IJEASM
International Journal of Engineering Applied Science and Management
ISSN (Online): 2582-6948
Vol. 3 Issue 4, April 2022

Power Quality Improvement Using Unified Power Quality Conditioner (UPQC)

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Abstract: *The advance use of power electronic devices introduces harmonics in the supply system which creates a problem in the quality of power delivered. Good Power Quality is very much important for our day to day use of appliances in both industrial and domestic sectors. Researchers have tried and implemented many useful technology for removing all the voltage and current related harmonic occurrence problems which in turn improves the quality of power delivered to the power system. The prime focus of this thesis is the implementation of control strategies like SRF theory and instantaneous power (p-q) for the operation of Unified Power Quality Conditioner (UPQC) which is one of the recent technology that includes both series and shunt active power filter operating at the same time and thereby improves all the current and voltage related problem like voltage sag/swell, flicker, etc. at the same time and helps in reduction of Total Harmonic Distortion (THD). In this work, it is shown via MATLAB simulation how UPQC model can be used to decrease the % THD in source voltage, source current and load voltage waveforms created due to non-linear/ sensitive loads usage.*

Keywords: *SRF, THD, UPQC, MATLAB, Power quality*

1. Introduction

1.1 Background

In the present scenario non-linear loads have become extremely important and people are becoming dependent on it. Few of these non-linear loads are televisions, printing and fax machines, rectifiers, inverters, speed drives, AC, etc. Harmonics are introduced in the lines due to the extensive use of these loads in our everyday purpose. The stability of any electrical devices depends on its voltage and current waveforms. If the fundamental waveform is sinusoidal, and its harmonics are sinusoidal too then these harmonics occurs in integral multiples of the fundamental waveform. Due to this harmonic distortion created by nonlinear loads several problems are caused in the appliances used in our purpose like: motor getting overheated, increase in several types of losses, permanent damage of equipment in the worst case, high error in meter reading, etc. Hence removal of these harmonics or harmonic mitigation from voltage and current waveforms are of great concern for electrical engineers. Due to the harmonics introduction in the lines by the nonlinear loads other problems of concern are voltage swell, voltage sag, flicker occurring in voltage, etc and thereby disturbing he overall power supply. In older days passive filters using tuned LC components were in very much use for improvement of power quality by removing voltage and current harmonics. But due to its high cost, resonance problems, large size and many more these filters are not in much use in the present days. All these problems are now improved by the use of active power filters (APF) and more advanced hybrid filters using several new technology. Series Active Filter is utilised for mitigation of voltage quality problems and Shunt Active Filter(SAF) is helpful for removing the disturbances present in the current waveforms.

1.2 Power Quality (PQ) Problems

The voltage quality which a consumer gets for operation of load or given from some particular utility is very important. PQ problem deals with deviation of voltage/current from their ideal sinusoidal waveforms. The power quality became mainly poor at those typical locations where we connect the loads in the grid. Power Quality has its various definitions and importance as per the its usage by which we define them in the process. From designer perspective, PQ is defined as that there should be no variation in voltage and there should be complete absence of noise generated in grounding system. From the point of view of a utility engineer, it is voltage availability or outage minutes. For the end users how much feasible is the available power in order to drive various types of loads is defined as power quality.

1.3 Active Power Filters

APF's are the electrical equipment, which are connected sometimes as series model or shunt model and sometimes as a combination of both series and shunt filters. UPQC is a model where both series and shunt APF connected via a common dc link capacitor are implemented in one circuit only and they help to solve all voltage and current harmonics problems simultaneously. Series APF are used for solving only voltage harmonics problems like voltage sag, swell, flickering etc whereas shunt APF is used for solving only current harmonics problems and hence improves power factor by supplying reactive power continuously regulates DC link voltage. Hence service reliability is achieved with the combination of series and shunt filter in the form of UPQC.

UPQC (Unified Power Quality Conditioner)

UPQC is the integration of series and shunt active filters, connected back-to back on the dc side and sharing a common DC capacitor .The series component of the UPQC is responsible for mitigation of the supply side disturbances: voltage sags/swells, flicker, voltage unbalance and harmonics. It inserts voltages so as to maintain the load voltages at a desired level; balanced and distortion free. The shunt component is responsible for mitigating the current quality problems caused by the consumer: poor power factor, load harmonic currents, load unbalance etc. It injects currents in the ac system such that the source currents become balanced sinusoids and in phase with the source voltages. Recent trends in the power generation and distribution system shows that the penetration level of DG into the grid has increased considerably. End user appliances are becoming more sensitive to power quality conditions. Extensive research on CPDs for the mitigation of PQ problems is also being carried out. CPDs can find significant application in integrating solar and wind energy sources to the grid. They play an important role in the concept of the custom power park in delivering quality power at various levels.

The quality of power supply has become a major concern of electricity users. If the quality of power supply is not good then it may result in malfunctions, instabilities, short life time, and so on. Poor power quality is mainly due to adjustable speed drives. The power quality disturbances are classified as impulse, notches, momentary interruption, voltage sag, voltage swell, harmonic distortion and flicker. These disturbances may cause malfunctioning of the equipments. To improve the quality of power for non-linear and voltage sensitive load, UPQC is one of the best solutions [6]. Unified Power Quality Conditioner (UPQC) consists of two IGBT based Voltage source converters (VSC), one shunt and one series cascaded by a common DC bus. The shunt converter is connected in parallel to the load. It provides VAR support to the load and supply harmonic currents. Whenever the supply voltage undergoes sag then series converter injects suitable voltage with supply. Thus UPQC improves the power quality by preventing load current harmonics and by correcting the input power factor. Voltage-Source Converter based Custom power devices are increasingly being used in custom power applications for improving the power quality (PQ) of power distribution systems. Devices such as distribution static compensator (DSTATCOM) and dynamic voltage restorer (DVR) are extensively being used in power quality improvement. A DSTATCOM can compensate for distortion and unbalance in a load such that a balanced sinusoidal current flows through the feeder. It can also regulate the voltage of a distribution bus. A DVR can compensate for voltage sag/swell and distortion in the supply side voltage such that the voltage across a sensitive/critical load terminal is perfectly regulated. A unified power-quality conditioner (UPQC) can perform the functions of both DSTATCOM and DVR. The UPQC consists of two voltage-source converters (VSCs) that are connected to a common dc bus. One of the VSCs is connected in series with a distribution feeder, while the other one is connected in shunt with the same feeder. The dc links of both VSCs are supplied through a common dc capacitor. This paper presents the new connection for UPQC. i.e. Interline Unified Power Quality Conditioner (IUPQC) which is the most sophisticated mitigating device for the power quality disturbances. It was firstly introduced to mitigate the current harmonics and voltage disturbances. The main aim of the IUPQC is to hold the voltages Vt1 and Vt2 constant against voltage sag/swell/any power disturbances in either of the feeders. Many contributions were introduced to modify the configurations and the control algorithms to enhance its performance.

2. Power Quality Improvement Using IUPQC

There are three ways to solve the problems of power quality and provide quality power customized to meet user's requirement: System improvement use mitigation equipment based on power electronics improvement of equipment immunity of these, the best way to handle power quality problems is to mitigate the effects of distorted voltage or current at the point of common coupling. This would ensure that the harmonics are restricted from entering the distribution system and contaminating the system power as a whole. Thereby, the other loads connected to the system are provided with clean power. This paper illustrates how various power quality disturbances are mitigated using equipment called IUPQC. With UPQC without UPQC Simulation results
Comparison of Waveforms for a voltage sag of 81% with and without UPQC
(a) rms load voltage (pu)
(b) Instantaneous load voltages (kV)
(c) Instantaneous load currents (kA)
(d) Load and source active powers (MW)
(e) Load and source reactive power (MVAR)

Mitigation of Voltage Sag
A 3-phase supply voltage (11kv, 50Hz) with impulsive sag of 0.5 p.u magnitude and the duration about 0.5 to 30 cycles is taken. With the system operating in the steady state, 15 cycle impulsive voltage sag of 0.5 p.u magnitude is occurring at 0.3 m/sec for which the peak of the supply voltage reduces from its nominal value of 10kv to 5kv.
The Total Harmonic Distortion (THD) at load side is found to be 0.95%. The source voltage THD is effectively found to be 0.045%. In order to supply the balanced power required to the load, the DC capacitor voltage drops as soon as the sag occurs. As the sag is removed the capacitor voltage returns to the steady state. Load voltage (kV) (c) Three phase load and source r.m.s voltage (d) Voltage injected by UPQC (kV) (e) Load current (KA) (f) Source and load active powers (MW) (g) Source and load reactive powers (MVAR).

Mitigation of Voltage Swell
A 3-phase supply voltage (11kv, 50Hz) with momentary swell of 0.26 pu magnitude and the duration about 0.5 to 30 cycles is taken. With the system operating in the steady state, a 21 cycle momentary voltage swell of 0.26 p.u magnitude is occurring at 0.3 m/sec for which the peak of the supply voltage raises from its nominal value of 10kv to 12.6kV. In order to supply the balanced power required to the load, the DC capacitor voltage raises as soon as the swell occurs. As the swell is removed the capacitor voltage returns to the steady state. The Total Harmonic Distortion (THD) at load side is found to be 1.71%. The source voltage THD is effectively found to be 0.045%.

3. Review of Literature

Today power quality is the most essential variable in both levels of transmission and distribution. It's very much essential to take care of the acceptable limits of power quality.
N.G hingorani has given the basic concept of custom power. It gives the reliability of power flow. Solid state circuit breakers, static compensators, static condensers provide the basis of the custom power.
Chellali Benachaiba et al. describes DVR, a compelling custom power gadget for moderating voltage swell and sag. Also gave the method of voltage restoration at the PCC i.e. the point of common coupling, DVR principles and also described about the different methods of voltage injection. DVR can handle both unbalanced and balanced situations effectively.
Mehmet Ucar et al. proposed the p-q theory which is also called instantaneous reactive power theory, another control calculation has been suggested for three-phase four-wire and four-leg parallel active power filter (APF), based on this proposal, for remuneration of reactive power, harmonic currents suppressions, and balancing of the load currents under non-perfect mains voltage conditions and unbalanced non-linear load.
Kamran and Habetler Has proposed a new method taking into account the deadbeat control, that treats UPQC inverter association as a solitary unit. The whole concept has been exhibited utilizing a 3-phase series-shunt active filter. It also uses a fullorder predictive state observer. Modeling the system as a solitary multi-input, multioutput framework has many advantages. It showed faster dynamic response and steady state precision and thereby giving enhanced control execution over the independently controlled converters.
K.H Kwan et al. propose a model predictive control design for the UPQC. Use of kalman filters makes it easy for the extraction of principal and harmonic parts of the given load current and the supplied voltage. The model predictive controller had been designed based on the state space model of the UPQC. The MPC controller proved beneficial in regulating the error in supplied voltage and the load current thereby regulating both supply voltage and load current. It is helpful in mitigating load variation, sag and swell.
Bhim Singh et al. proposed a control method for the DVR i.e. dynamic voltage restorer in order to overcome the

problems in the quality of power and regulate the terminal voltage. For regulation of dc bus voltage of the DVR and the terminal voltage proportional integral (PI) controllers are used. Synchronous reference frame hypothesis is likewise utilized for the extraction of fundamental component of the terminal voltage.

V.Khadkikar et al. introduced a control procedure for UPQC. The control methodology depends on UVTG (unit vector template generation). Voltage harmonics present in the utility voltage. Steady state analysis and mathematical analysis of UPQC is given. Parallel APF maintains the overall power balance in the entire network. The current harmonics and input voltage harmonics can be repaid proficiently by the proposed control system.

4. Proposed Methodology

The standards in Power quality (IEEE-519) has compelled the engineers for limiting the total harmonic distortion (THD) to an acceptable range which is mostly caused due to daily and regular usage of power electronic devices in industries and domestic appliances. The total harmonic distortion, or THD, of a signal is a measurement of the harmonic distortion present and is defined as the ratio of the sum of the powers of all harmonic components to the power of the fundamental frequency. Mathematically it is given as:-

$$THD\% = 100 \times \sqrt{\sum_{n\neq 1}^{\infty} \left(\frac{I_{sn}^2}{I_{s1}^2}\right)}$$

Instantaneous power theory or p-q theory is useful for the analysis of both transient-state and steady state. In this method the commanding or driving signals required for filter operation is obtained from instantaneous active and reactive power and hence there is no need of phase synchronization of phase.

Instantaneous Power Theory

An theory on the basis of instantaneous power in three phase system either in the presence or absence of neutral wire. This p-q approach is valid for operation under all conditions namely transient and steady state operation. This theory makes use of some famous transformation models defined like Clarkes Transformation. Here the voltage and current waveforms are sensed and then made to transform from a-b-c coordinates to $\alpha - \beta - 0$ coordinates. After this transformation, based on a certain set of equation we calculate active and reactive power and then eliminate the power components having harmonics in it by passing through a certain suitable low pass filter of suitable frequency. This new set of power and already derived new voltages in a different coordinate namely $\alpha - \beta - 0$ coordinates ,we again find out the reference source current in this frame only and then using Inverse Clarkes Transformation we convert this reference source current again back to a-b-c coordinates. This new reference source current is then compared against actual sensed source current waveforms and the error is driven through a hysteresis controller with a certain band for getting the different gate pulse for the operation of inverter. A simple block diagram explaining the complete operation of this important p-q theory is given below-

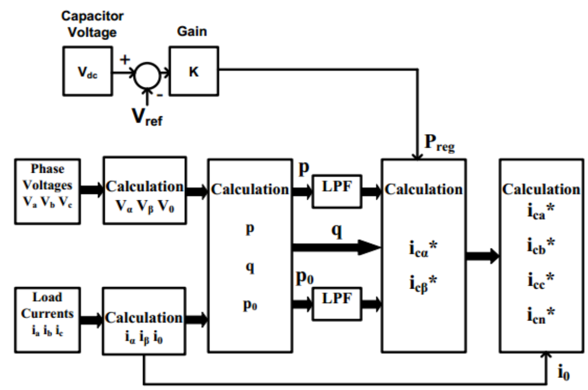

Fig 1 P-Q Control Strategy to Generate Reference Current

Analysis of P-Q Approach

Clarkes transformation needed for converting source voltage and current from a-b-c to $\alpha - \beta - 0$ coordinate is given by following matrix:-

$$\begin{bmatrix} V_{0s} \\ V_{\alpha s} \\ V_{\beta s} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_{sa} \\ V_{sb} \\ V_{sc} \end{bmatrix}$$

Similarly current transformation is:-

$$\begin{bmatrix} i_{0s} \\ i_{\alpha s} \\ i_{\beta s} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{vmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{vmatrix} \begin{bmatrix} i_{sa} \\ i_{sb} \\ i_{sc} \end{bmatrix}$$

3-∅ instantaneous power is given by:-

$$P_{3\emptyset}(t) = V_{sa}i_{sa} + V_{sb}i_{sb} + V_{sc}i_{sc} = V_{\alpha s}i_{\alpha s} + V_{\beta s}i_{\beta s} + V_{0s}i_{0s}$$

$$= p_a(t) + p_b(t) + p_c(t) = p_{\alpha s}(t) + p_{\beta s}(t) + p_{0s}(t)$$

$$= p_r(t) + p_{0s}(t)$$

Here we define $pr\ (t) = p\alpha s(t) + p\beta s(t)$ as instantaneous real power & $pos(t) = p0s(t)$ as inst. Power of zero sequence. Here we can note down an important benefit of this transformation in which separation of system zero sequence component is easily done.

The active (Ps) and reactive power (Qs) is then calculated by the following equations:-

$$\begin{bmatrix} P_s \\ Q_s \end{bmatrix} = \begin{bmatrix} V_{\alpha s} & V_{\beta s} \\ -V_{\beta s} & V_{\alpha s} \end{bmatrix} \begin{bmatrix} i_{\alpha s} \\ i_{\beta s} \end{bmatrix}$$

Hence from above matrix we can write $Qs = V\alpha s i\beta s - V\beta s\ i\alpha s$. In terms of a-b-c components Qs is written as:-

$$Q_s = \frac{[(V_{sa}-V_{sb})i_{sc} + (V_{sb}-V_{sc})i_{sa} + (V_{sc}-V_{sa})i_{sb}]}{\sqrt{3}}$$

Hence 3-∅ active power is again rewritten as:-

$P3\emptyset(t) = P\alpha + P\beta + P0s$

$= P\alpha p + P\alpha q + P\beta p + P\beta q + P0s$

$= P\alpha p + P\beta p + P0s$

We define all power abbreviations as:-

$P\alpha p$- α axis instantaneous active power.

$P\beta p$- β axis instantaneous active power.

$P\alpha q$- α axis instantaneous reactive power.

$P\beta q$- β axis instantaneous reactive power.

Here it is observed that reactive power is corresponding to those parts of instantaneous power which depends on imaginary power Qs in every independent phase and it becomes zero when added ($P\alpha q + P\beta q = 0$.) in a two phase $\alpha - \beta$ system.

Instantaneous real power Ps, tells us net energy every second being transferred from source to load and vice-versa at each instant, which depends only on current and voltage in α & β phases and has no zero sequence present.

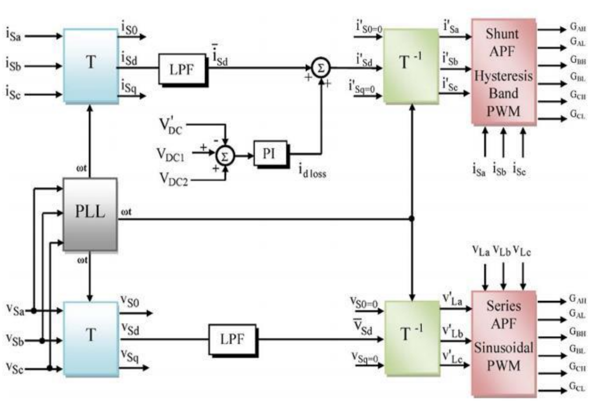

Fig 2 SRF Control For UPQC Operation

The new transformed instantaneous source current in *d-q-0* frame namely i_{sd} & i_{sq} again includes in it both oscillating components ($\tilde{i}_{sd}$ & $\tilde{i}_{sq}$)and average components ($\overline{i_{sd}}$ & $\overline{i_{sq}}$)as well.

Oscillating component will contain in it a combination of harmonic and negative sequence component whereas the average component is including only positive sequence current component which corresponds to reactive current. The zero sequence part namely i_{s0} will appear under unbalanced load conditions. In our SRF method average component of positive-sequence ($\overline{i_{sd}}$) in the d-axis and the zero- and negative-sequence component (i_{s0} & i_{sq}) in the 0- and q-axes of the source currents, in for compensating harmonics and unbalances produced in the non-linear load. Series APF injects active power in the power system for compensating the active power losses of the UPQC power circuit, which results in regulation of dc-link voltage across capacitor. A part of active power is taken from the power system by shunt APF to make dc-link voltage constant. For this task, the voltage of dc-link is compared with a set reference value (V_{dc}), and then passed via a PI controller whose output is the required active current (i_{dloss}). The d-component of source current i.e i_{sd} is passed via a LPF to get its average component i.e ($\overline{i_{sd}}$). Now this average component and required active current i.e $idloss$ are added to get fundamental reference component.

In today's distribution system power electronics based gadgets have gotten to be the most essential part. They have a numerous advantages but on the other hand they also show many lacunas. They draw harmonic current along with the fundamental power frequency which contaminates the distribution system. Keeping in mind the end goal to give specialized answers for the new difficulties forced on distribution system, the idea flexible AC transmission systems (FACTS) has been incorporated. These FACTS devices use to upgrade the controllability and to build power exchange ability of the transmission framework. Two methodologies are there for the control of reactive and active power one utilizes traditional thyristor switched capacitors (TSC) and thyristor switched reactors (TSR), and alternate uses self-commutated Switching converters. Both the plans help to productively regulate the real and reactive power, yet as it were the second one can be utilized to remunerate current and voltage harmonics. In addition, self-commutated switching converters introduce a superior response time and more remuneration adaptability. 2.1 STATIC VAR COMPENSATOR various types of compensators are used that includes SVC, TSC, TCR, STATCOM etc. Static VAR compensators (SVC) control the AC voltage by creation and absorption of reactive power by the passive elements like resistor and capacitor. SVC mainly contains anti parallel thyristors along with the

International Journal of Engineering Applied Science and Management
ISSN (Online): 2582-6948
Vol. 3 Issue 4, April 2022

passive elements. If its thyristor switched capacitor then the passive element is capacitor and reactor in case of thyristor controlled reactor. The main problem with the utilization of SVC is that the reactive power took care of by the SVC is restricted by the passive element size. 2.2 STATCOM is one of the standout FACT devices amongst all the FACTS devices. It may contain a voltage source converter or a current source converter and provides a better response. It helps in maintaining a good voltage profile and improves the stability. If we are using this in the distribution system then it can be referred as D-STATCOM i.e. the distribution STATCOM. It mainly consists of an inverter circuit, inductor, a capacitor acting as DC source, control circuit for reference current generation. D-STATCOM helps in compensation of the load harmonic as it acts as a current source.

In addition to this it as many more advantages like source current balancing, suppression of DC offset in the load and it helps the load to work at power factor of unity. 2.3 DYNAMIC VOLTAGE RESTORER Dynamic voltage restorer (DVR) provides series compensation. It consists of a voltage source inverter in series with the supply line that helps in achievement of a particular load voltage. At the point when an outside DC voltage source is used for VSI, the DVR can be utilized for compensation of voltage harmonics, management of load voltage, and to remunerate voltage imbalance.

5. Results and Discussion

5.1 Single Phase Shunt Active Power Filter

For the contents discussed for single phase shunt active filter the Simulink diagram with the said control strategy is given below:-

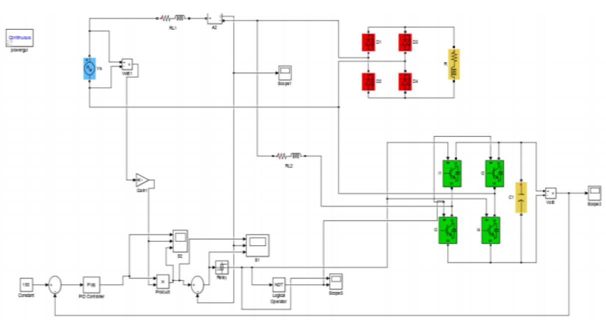

Fig 3 MATLAB Simulation of Single Phase Shunt APF

System Parameters:
Supply voltage (single phase): 165 volt;
Frequency: 50Hz , DC capacitor: 2000μF
Source Rs= 1ohm & Ls=25mH
Filter parameters: R=0.5ohm & L=2.4mH.
Non-linear rectifier load: $R1$= 10ohm & $L1$ =100mH.
The results of the simulation model for source current with and without shunt APF are shown below:

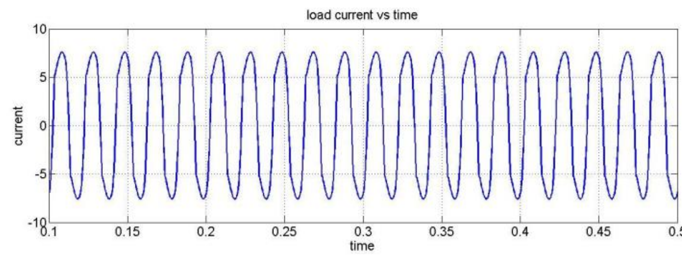

Fig 4 Load Current without Shunt APF

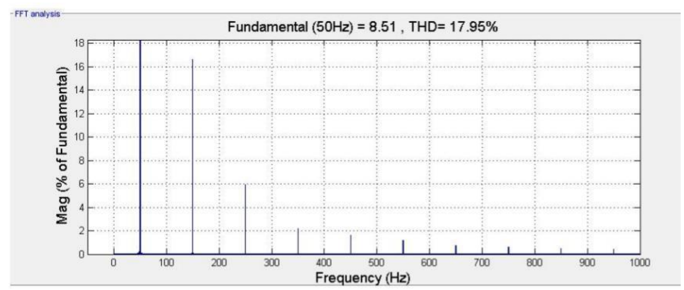

Fig: 5 Load Current Harmonic Spectrum Without Shunt APF

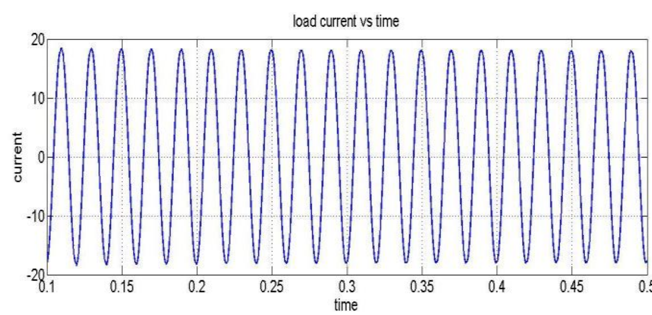

Fig: 6 Load Current With Shunt APF

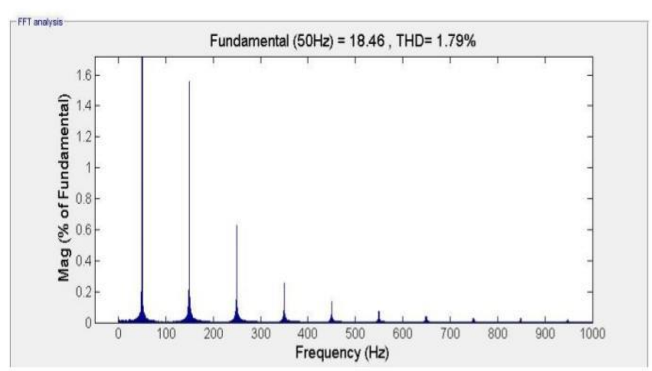

Fig 7 Load Current Harmonic Spectrum With Shunt APF

5.2 Discussion

The load current of system with non linear load in absence of shunt APF is seen in Fig 4 and the total harmonic distortion (THD) in load current as shown in Fig 5. without the use of shunt active power filter(SAPF) is found to be 17.95% .Now after introducing shunt APF the new improved load current waveform is seen in Fig. 6 with the use of shunt active power filter its THD is shown in Fig 7 & is found to be 1.79% which is within the harmonic limits.

5.3 Result of Complete UPQC Model with Non-Linear Load

A configuration of UPQC model simulated given below:-

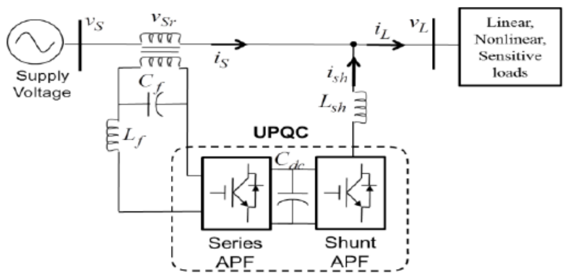

Fig 8 UPQC Model to Be Simulated

Table 4.1 UPQC Simulation Parameters

Source voltage- 220V (phase)	Shunt passive filter Parameter: Lsh=3.5Mh, Rsh=5ohm Csh=4.7 μF
Frequency: 50Hz	$Vdc\ ref$ = 500V C=2200 μF
Ls=1mH & Rs= 0.1ohm	Non-linear load: Rdc=30ohm Ldc=11.5mH
Series Filter inductance Lse=1.5mH Series passive filter=Rse=5ohm Cse=25μF	P-I controller: Kp=1.7 & Ki=0.2

Before applying the UPQC in the system we sensed the source voltage, source current, load voltage and load current in presence of the non-linear load in our system. Due to the non-linear load we get distortions the supply voltage, current and also load voltage. The waveforms for all the sensed voltages and currents before application of UPQC is shown below for A-phase:-

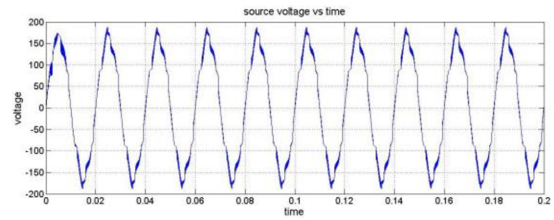

Fig 9 Source Voltage(A-Phase) In Non-Linear Load

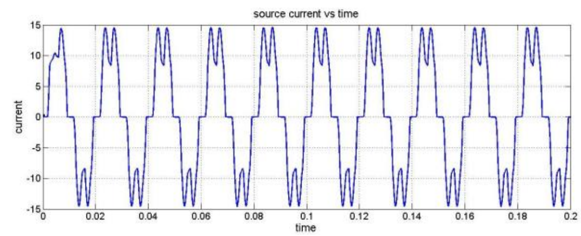

Fig 10 Source Current (A-Phase) In Non-Linear Load

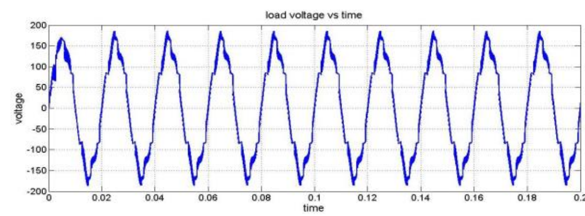

Fig 11 Load Voltage (A-Phase) In Non-Linear Load

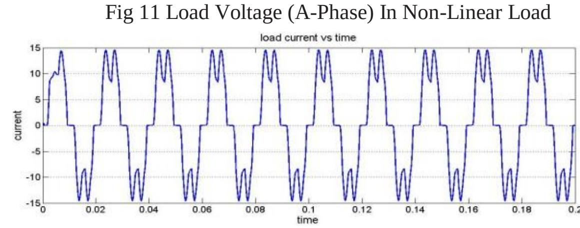

Fig 12 Load Current (A-Phase) In Non-Linear Load

The waveforms obtained after the application of UPQC in the given system compensated the harmonics introduced in the source voltages, source current and load voltage due to the presence of non-linear load. The results of the improved waveform due to UPQC operation for the considered A-phase is shown in the following figures:-

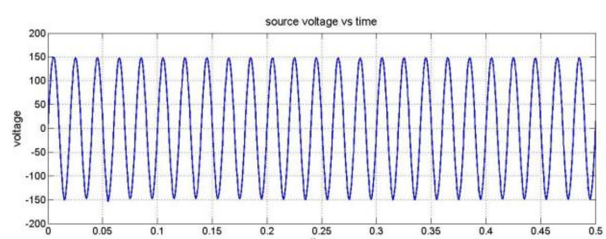

Fig 13 Source Voltage (A-Phase) After UPQC Compensation In Non-Linear Load

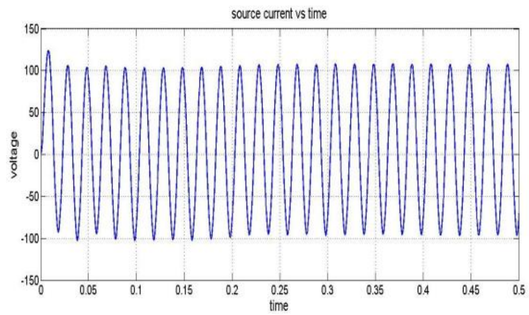

Fig 14 Source Current (A-Phase) After UPQC Compensation In Non-Linear Load

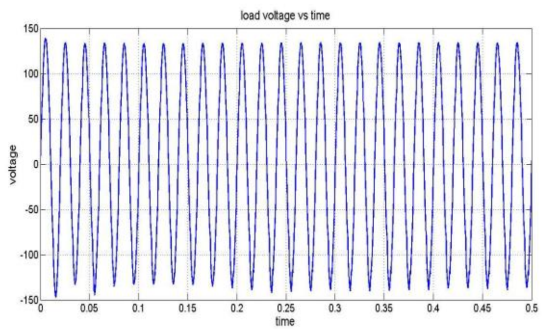

Fig 15 Load Voltage (A-Phase) After UPQC Compensation In Non-Linear Load

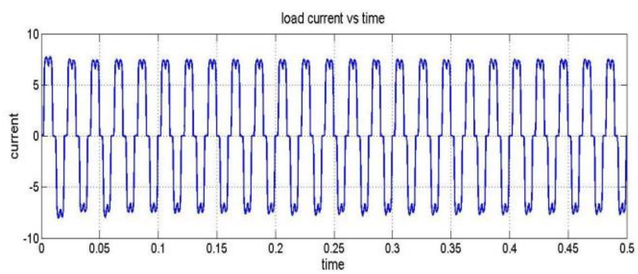

Fig 16 Load Current(A-Phase) After UPQC Compensation In Non-Linear Load

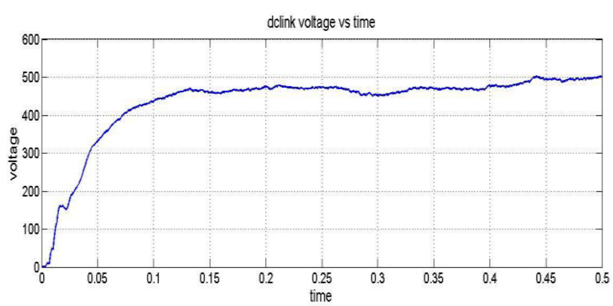

Fig 17 Dc Link Voltage across Capacitor

5.4 Result of THD in Every Phase

Table 4.2 Comparison Of THD Before And After UPQC Application

	THD before Compensation	THD after Compensation
Source voltage A-phase B-phase C-phase	9.36% 9.16% 7.85%	2.23% 2.33% 2.33%
Source current A-phase B-phase C-phase	25.68% 25.78% 25.71%	3.57% 3.43% 3.63%
Load voltage A-phase B-phase C-phase	13.53% 13.24% 11.37%	4.05% 4.10% 4.13%

6. Conclusion

This work describes an improved control strategy for the operation of UPQC system. Several control strategy is studied like p-q theory, SRF based approach, unit vector template generation for the APF operation. The UPQC model is simulated in MATLAB using instantaneous power theory. Shunt part of UPQC removes all the current related harmonic problems in the system and series connected APF of UPQC system removes all voltage harmonics which comes up due to the use of nonlinear load. The overall THD is now improved in the system which is clearly observed from the waveforms and also from Table 4.2 giving the resultant THD before and after UPQC operation. Preventing the harmonics due to presence of nonlinear load is difficult but its controlling is possible and much research work is still going on for the same. Sliding Mode(SM) and feedback linearization strategy of control is an advanced method for the operation of UPQC due to their ease in implementation and robust in external disturbance. Further dSPACE software which is a good interface between real time hardware and computer, it can be used to implement UPQC model using a further new strategy called Fuzzy control method.

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