GSJ: Volume 10, Issue 1, January 2022, Online: ISSN 2320-9186
www.globalscientificjournal.com

Generalized UPQC system with an improved Control Method under distorted

SUNIL KUMAR, SHOYAB ALI, PRAMOD SHARMA

1. ABSTRACT

One of the most critical tasks of the energy grid is to supply electricity in pure sinusoidal form atpoints where sufficient measurements and frequencies are related to the customers. While synchronous power plant voltage is almost sinusoidal but some uncertain conditions, such as lightning, short circuit errors or nonlinear loads (Industrial Drive), result in permanent status errors, transient voltages and disruptions of the current. For example Power converters are produce current harmonics, distortion in waveforms and short-circuit defects are produce voltageslumps.

To resolve power quality issue, Custom Power Devices are available to increase the power efficiency of electricity in our power system. There are several custom power devices like Surge Arrestor, Active Power Filter, Solid State Current Faults Limiter, Storage devices (Battery Energy Storage System), Mega Magnetic Energy Systems, Dynamic Voltage Restore (DVR), Distribution Static Synchronous Compensator, Standard Power Quality Conditioning, Uninterruptible Power Supplies, Synchronous Compensators, Solid State Transfer Switches (SSTS) and Static VAR Compensator.

The purpose of this research is to improve power quality in the power system by introducing a Dynamic Voltage Restorer with unbalance load condition for voltage control and for Harmonic mitigation we use Fuzzy Controlled Shunt Active Power Filter. Dynamic Voltage Restorer is a power electronic converter mounted in a responsive load array to protect against any interference in the supply side against critical loads. Its quick reaction and high reliability make reliable tool for power quality improvement.

2. **Keywords-** Dynamic Voltage Restorer, Power System, Power Quality, Total Harmonic Distortion, Efficiency, Sag, Swell, Active Power Filter.

3. INTRODUCTION

Due to the widespread use of frequency and variable speed drives we need robot systems, automated production lines, precise digital control systems, programmable logic control systems, computer data management systems etc. These structures and devices are particularly vulnerable to wave power and various disorders. Non-linear loads and harmonic sources are many of these devices. Any power quality problems can reduce product quality or lead to management uncertainty.

The problem of power quality is not new, but the consumer awareness of these issues has recentlyincreased. For example, for a number of years interruptions that were less than a few minutes were not seen for most consumers as cause of concern. With higher quality customer demands, the term power quality becomes particularly relevant. In many cases, consumers are impacted bypoor quality electricity.

The lack of quality power may also affect the health of people by losing productivity and damaging machinery or equipment. Consequently, it is very important to maintain high power efficiency. The long-standing issues of power quality include a number of conventional solutions. However, these conventional solutions use passive elements and do not always respond properly as the power system conditions change. Energy converters are accessible in a range of applications thanks to the rising capacity, controlling and cost-saving capabilities of modern semiconductor equipment. New flexible solutions to various power quality issues have become possible with the help of these power conversion devices. Non-linear devices like electricity converters increase the total reactive power demanded by equivalent load and the distribution gridis fed into harmonic currents. The need for sensitive power reduces the feeder's violation and increases the loss. The harmonic currents can result in additional losses and distortion of voltage, which contributes to a poor energy quality. Furthermore, the number of sensitive loads requiring optimum sinusoidal tension for proper operations has increased. Increased use of electronic equipment responsive power fuels in the area of power technology. There is also a need for some kind of compensation to keep the efficiency of the power within the standards. Customer power quality can be improved by using power electronic energy-conditioning systems. Increasing power efficiency, compact in size and better control is achieved with power electronic transformation. However, due to switching operations, such systems are operating as non-linear loads

Power Quality (PQ) related issues are of most concern nowadays. Electrical Power quality is the degree of any deviation from the nominal values of the voltage magnitude and frequency. From the customer perspective, a power quality problem is defined as any power problem manifested in voltage, current, or frequency deviations that result in power failure or disoperation of customer of equipment [1]. The waveform of electric power at generation stage is purely sinusoidal and free from any distortion. Many of the Power conversion and consumption equipment are also designed to function under pure sinusoidal voltage waveforms. However, there are many devices that distort the waveform. These distortions may propagate all over the electrical network. The widespread use of electronic equipment, such as information technology equipment, power electronics such as adjustable speed drives (ASD), programmable logic controllers (PLC), energy-efficient lighting, led to a complete change of electric loads nature. These loads are simultaneously the major causers and the major victims of power quality problems. Mainly there are different power quality problems. Voltage sag, voltage swell, harmonics, very short interruptions, long

Interruptions, voltage spike, noise, voltage unbalance these are the main PQ problems in power system. A wide diversity of solutions to power quality problems is available for both the distribution network operator and end user. The measure of power quality depends upon the needs of the equipment that is being supplied. Custom Power devices are a better solution for these Power Quality related issues in distribution system [2]. Out of these available power quality enhancement devices, the UPQC has better sag/swell compensation capability. Controlling methods has the most significant role in any power electronics based system. It is the control strategy which decides the efficiency of a particular system. The efficiency of a good UPQC system solely depends upon its various used controlling algorithm. [2]The UPQC control strategy determines the current and voltage reference signals and thus, decides the switching times of inverter switches, so that the expected performance can be achieved. In this proposed work Particle Swarm Optimization is used as the control algorithm and the effect of this controlling method based UPQC in a 14 bus test systems is presented. In the proposed control method, load / source voltages and source voltage /current are measured, analysed, and tested under unbalanced and distorted load conditions.

3.1 OVERVIEW OF UPQC-S CONCEPT

At distribution level UPQC is the most attractive solution to compensating many power Quality problems. The term active power filter (APF) is a widely used in the area of electric power quality improvement. APF s have the ability to mitigate some of

GSJ: Volume 10, Issue 1, January 2022
ISSN 2320-9186

the major power quality problems effectively. The UPQC is one of the APF family members where shunt and series APF functionalities are integrated together to achieve superior control over several power quality problems simultaneously. The system configuration of a UPQC is shown in fig.1.

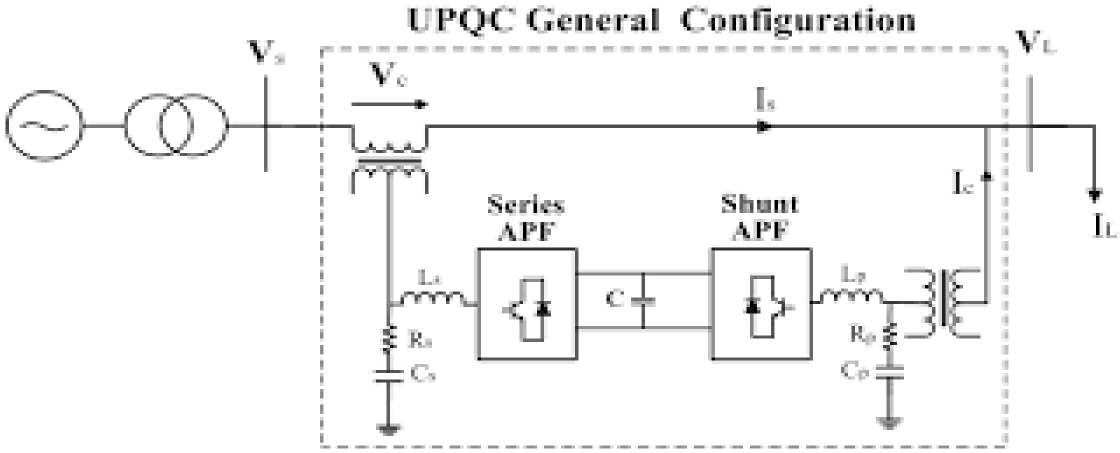

Fig 3.1 UPQC General Configuration

The UPQC is a combination of series active filter and shunt active filter linked through a common DC link capacitor. Series active filter and shunt active filter compensate the power quality problems of the source

voltages and load currents, respectively. In order to improve the power quality of the system, UPQC has to inject required amount of Volt Ampere (VA) into the distribution system. For cost effectiveness, the VA loading of the UPQC need to be minimized[3]. Mainly three significant control approaches for UPQC can be found to control the sag on the system: 1) active power control approach in which an in-phase voltage is injected through series inverter , popularly known as UPQC-P; 2) reactive power control approach in which a quadrature voltage is injected, known as UPQC-Q; and 3) a minimum VA loading approach in which a series voltage is injected at a certain angle, which is known as VAmin. The VA loading in UPQC-VAmin is determined on the basis of voltage sag, may not be at optimal value. The voltage sag/swell on the system is one of the most important power quality problems in distribution. In the paper [9], the authors have proposed a concept of power angle control (PAC) of UPQC. The PAC concept suggests that with proper control of series inverter voltage the series inverter successfully supports part of the load reactive power demand, and thus reduces the required VA rating of the shunt inverter. In this paper, the concept of PAC of UPQC is further extended for voltage swell and sag conditions. This modified approach is utilized to compensate voltage sag/swell while sharing the load reactive power between series and shunt inverters. Since the series inverter of UPQC in this case delivers both active and reactive powers, it is given the name UPQC-S (S for complex power). The series inverter of the UPQC-S is controlled using a Particle Swarm Optimization based fuzzy logic controller. Here PSO is used as an optimization technique to find the optimum value of reactive power with different constraints.

3.2 Improvement in UPQC

UPQC is used to reduce both current and voltage harmonics on the distribution terminus of the power system network as a universal ACC. The efficiency of UPQC depends mainly on the speed and precision with which compensation signals are derived. Furthermore, UPQC's output depends on the design of power semiconductor devices, on the modulation technology of the switches, on the design of coupling components, on the method for determining the current and voltage active filter references, on the dynamic of current and voltage control loops, and on their robustness. Band voltage control techniques and current control methods are built in which the band is modulated to keep modulation frequency almost constant with the device parameters. The FLC compensation system reduces stress and current harmonics with good dynamic response.

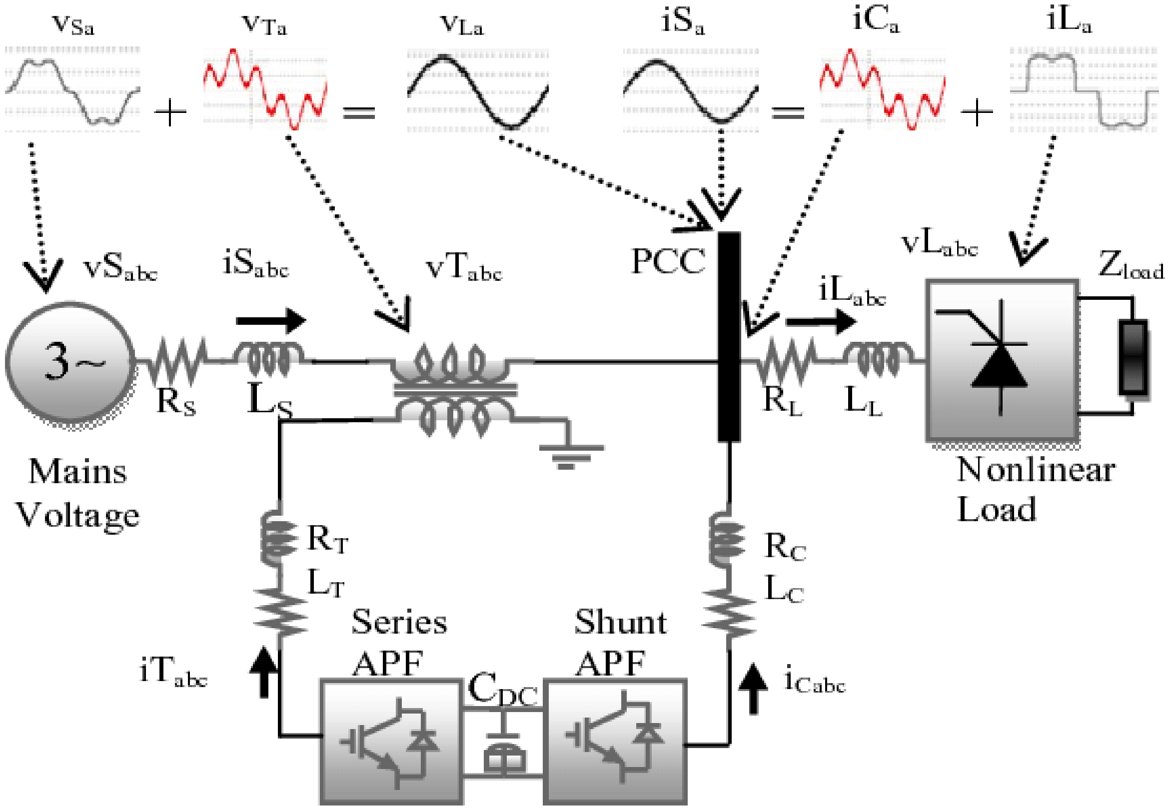

Figure 3.2 Connection Diagram of Unified Power Quality Conditioner

UPQC is an active power filter sharing a shared dc connation between a shunt and a series. It is capable of offsetting almost all problems of power quality, such as tensile harmonics, voltage imbalances, voltage splinters, voltage swells, current harmonics, current imbalance, reactive current, etc. Recently, greater attention has been paid to voltage reduction and the use of UPQC. The goal is to maintain the sinusoidal voltage of the load bus under all operating conditions at the desired constant stage. Figure 5.1 displays one form of UPQC structure used in distribution systems. The active power filtering has shown that it is one of the best solutions to mitigate major problems of power quality. The APF shunt is used to address all relevant issues such as current harmonics, reactive current and current imbalances. In comparison, the APF series handles all problems related to voltage, such as violation harmonics, voltage sag and swell, and voltage imbalance. The UPQC is controlled in order to always maintain sinusoidal voltage in the load bus and to the desired magnitude. The voltage injected with an APF series must therefore equate to the difference between the supply tension and the optimum charging tension. The APF series is therefore the regulated source of voltage. The shunt APF purpose is to keep the dc link voltage constantly. Furthermore, the APF shunt supplied the VAR needed by the load, so the input power factor is uniform and the source supplies only critical power. The efficacy of the active power filter essentially depends on the design characteristics of the current controller, the process used to create the reference template and the technique used for modulation. A shunt enabled power filter control scheme must compute for each step of the inverter the current reference waveform, maintain the dc voltage constant, and generate inverter gating signals. The compensation efficiency of an active power filter is also based on its ability to obey the reference signal calculated to compensate with minimal error and time delay for the distorted load current.

There are two control methods, one indirect and the other direct, which is widely used. The series inverter is regulated as a source of non-sine voltage, while a non-sineid current source controls the shunt inverter. The distortion of voltage and the fundamental difference in wave power need to be observed Grid. These voltage controls are used to monitor compensated voltages of the inverter series which run counter to the commands to ensure that the load voltage is the rated sinusoidal voltage. The reactive current and harmonic current of loads must also be detected. These quantities are used to control the shunt inverter in order to produce compensated currents that are contrary to control, such that the input power of the grid is the sinusoidal current and the power factor is the unit.

Direct control technique is to control the sery inverter as a sine quaver and the shunt inverter as a sine quaver. The power factor is unitary and the load output voltage is the sinusoidal current to ensure the input current of the grid. With this process, the series inverter isolates power grid and load voltage disruption while the shunt inverter isolates reactive energy and harmonic load currents into the grid, as well as the neutral current. The other benefit of this approach is that when the grid fails or is resumed, UPQC is not required to adjust operation modes, since the shunt inverter is still operated as a sinusoidal voltage source.

PWM switched inverters perform best in the control of asymmetries and, above all, in unbalanced fault currents. This control technique uses three single step PWM VSIs. Injection of positive, negative and zero sequence voltages with the use of single-phase H-bridge PWM converters on DVR power circuits is possible. Voltage regulation is accomplished by modulating the waveform of the output voltage in the inverter. The key benefit of the PWM inverter is that the power switches turn fast. Simplicity and good response provided via PWM technology. Moreover, high frequencies of switch can be used to increase the converter’s efficiency without substantial loss of switching.

4. Model Equation of UPQC

4.1 Computation of control Quantities of Shunt Inverter

In the three step sensed values the amplitude of the supply voltage is determined as:

$$V_{sm} = [2/3\ (v_{sa}^2 + v_{sb}^2 + v_{sc}^2)]^{1/2} \tag{4.1}$$

The current vectors of the three-phase unit are calculated as:

$$u_{sa} = v_{sa}/v_{sm};\ u_{sb} = v_{sb}/v_{sm};\ u_{sc} = v_{sc}/v_{sm} \tag{4.2}$$

The multiplication with the amplitude of the supply current (isp) of three phase vectors (USA, USB and USC) results in a three phase supply reference currents as follows:

$$i_{sa}^* = i_{sp}.u_{sa};\ \ i_{sb}^* = i_{sp}.u_{sb};\ \ i_{sc}^* = i_{sp}.u_{sc} \tag{4.3}$$

Three phase load currents are removed from three phase reference currents in order to obtain reference currents:

$$i_{sha}^* = i_{sa}^* - i_{la};\ i_{shb}^* = i_{sb}^* - i_{lb}$$

$$ishc^* = isc^* - ilc \tag{4.4}$$

This i_{ref} is the guiding principle for shunt inverter direct control technology. In order to obtain the commutation signals for the devices used in the inverter, the IRAF is compared to the IC in the PWM current controller.

4.2 Inverter Series Control Quantity Computation

The voltage of supply and the voltage of charge are sensed, and the desired injected voltage is calculated accordingly:

$$v_{inj} = v_s - v_l \tag{4.5}$$

The size of the voltage injected is as follows:

$$v_{inj} = |v_{inj}| \tag{4.6}$$

The injected tension step is indicated as:

$$_{inj} = \tan(Re[v_{pq}]/Im[v_{pq}]) \tag{4.7}$$

The following inequalities are followed for the purpose of compensating harmonics in load voltage:

a) $v_{inj}<v_{inj}max$; control of magnitude;

b) 0 $<_{inj}<$ 360 °; control phase;

The injected voltages express three phase reference values as:

$$v_{la}* = 2v_{inj} \sin(wt+ _{inj})$$

$$v_{lb}* = 2v_{inj} \sin(wt+2 /3 + _{inj})$$

$$v_{lc}* = 2v_{inj} \sin(wt-2 /3 + _{inj}) \quad (4.8)$$

The three stage benchmarks (i_{ref}) of the inverter series are determined as follows:

$$i_{sea}* = v_{la}*/z_{se}; \quad (4.9)$$

$$i_{seb}* = v_{lb}*/z_{se}; \quad (4.10)$$

$$i_{sec}* = v_{lc}*/z_{se}; \quad (4.11)$$

The z^{se}impedance requires the insertion transformer impedance. The currents (i^{sea} *, i_{seb} * and i_{sec} *) are the best current to hold through the secondary winding of the insertion transformer to inject tension (v_{la}, v_{lb} and v_{lc}) to compensate for the voltage sag that is needed. The i_{ref}currents (i_{sea}*, i_{seb}* and i_{sec}*) in PWM current controller are compared to iakt (i_{sea}, i_{seb} and i_{sec}*), resulting in six switching signals for series inverter IGBTs.

5.RESULTS

In this work, Simulation design and performance assessment of unified power quality controller based on fuzzy logic controller has been discussed and simulated for harmonic mitigation and power quality improvement. The objectives can be classified into following points:

• Design of sag mitigation with help of improved unified power quality conditioner.

• Design of swell mitigation with help of improved unified power quality conditioner.

• Compensation for power quality improvement under unbalanced load condition.

• Design of sag and swell mitigation with help of improved unified power quality conditioner.

• Design and Simulation of Fuzzy Logic controlled unified power quality conditioner.

5.1 Simulation and Results

Throughout the design phase of power electronics, computer simulation has become a critical component. UPQC is a sophisticated power electronic device, and analysing its behaviour without computer simulations would be extremely difficult, resulting in improved comprise. Because the influence of a parameter on the computational behaviour of the simulation is often easier to examine, the entire design process can be simplified by employing computer simulations. When a fugitive logic controller is utilised for harmonic compensation and dc capacitor voltage balancing in load terminals, simulation findings show that the UPQC is more efficient in switching and unbalanced scenarios. In the supply voltages phase, the goal is to obtain sinusoidal line currents at the common connector point. The current control of hysteresis, linear control comparison approaches, and current control predictable are the three existing control strategies. The existing hysteresis control technique is simple to implement, however it has an unmanageable high switching frequency. This high frequency damages the power transistors, resulting in switching loss. The second and third approaches operate at a fixed switching frequency and are often implemented by software using system parameters. The fuzzy logic controller's dynamic response was faster in this case. The efficacy of the proposed control algorithms for harmonic current filtration, reactive power compensation, load current equilibrium, and neutral power elimination of the active filter is demonstrated in this section using a MATLAB simulation. To accommodate all compensators, similar discrete blocks are employed. The shunt filter is turned on and the serial filter is enabled in order to monitor the voltage correction efficiency of the shunt filter. The source impedance is almost non-existent with Rs and Ls values of 0.1 ohms and 0.1mH, respectively. IGBT / diodes universal bridge is used to mimic both inverter series and shunt. A nonlinear 3-phase 4-wire system with a three-phase RL-loaded diode-bridge corrector is used to mimic the power circuit.

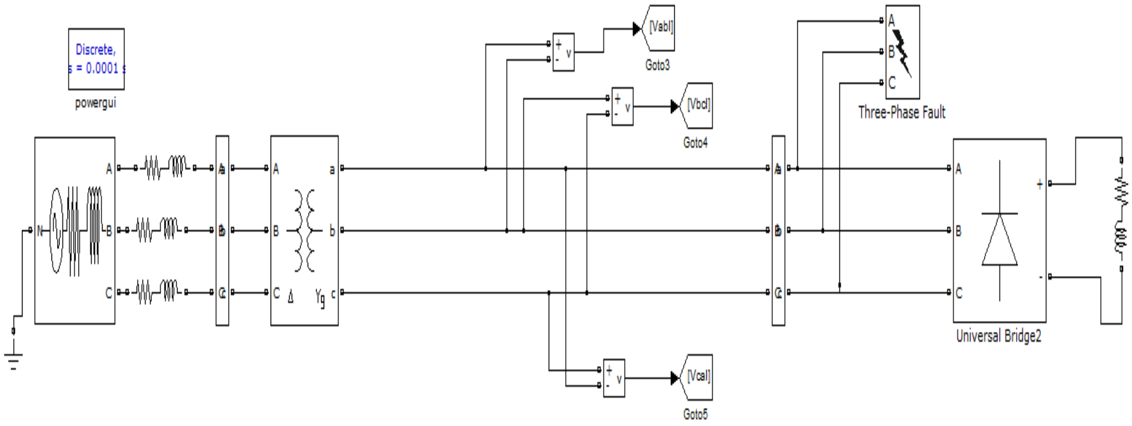

Figure 5.1 Simulink model of grid with fault without UPQC

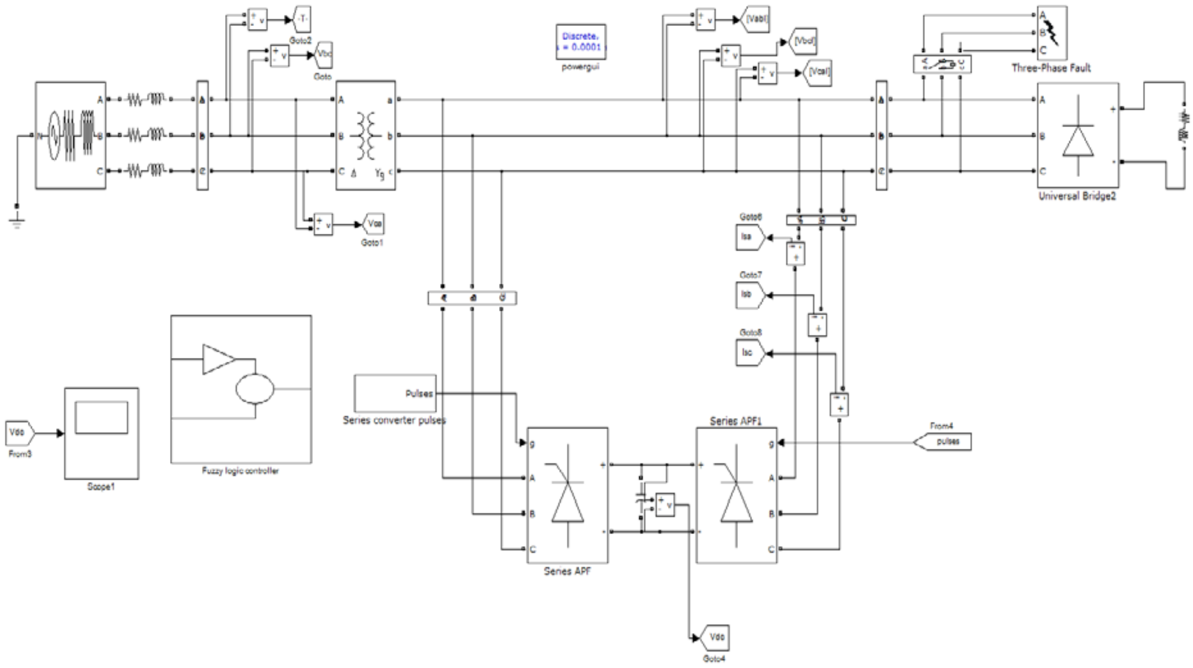

Figure 5.2 Simulink model of grid with UPQC using fuzzy logic controller

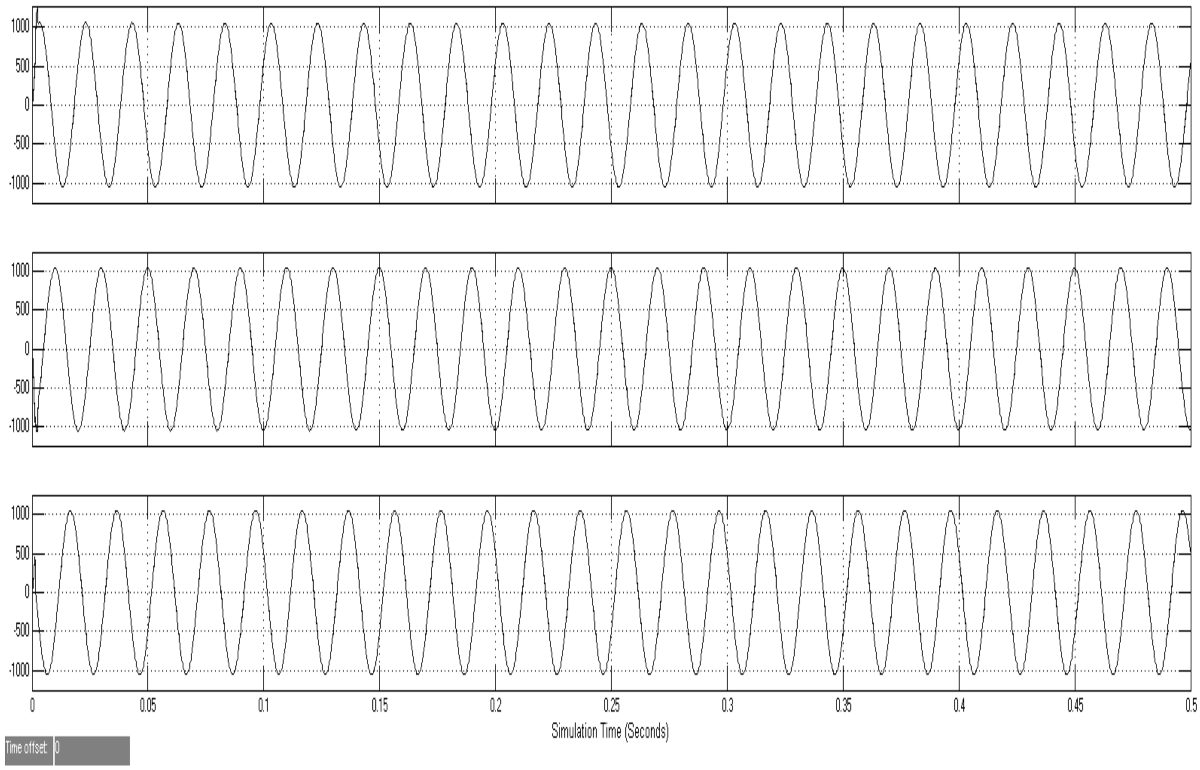

Figure 5.3 Output Waveforms for Voltage with Proposed UPQC

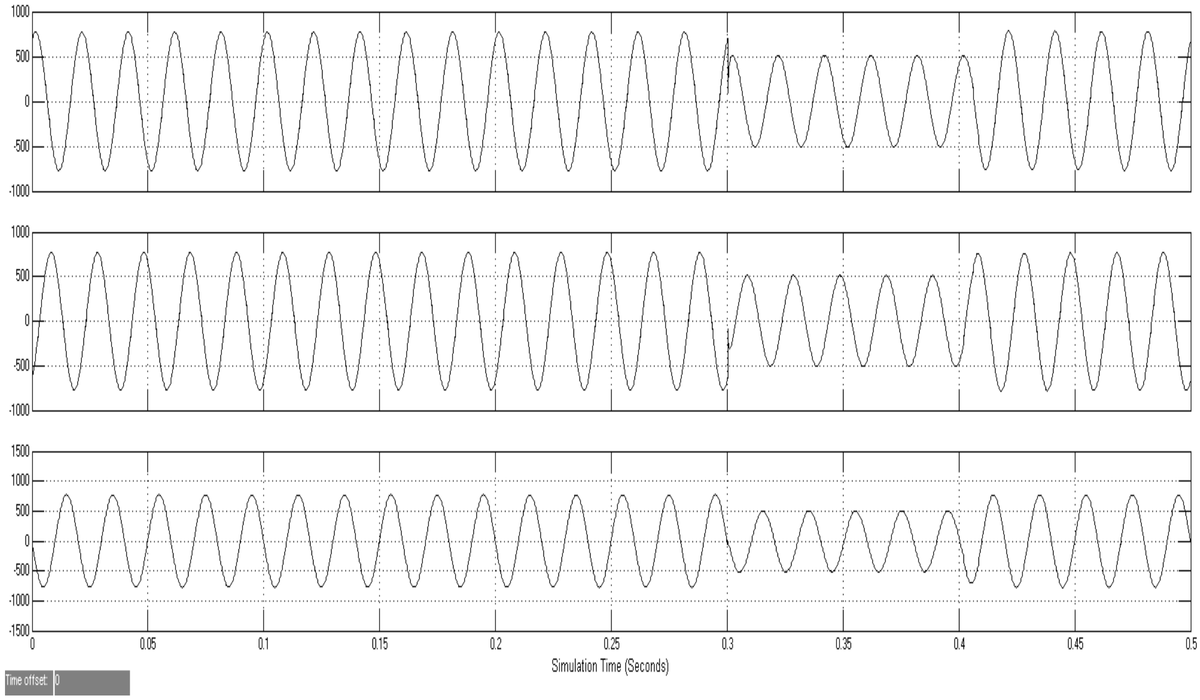

Figure 5.4 Output Waveforms for Voltage without Compensation

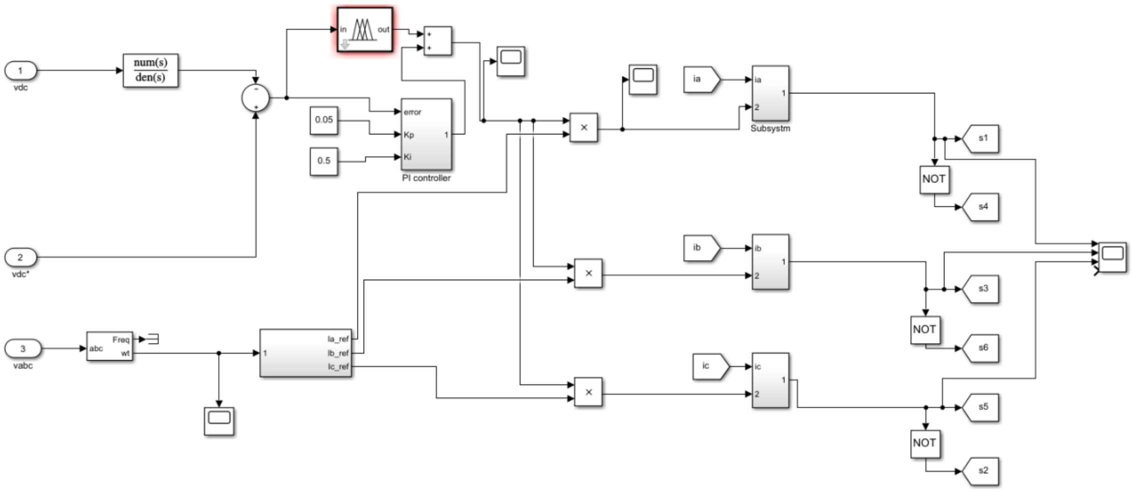

Figure 5.5 Simulink model of fuzzy logic controller and its system

5.2 Load voltage compensation

Figure 5.3 shows the three-phase load voltages before correction is applied. The APF series begins by injecting the harmonic voltage out of phase, so releasing the load voltage from distortion. The voltage injected through the array is seen in Figure 5.2. Three-phase load voltages after correction are shown in Figure 5.10.

The three-phase distorted load voltages have THDs of 47.15%, 44.78%, and 43.29%, respectively. THD of load voltages fell to 4.4 percent, 4.06 percent, and 3.99 percent in Phase A, Band C, respectively. The use of fluid logic in regulating loops enables even the most adverse conditions to satisfy the desired requirements, as demonstrated by these simulation findings.

5.3 Voltage Disruption Compensation

The simulation's consequences when a 0.06 s voltage interruption is applied to the source from 0.06 to 0.12s, using 3-stage charging voltages at a voltage interruption. During a voltage outage, the shunt inverter only delivers load power. The DC bus voltage is maintained at a steady level via FLC assistance throughout the voltage interruption. 3-phase load voltages following voltage interruption adjustment As a result, the proposed system's stability and dependability are demonstrated.

Table 5.1

Harmonic Analysis of Proposed Methodology

Methods	**%THD**		
	Phase-A	**Phase-B**	**Phase-C**
Uncompensated	47.15%	44.78%	43.29%,
UPQC	6.1 %	5.12 %	4.9 %
Proposed-UPQC	4.4 %	4.06 %	3.1 %

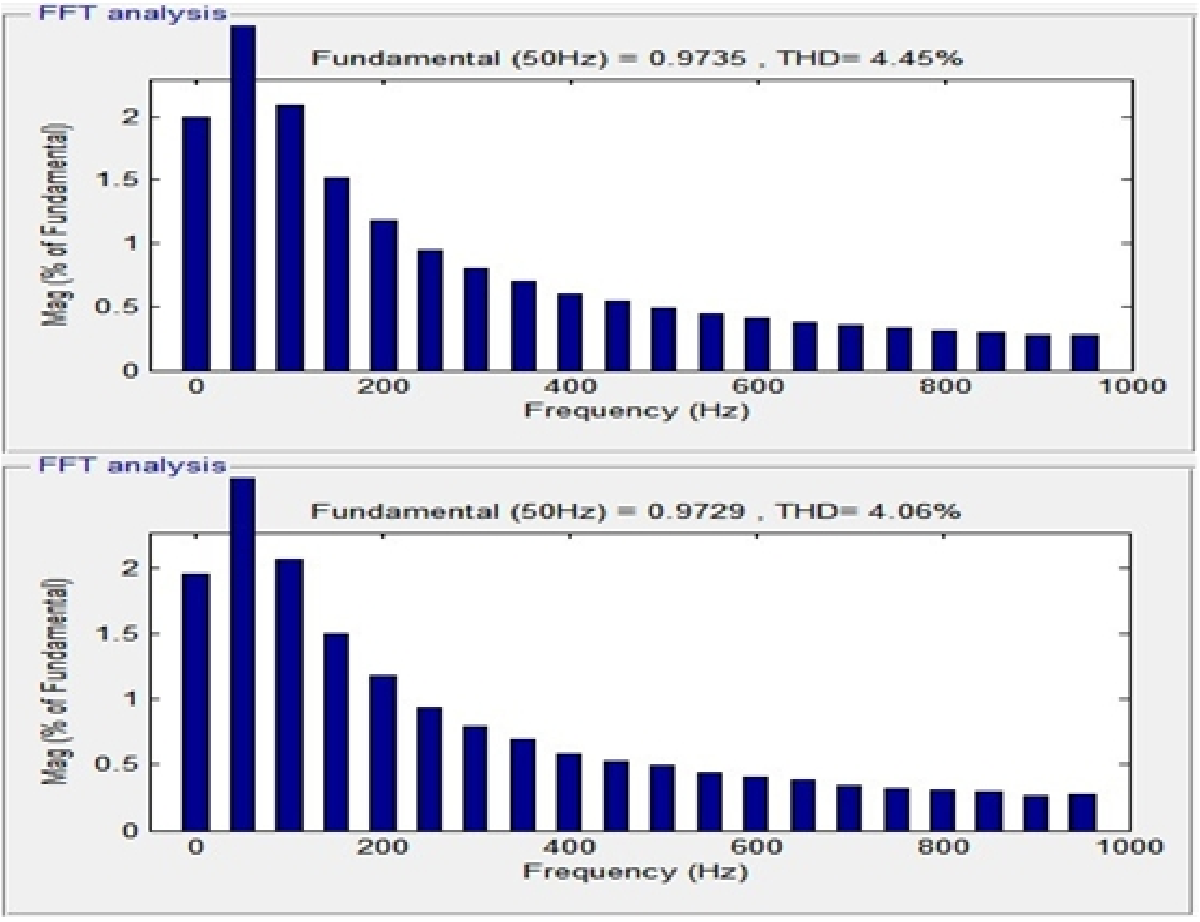

Fig. 5.6 Spectrum Analysis of Proposed UPQC

The implementation of the proposed approach in the application of lowering harmonics using the fuzzy logic driven UPQC is illustrated in the figure of merits outlined above. The approach has been effectively implemented for the elimination of harmonics in unbalanced load conditions, and its analysis and enhancement have been compared to traditional methods, uncompensated research, and current research. Table 5.1 also shows a harmonic analysis of the proposed methodology.

6.CONCLUSION

The main power quality problems of commercial and industrial utilities customers are the voltage slopes and current harmonics. Sensitive electronic equipment, abnormal installation operations and enormous economic losses can result from these energy quality issues. Sustainable power systems are now attractive for over a decade, allowing energy users to boost their efficiency and quality of power supply. UPQC, made up of two voltage source inverters that have a standard DC connation, is a specialised power unit that can perform APF and DVR tasks simultaneously. However, UPQC provides its customers with no separate power levels since UPQC only addresses end-user power problems.

7.REFERENCES

[1] Toshifiimi Ise, Yusuke Hayashi and Kiichiro Tsuji, "Definitions of Power Quality Levels and the Simplest Approach for Unbundled Power Quality Services", *IEEE Proceedings of Ninth International Conference on Harmonics and Quality of Power*, vol.-2, pp. 385 - 390, 2000.

[2] Roger C.Dugan, Mark F. McGranaghan, Surya Santoso and H.Wayne Beaty, "Electrical Power Systems Quality", *The McGraw-Hill*, Second Edition, 2004.

[3] K.R.Padiyar, "Facts Controllers in Power Transmission and Distribution", *New Age International Publishers*, 2007.

[4] Alexander Kusko, Sc.D. and Marc T.Thompson, "Power Quality in Electrical Systems", *McGraw-Hill*, 2007.

[5] Swati Pal, Pallavi Singh Bondriya and Yogesh Pahariya, "MATLAB-Simulink model based Shunt Active Power Filter using Fuzzy Logic Controller to Minimize the Harmonics", *International Journal of Scientific and Reserch Publications*, vol.-3, no.-12, pp. 2250-3153, December 2013.

[6] N.G.Hingorani, "Introducing Custom Power", *IEEE Spectrum*, vol.-32, no.-6, pp. 41-48, June 1995.

[7] Arindam Ghosh and Gerard Ledwhich, "Power Quality Enhancement Using Custom Power Devices", *Kluwer Academic Publishers*, 2002.

[8] Angelo Baggini, "Handbook of Power Quality", *John Wiley & Sons Ltd*, 2008.

[9] T.A.Short, "Distribution Reliability and Power Quality", *Taylor & Francis Group, CRC Press*, 2006.

[10] Afshin Lashkar Ara and Seyed Ali Nabavi Niaki,“Comparison of The Facts Equipment Operation In Transmission and Distribution Systems”, *17th International Conference on Electricity Distribution Barcelona*, Session No.2, Paper No.44, pp. 12-15 May 2003.

[11] Juan W. Dixon, Gustavo Venegas and Luis A. Mor´an, “A Series Active Power Filter Based on a Sinusoidal Current-Controlled Voltage-Source Inverter”, *IEEE Transactions on Industrial Electronics*, vol.-44, no.-5, pp. 612-620, October 1997.