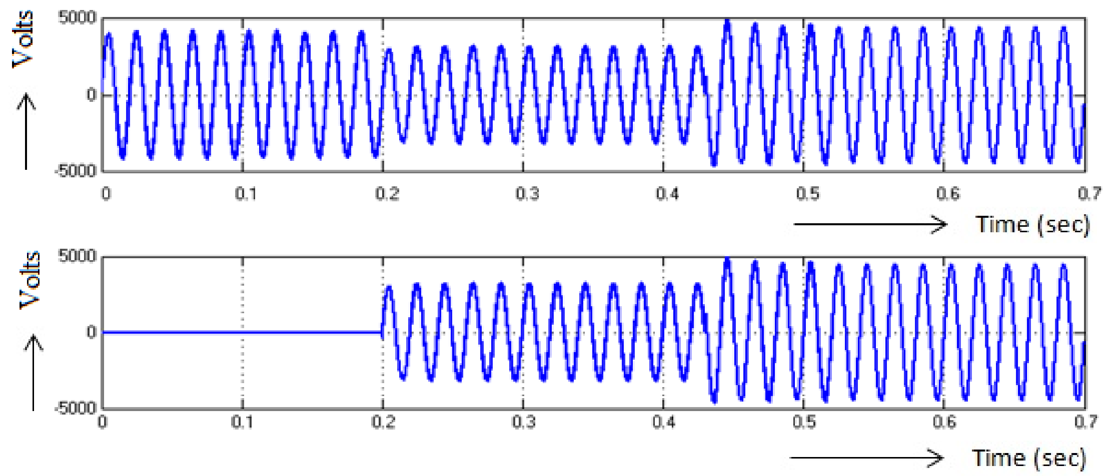

Fig.4.4: Voltage across Load-1 and Load-2

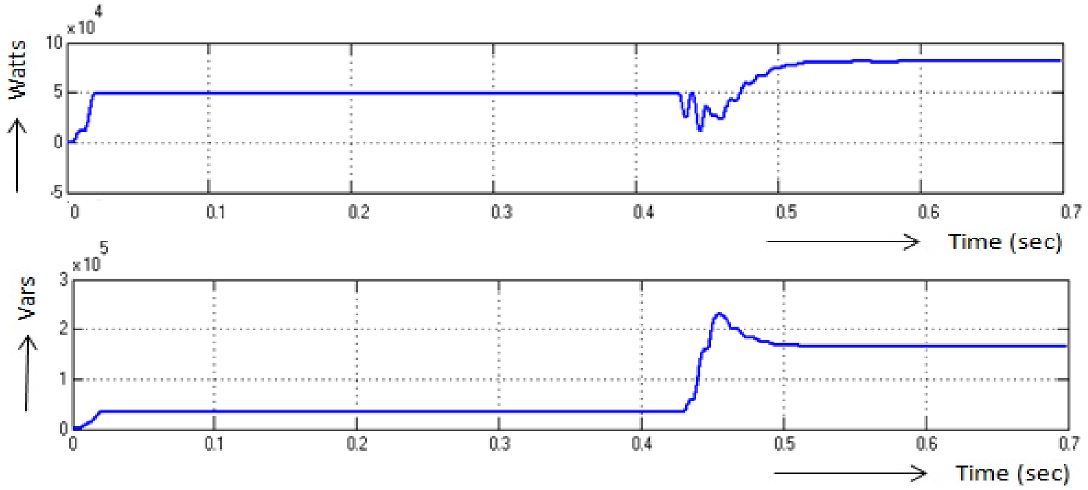

Fig.4.5: Real and Reactive power at Bus-5

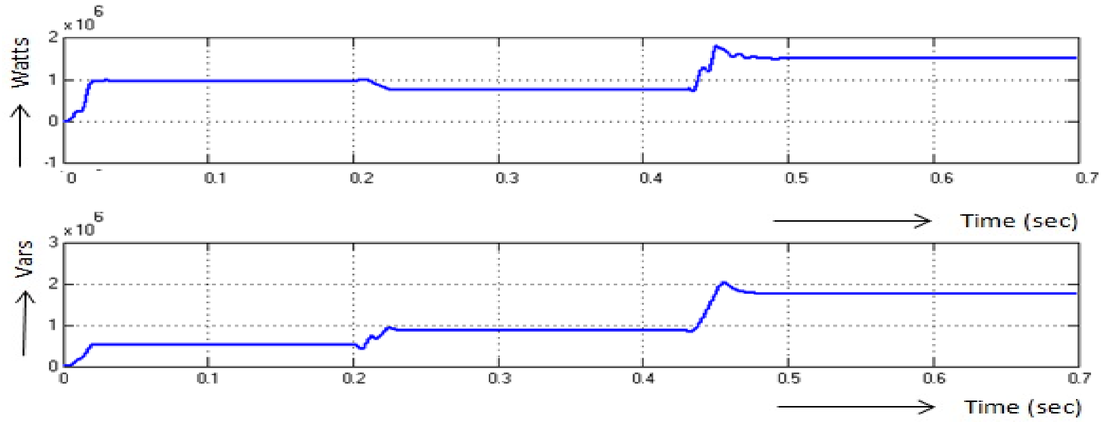

Fig.4.6: Real and Reactive power at Bus-9

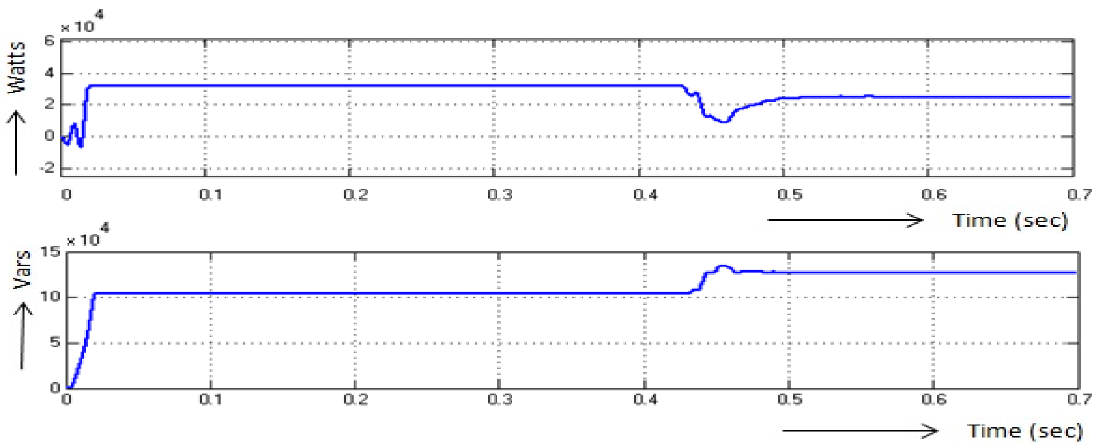

Fig.4.7: Real and Reactive power at Bus-11

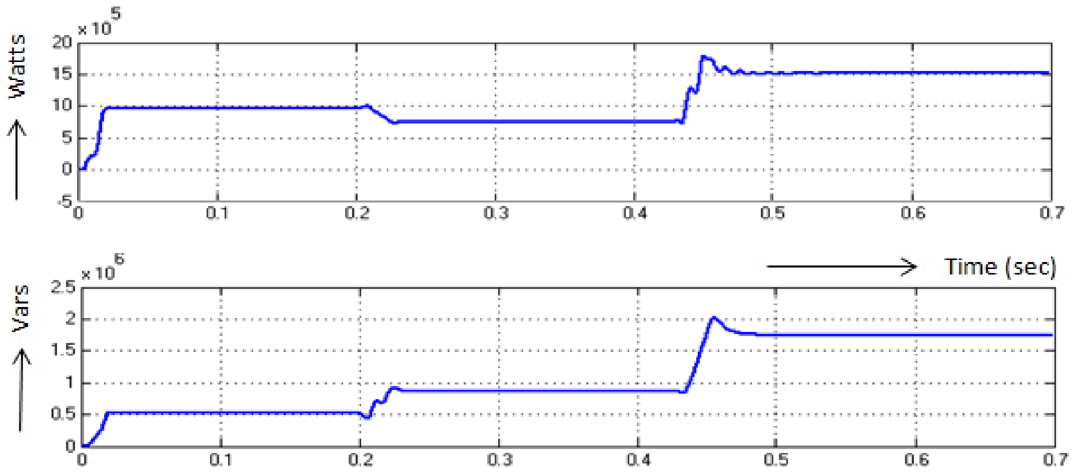

Fig.4.8: Real and Reactive power at Bus-13

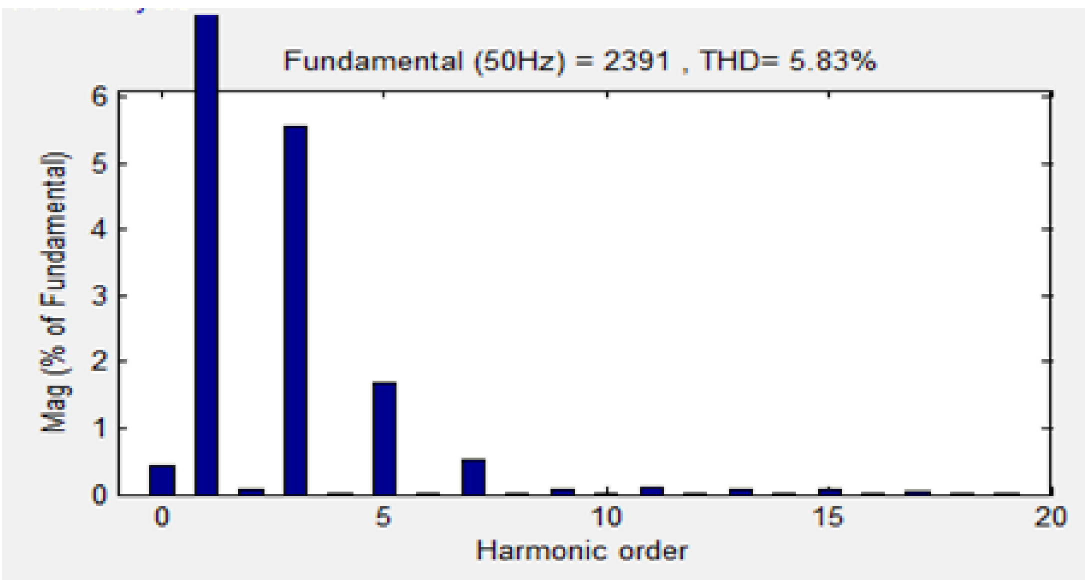

Fig.4.9: FFT Analysis

Table.1: Summary of Real & Reactive power

line	Real power Without UPQC (MWatts)	Reactive power Without UPQC (VARs)	Real power With UPQC (MWatts)	Reactive power With UPQC (MVARs)
Bus-1	0.277	0.275	0.304	0.352
Bus-5	0.420	0.575	1.320	1.801
Bus-9	0.013	1.217	0.032	1.753
Bus-11	0.210	0.321	0.253	0.456

Table 2: Line Losses

line	Real power loss Without UPQC	Real power loss With UPQC
Line-1	0.0490	0.0464
Line-2	0.0954	0.0741
Line-3	0.0610	0.0568
Line-4	0.1176	0.1053
Line-5	0.0786	0.0658
Line-6	0.0869	0.0828
Line-7	0.1125	0.1108
Line-8	0.1023	0.0986
Line-9	0.0956	0.0921
Line-10	0.0986	0.0958
Line-11	0.0869	0.0879
Line-12	0.1115	0.1186
Line-13	0.0902	0.0986
Line-14	0.0856	0.0921
Average loss	1.2717	1.2257

Table.3: Summary of Average Real power loss and THD

Description	Without UPQC	With UPQC
Average Real Power loss	1.2717 kW	1.2257 kW
T.H.D	9.3%	5.8%

5. CONCLUSIONS

The UPQC based fourteen bus system was successfully designed, modeled and simulated using MATLAB. The comparison of results of fourteen bus system with and without UPQC is presented. The comparison indicates that the real power losses are reduced by 5% by introducing the UPQC in the multibus system. The THD is reduced from 9.3% to 5.8% by adding UPQC to 14-Bus system. The benefits of UPQC are voltage injection ability and harmonic reduction. The disadvantage of three phase UPQC system is that it requires twelve IGBT's.

The Scope of the present work is to estimate the reduction in losses & T.H.D of Thirty bus system employing UPQC.

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