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SIMULATION OF HYBRID UPQC SYSTEM FOR POWER QUALITY ENHANCEMENT IN GRID

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Abstract: Power quality problems have been resolved in past using shunt passive or active filter. Lately, several solutions have been suggested and the recent developments in FACTS and power devices have opened new opportunities to apply power electronics based solutions to power system problems. The use of power devices is the topic of current research and Unified Power Quality Conditioner (UPQC) is one of the most popular solutions used nowadays. The UPQC as classified in literature as simultaneous control device to control the active power and reactive power and it protects the sensitive load from major disturbances. This paper proposed a reduced rating star-connected transformer based unified power quality conditioner with distributed generator for power quality improvement. This hybrid approach significantly improves the performance of UPQC under unbalance source voltage condition. The UPQC adopted to compensate current and voltage quality problems of sensitive loads and suppressing the load current harmonics under distorted supply conditions. This paper presents a reduced rating star connected hybrid UPQC in distribution systems for simultaneous compensation of load current harmonics, voltage sag/swell and source neutral current. The performance of proposed UPQC has been investigated through extensive simulation studies. From these studies it is observed that the proposed scheme completely compensated the source current harmonics, load current harmonics, voltage sag/swell and neutral current.
Keywords: UPQC, THD, PQ, Hybrid UPQCetc.

I. INTRODUCTION

The recent development in power electronics led to development of solid-state controllers, which are in use with industry, commercial and domestic sectors extensively. The quality of power is being deteriorated due to use of these electronic controllers, which in turn demands quality power from source. A distribution system faces power quality (PQ) problems related to load current and supply voltage. Current related PQ issues are distorted and unbalanced source currents, poor power factor, and source neutral current, whereas voltage related PQ issues are sag, swell, unbalance, flicker, and distortion [1].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 these 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 utilized for mitigation of voltage quality problems and Shunt Active Filter (SAF) is helpful for removing the disturbances present in the current waveforms.

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 it's 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 an 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.

II. BACKGROUND AND RESEARCH OBJECTIVES

Active Power Filter is a shunt connected compensating device. The main purpose of this device is to protect supply currents from current harmonics in the load side (downstream). This is accomplished by rapid shunt current injection to compensate for the harmonics in the load current. Dynamic Voltage Restorer is a series connected compensating device that protects sensitive loads from sag/swell disturbances in the supply side (upstream). This is performed by rapid series voltage injection to compensate for the drop/rise in the supply voltage.The word "Power Quality" is the most important facts of any power delivery system. Low quality power affects electricity consumers in many ways. The lack of quality power can cause loss of damage of equipment, production or appliances, increased in power losses, interference with communication lines. The widespread use of power electronics equipment has produced a significant impact on quality of electric power supply by generating harmonics in voltages and currents. Therefore, it is a very important to maintain a high standard of power quality [1]. The word active power filter (APF) is a widely used terminology in area of a power quality improvement. Conventional power quality mitigation equipments use passive elements and do not always respond correctly as a nature of power system condition change.

In recent years, Unified Power Quality Conditioner which offers customers high quality of power has become an increased concern of engineers. UPQC is a combination of a shunt (APF) and a series compensator (DVR) connected together via a common direct current (DC) link capacitor. These devices compensate the power quality disturbances such as current harmonics and voltage sag/swell to protect sensitive process loads as well as improve service reliability. However, these devices do not allow local distributors to guarantee different quality demand levels to the final customers, because they improve power quality for all the supplied end users. The installation investments are also quite high relative to the power quality level obtained. A solution that has similar performances and advantages, but also makes cost reduction possible, is OPEN UPQC. One modern solution that deals with both load current and supply voltage imperfections is the UPQC. The UPQC is a one of the APF family members. Unified power quality conditioner (UPQC) has been proposed for simultaneously eliminating both types of PQ problems. The UPQC achieves its objectives by integrating series and shunt active power filters (APFs), where both share a common dc link. The combination of APF and DVR concept being relatively new is still being researched. It is considered that this will be a universal solution to all power quality issues because of its voltage and current compensating capability. In order to achieve the mitigation of PQ disturbances, new circuit topologies for UPQC and new control techniques to detect and extract the PQ disturbances should be examined.

The main objectives of this thesis are as follows.

- To describe the power quality definitions, types of the PQ problems, main sources of the PQ problems, negative influences of the PQ problems, PQ standards, solutions to PQ problems and Custom Power concept.
- To present literature survey of APF, DVR and UPQC with their control algorithms and power circuit topologies.
- To find/develop control methods for reference voltage generation and sag/swell detection for UPQC
- To describe the modelling of UPQC
- To evaluate the performance of the UPQC with simulation studies

III. POWER QUALITY ISSUES

The power quality is seriously disturbed due to the widely use of nonlinear loads and various faults in power system. Moreover, the controlling equipment and electronic devices based on computer technology demand higher levels of power quality. This kind of devices are sensitive to small changes of power quality, a short time change on PQ can cause great economical losses. Because of the two reasons mentioned above, no matter for the power business, equipment manufacturers or for electric power customers, power quality problems had become an issue of increasing interest. Under the situation of the deregulation of power industry and competitive market, as the main character of goods, power quality will affect the price of power directly in near future.A number of national and local surveys helped to quantify the statistical aspects of this problem. The most common disturbances and the most commonly affected equipments are illustrated in Figure 3.1. One report shows that power outages and interruptions cost the U.S. economy between $104 billion and $164 billion a year due to equipment damage, materials loss, idled labor and lost production or sales and another $15 billion to $24 billion a year is lost due to power quality phenomena.

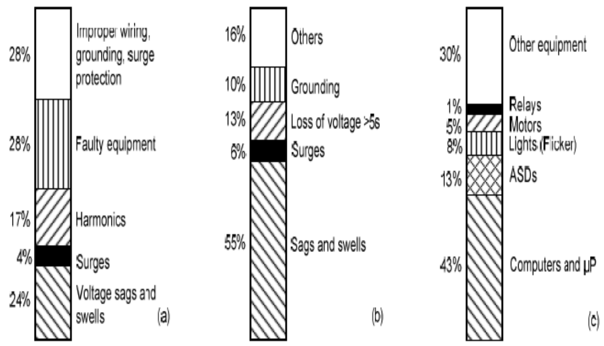

Figure 3.1. Basic disturbances: (a) Causes at customer side, (b) Causes at utility side and (c) Affected equipment

Another survey result is given in Figure 3.2. It is concluded that the voltage sag/swell and harmonics are most common power problems encountered in the industrial processes.

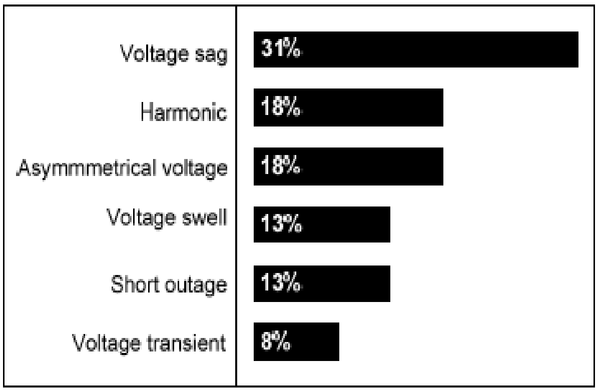

Figure 3.2. Percentage occurrences of PQ disturbances in equipment interruptions

This paper takes into account the most common power quality problems such as voltage sags/swells and current harmonics as shown in Figure 3.3. Together they account for high percentage of the power quality disturbances affecting most commercial and industrial customers. The more detailed descriptions of power quality problems were explained below. Power quality problem is any power problem manifested in voltage, current, or frequency deviation that results in failure or malfunctioning of customer equipment. Power quality is a two-pronged issue, with electronic equipment playing both villain and victim. Most new electronic equipment, while more efficient than its mechanical predecessors, consumes electricity differently than traditional mechanical appliances. Power supply quality issues and resulting problems are consequences of the increasing use of solid state switching devices, nonlinear and power electronically switched loads, electronic type loads .the advent and wide spread of high power semiconductor switches at utilization, distribution and transmission leaves have non sinusoidal currents.

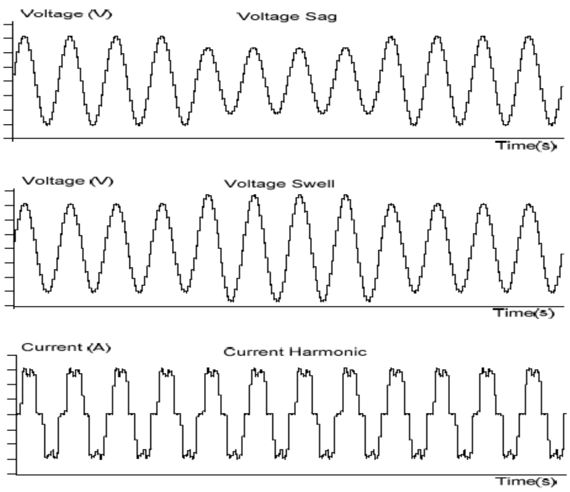

Figure 3.3. Most common types of power quality problems

Current Harmonic Distortion

The harmonic voltage and current distortion are strongly linked with each other because harmonic voltage distortion is mainly due to non-sinusoidal load currents. Current harmonic distortion requires over-rating of series components like transformers and cables. As the series resistance increases with frequency, a distorted current will cause more losses than a sinusoidal current of the same rms value. Types of equipment that generate current harmonics are single-phase loads, switched mode power supplies, electronic fluorescent lighting ballasts, small Uninterruptible Power Supply (UPS) units and variable speed drives.

Voltage Sags

Voltage sag is defined as a decrease to between 0.1 and 0.9 per unit (p.u) in rms voltage at the power frequency for durations from 0.5 cycle to 1 min. Voltage sags are generally related with system faults but can also be caused by energization of heavy loads or starting of large motors and overloaded wiring. The term sag describes a short-duration voltage decrease. Voltage sags and momentary power interruptions are probably the most important Power Quality problem affecting industrial and large commercial customers. These events are usually associated with a fault at some location in the supplying power system. Interruptions occur when the fault is on the circuit supplying the customer. But voltage sags occur even if the faults happen to be far away from the customer's site. Voltage sags lasting only 4-5 cycles can cause a wide range of sensitive customer equipment to drop out. To industrial customers, voltage sag and a momentary interruption are equivalent if both shut their process down. A typical example of voltage sag is shown in fig.3.3.

Voltage Swells

A voltage swell can be defined as an increase to between 1.1 and 1.8 p.u in rms voltage or current at the power frequency for durations from 0.5 cycle to 1 min. The voltage swells are usually associated with system fault conditions, but they are not as common as voltage sags. One way that a swell can occur is from the temporary voltage rise on the un-faulted phases during a single line to ground fault. Swells can also be caused by switching off a large load or energizing a large capacitor bank, insulation breakdown, sudden load reduction and open neutral connection. It causes nuisance tripping and degradation of electrical contacts.A swell is the reverse form of Sag, having an increase in AC Voltage for duration of 0.5 cycles to 1 minute's time. For swells, high-impedance neutral connections, sudden large load reductions, and a single-phase fault on a three phase system are common sources. Swells can cause data errors, light flickering, electrical contact degradation, and semiconductor damage in electronics causing hard server failures. Our power conditioners and UPS Solutions are common solutions for swells.

IV. UPQC FOR P-Q PROBLEM

The power circuits of the proposed UPQC topologies namely UPQC and OPEN UPQC in a three-phase network are shown in Figure 4.1. The shunt unit (APF) is designed to minimize load current harmonics from 23.5% to <5% at the supply side. The series unit (DVR) is designed to inject30% of the network power supplied from a storage system.

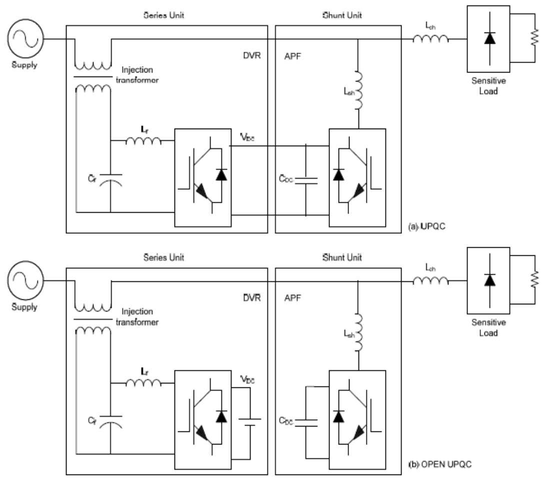

Figure 4.1 Power diagram of (a) Proposed UPQC and (b) OPEN UPQC

UPQCs consist of combined series and shunt APFs for simultaneous compensation of voltage and current. The series APF inserts a voltage, which is added at the point of common coupling (PCC) such that the load end voltage remains unaffected by any voltage disturbance, whereas, the shunt APF is most suitable to compensate for load reactive power demand and unbalance, to eliminate the harmonics from supply current, and to regulate the common DC link voltage [2].

Figure 4.2 shows the basic configuration of the UPQC. The UPQC has two distinct parts:-
• Power circuit formed by series and shunt PWM converters
• UPQC controller

The series PWM converter of the UPQC behaves as a controlled voltage source, that is, it behaves as a series APF, whereas the shunt PWM converter behaves as a controlled current source, as a shunt APF. No power supply is connected at the DC link. It contains only a relatively small DC capacitor as a small energy storage element.

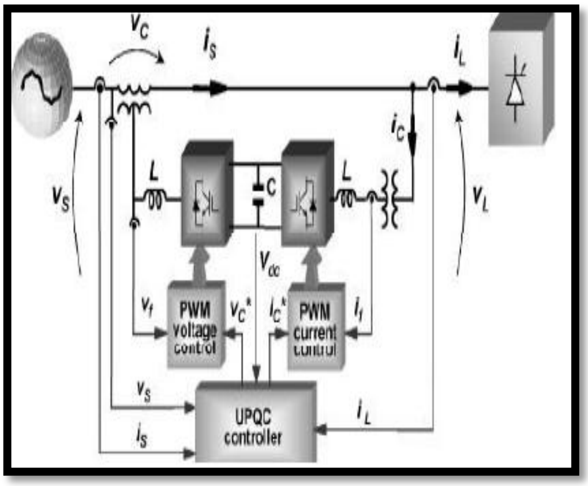

Figure 4.2- Basic configuration of the UPQC [2]

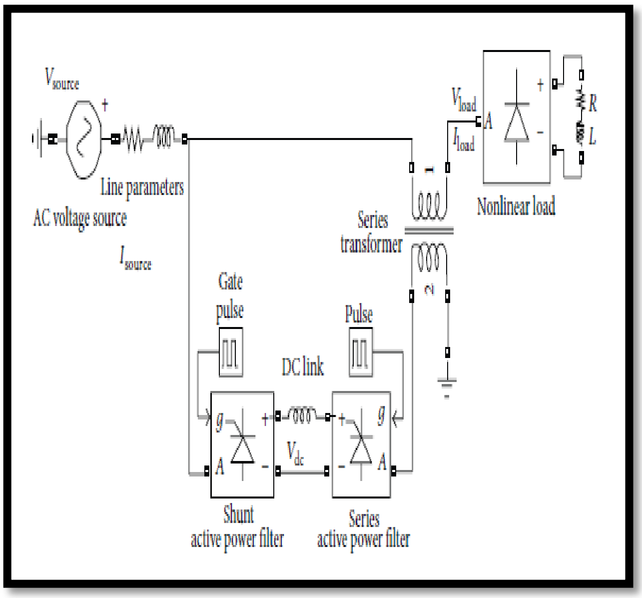

Figure 4.3: The design configuration of UPQC-CSC [3]

In this, the design configuration is right series and left shunt with the current source converter (CSC). In thesis, UPQC-CSC is designed and analysis of the results has been done.

Unified power quality conditioner (UPQC) for nonlinear and voltage sensitive load has following facilities:-

1. It reduces the harmonics in the supply current, so that it can improve utility current quality for nonlinear loads.
2. UPQC provides the VAR requirement of the load, so that the supply voltage and current are always in phase; therefore, no additional power factor correction equipment is required.
3. UPQC maintains load end voltage at the rated value even in the presence of supply voltage sag.

V. SIMULATION AND RESULTS

Matlab Simulation of Voltage Sag Mitigation using UPQC

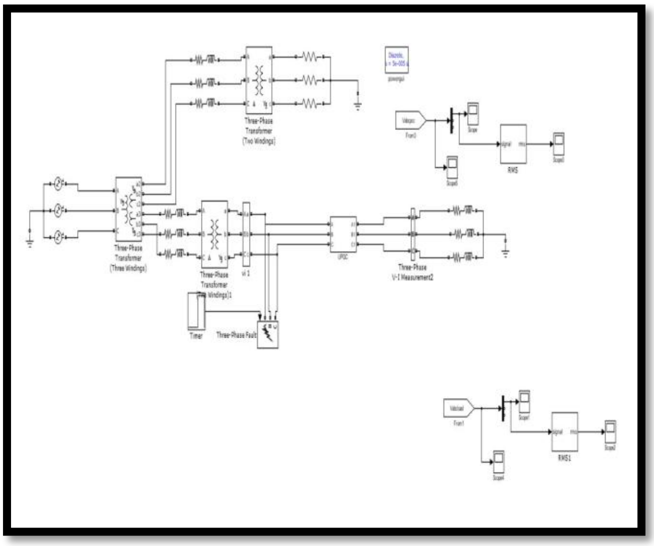
Fig 5.1- Voltage Sag mitigation system using UPQC

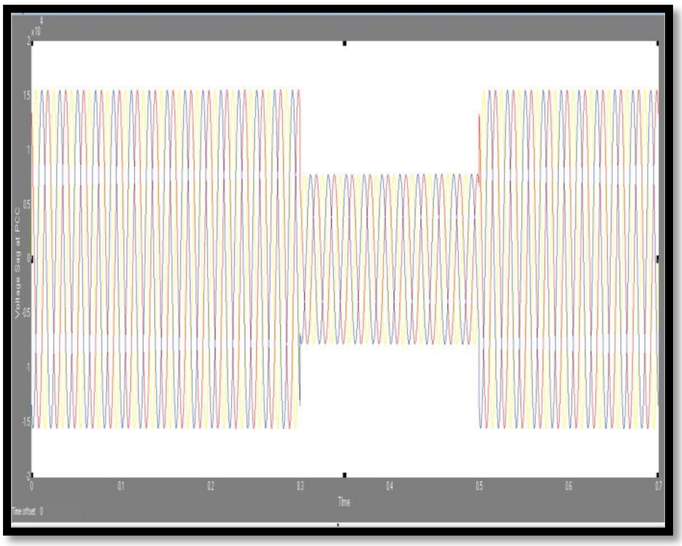
Fig 5.2- Voltage Sag at PCC

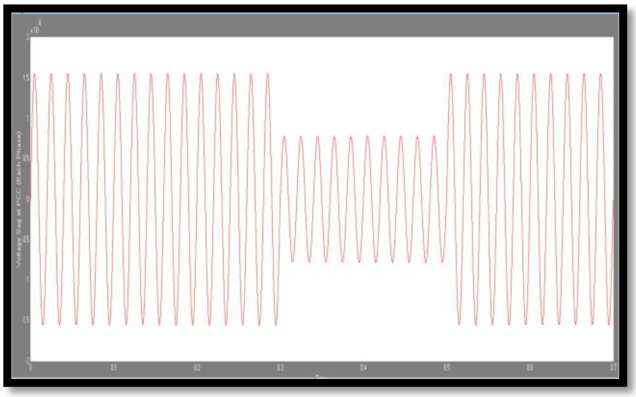

Fig 5.3- Voltage sag effect in individual phase

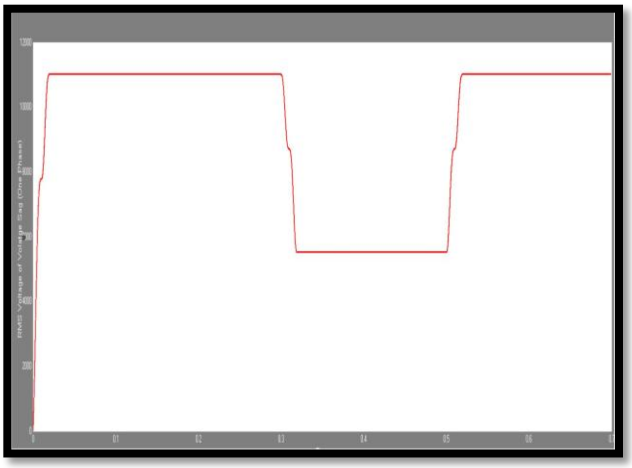

Fig 5.4- RMS Voltage at PCC individual phase (sag condition)

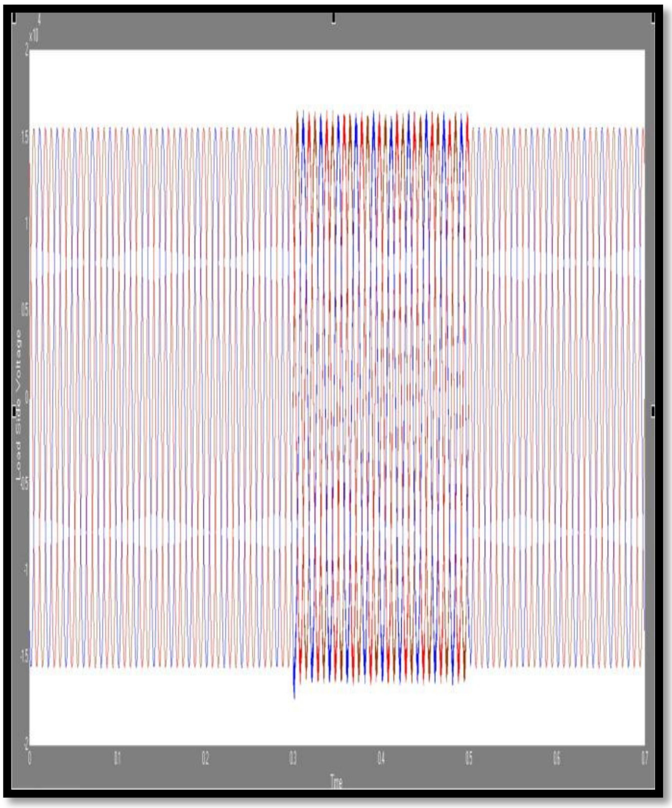

Fig 5.5- Load side voltage with UPQC sag mitigation

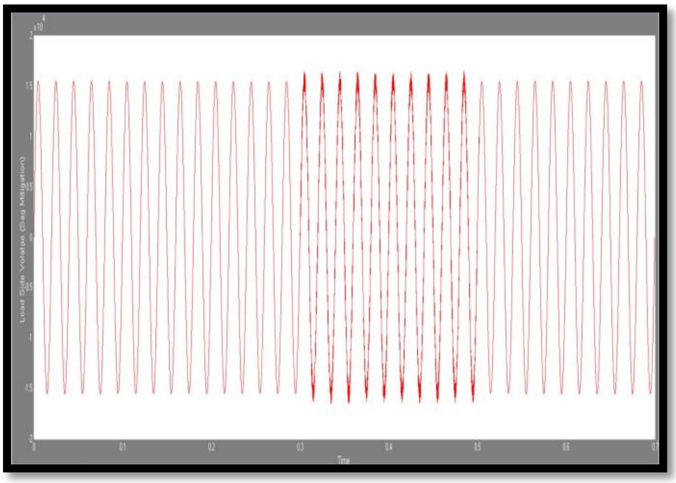

Fig 5.6- Voltage sag mitigation with UPQC in individual phase

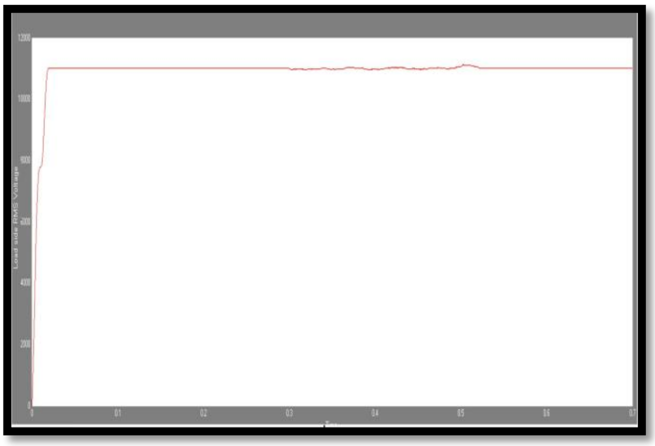

Fig 5.7- RMS Voltage at Load side individual phase (sag mitigation with UPQC)

Matlab Simulation of Voltage Swell Mitigation using UPQC

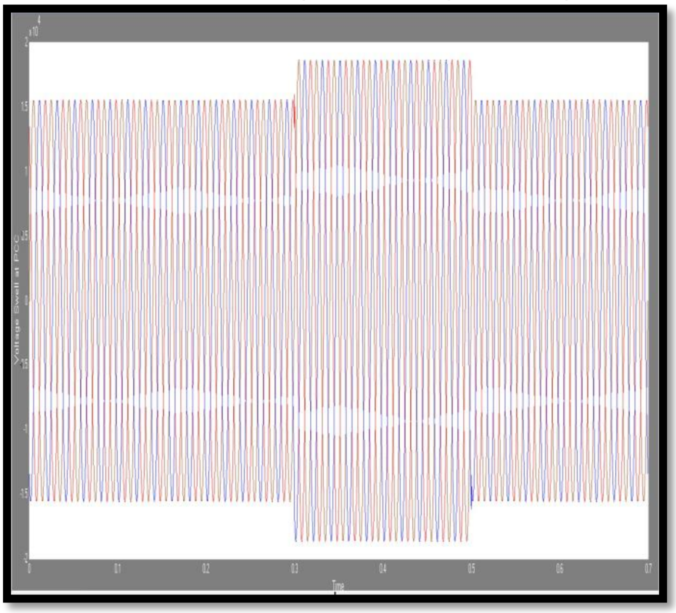

Fig 5.8- Voltage Swell at PCC

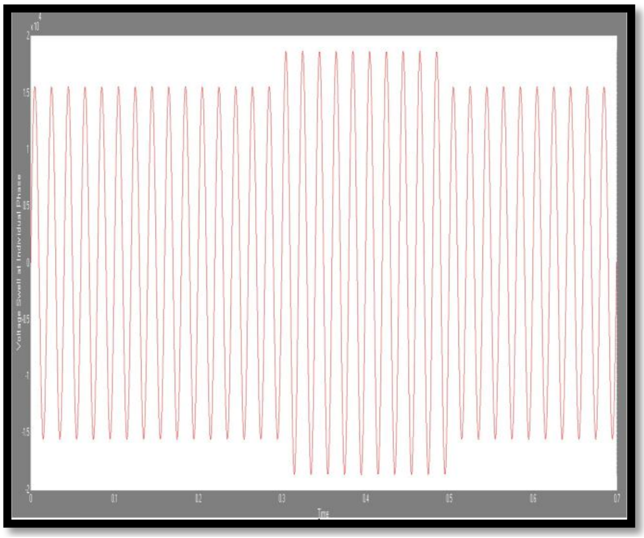

Fig 5.9- Voltage swell effect in individual phase

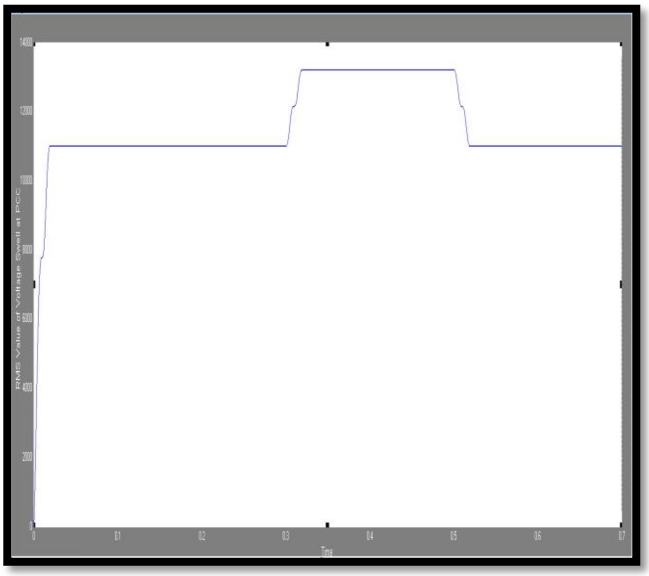

Fig 5.10- RMS Voltage at PCC individual phase (swell condition)

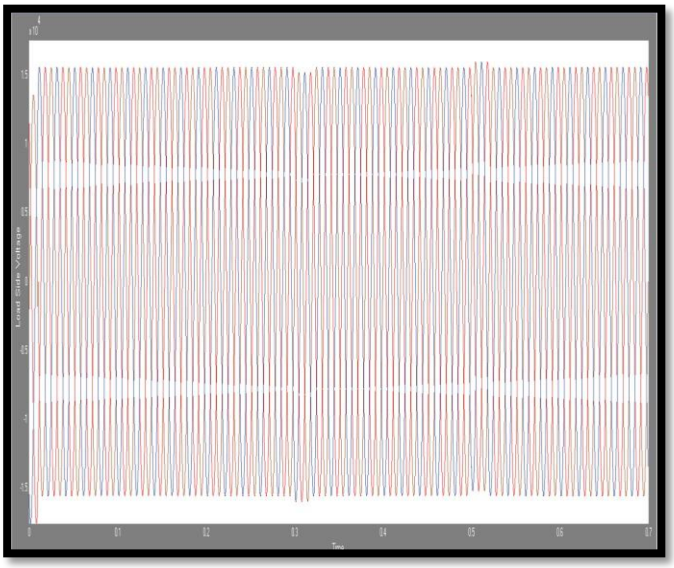

Fig 5.11- Load side voltage with UPQC swell mitigation

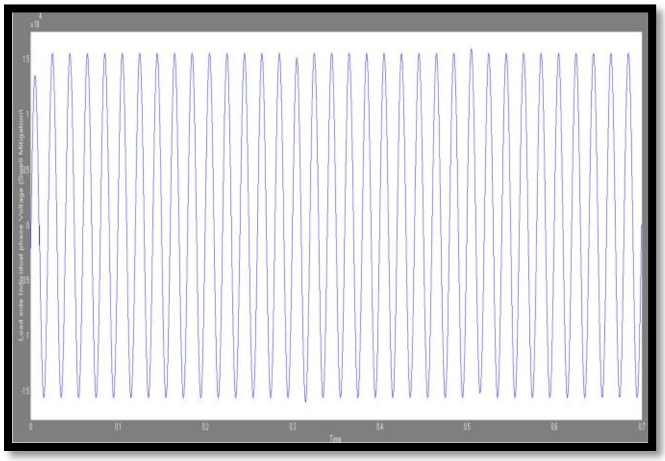

Fig 5.12- Voltage swell mitigation with UPQC in individual phase

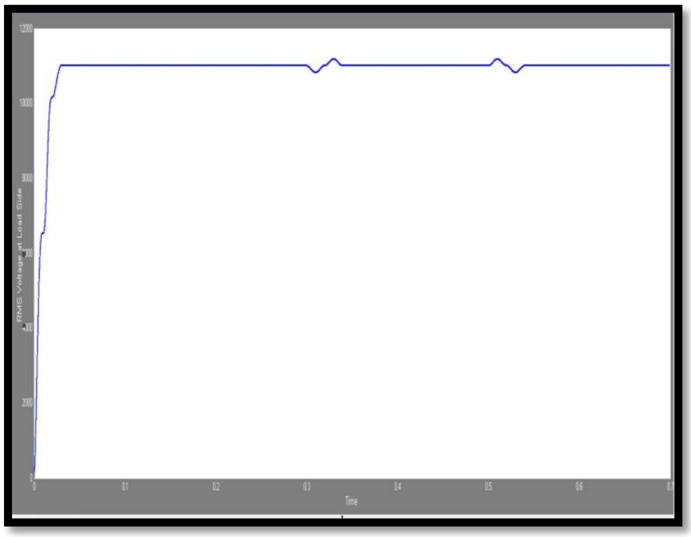

Fig 5.13- RMS Voltage at Load side individual phase (swell mitigation with UPQC)

Matlab Simulation of Hybrid UPQC

The voltage source converter topology is provided for power flow management in Hybrid UPQC. There is two voltage source converter provided at input side of Hybrid UPQC and one VSC is provided at output side.

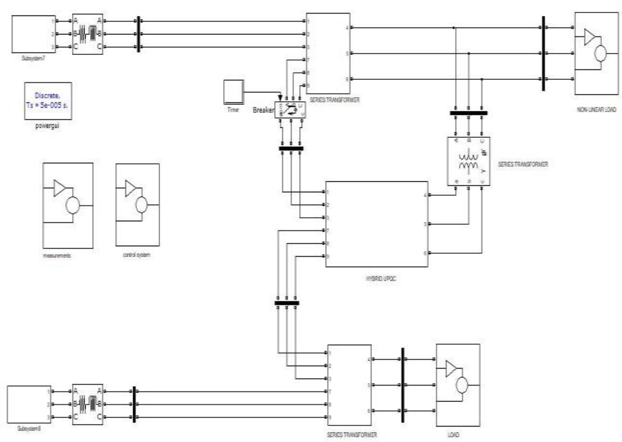

Fig 5.14- Hybrid UPQC Simulation

Sine wave signal is provided at input side for switching pulse control of individual load. There is external time signal is provided to the sine wave. The input of sine wave is varying according to time value. Now the output of this block will add with variable sine wave so the variable output is multiply with constant value.

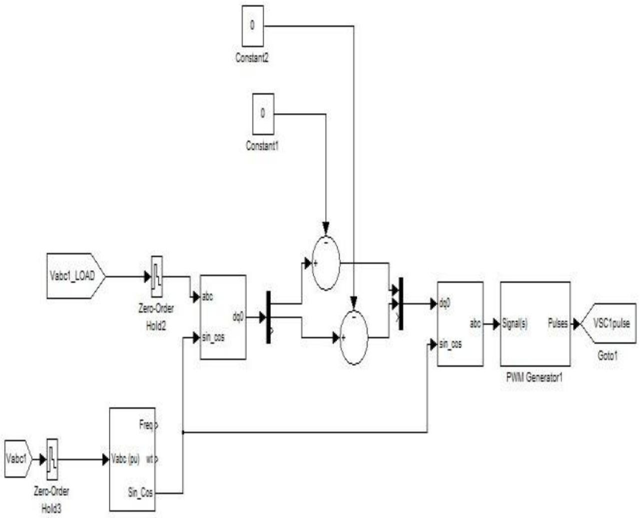

Fig.5.15- VSC Converter-1 Control System

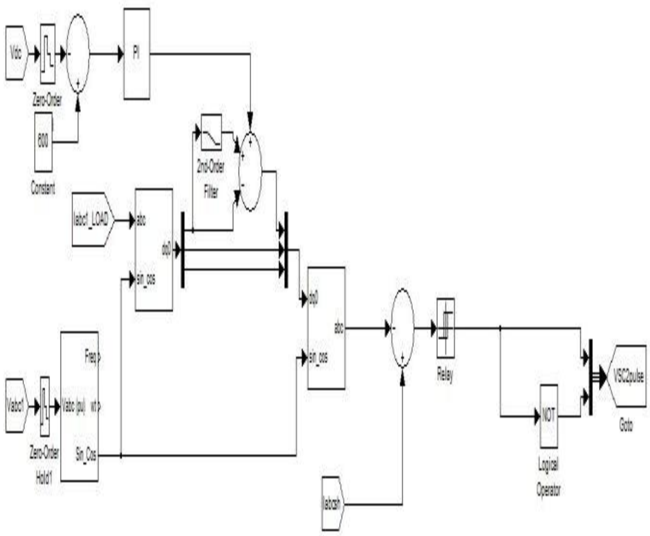

Fig 5.16- VSC Converter-2 Control System

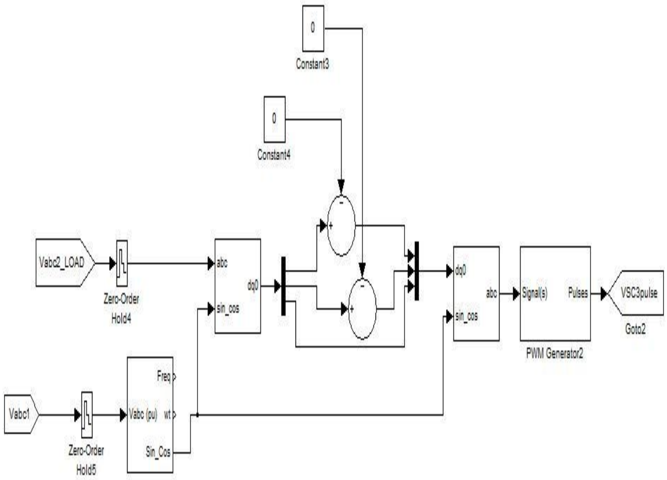

Fig 5.17- VSC Converter-3 Control System

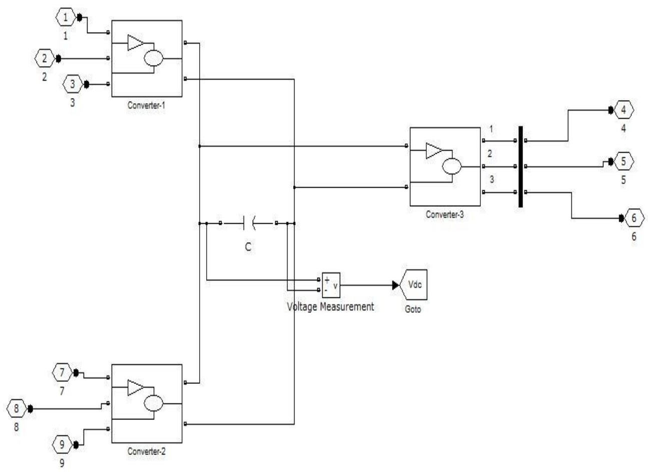

Fig 5.18- VSC Converter Configuration for Hybrid UPQC

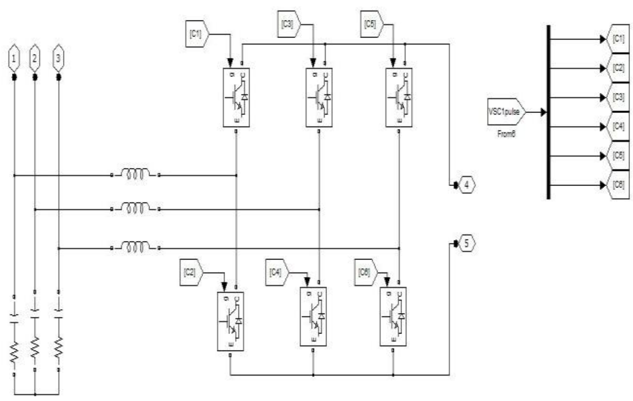

Fig 5.19- VSC Converter Subsystem
Simulation Results

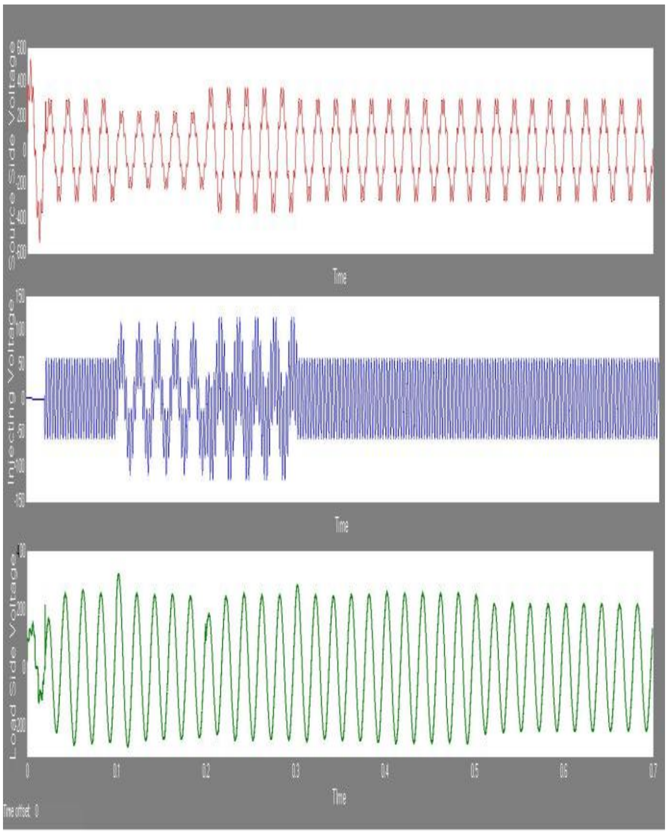

Fig. 5.20-Line-1 Output Parameters

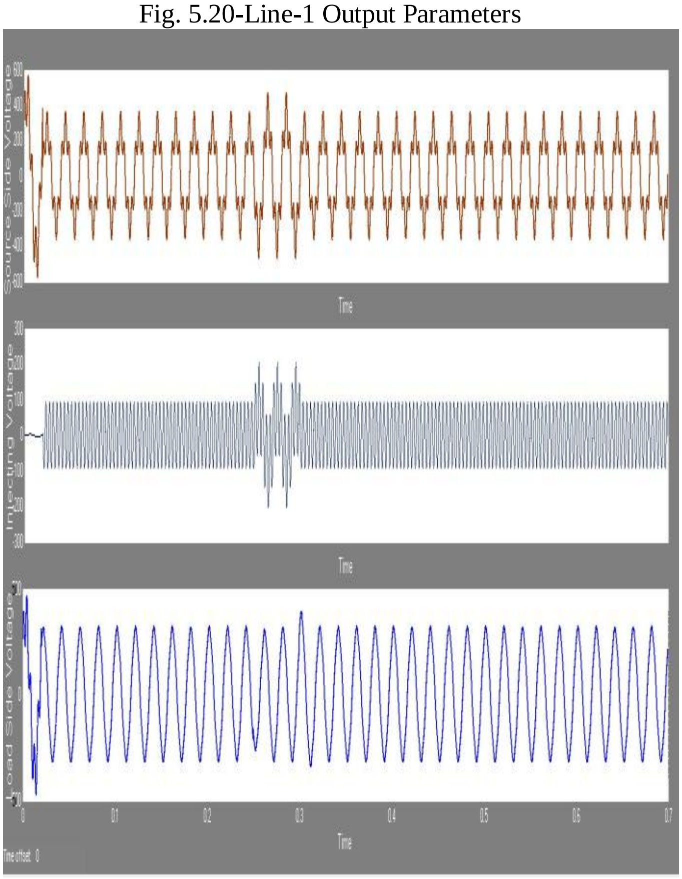

Fig.5.21- Line-2 Output Parameters

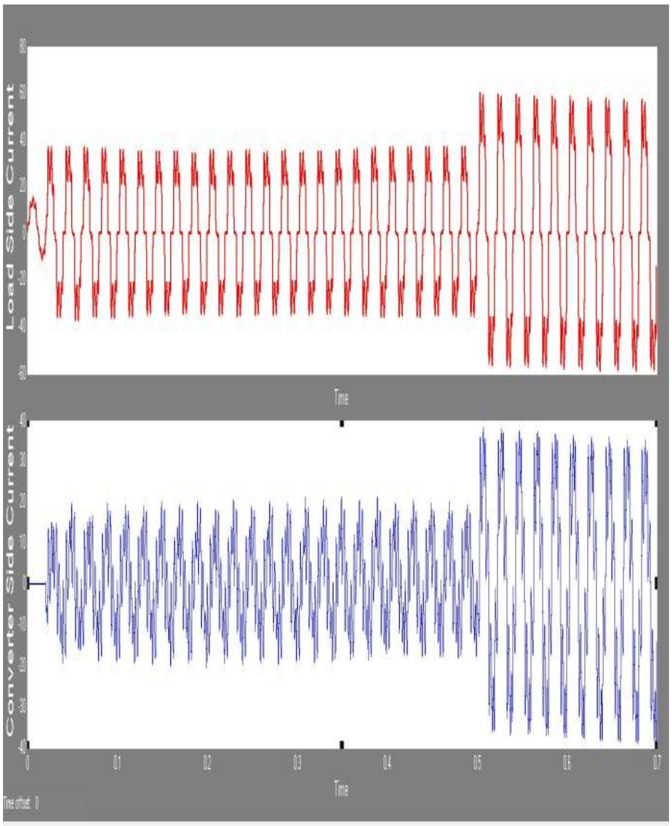

Fig.5.22- Line-1 output current Parameters

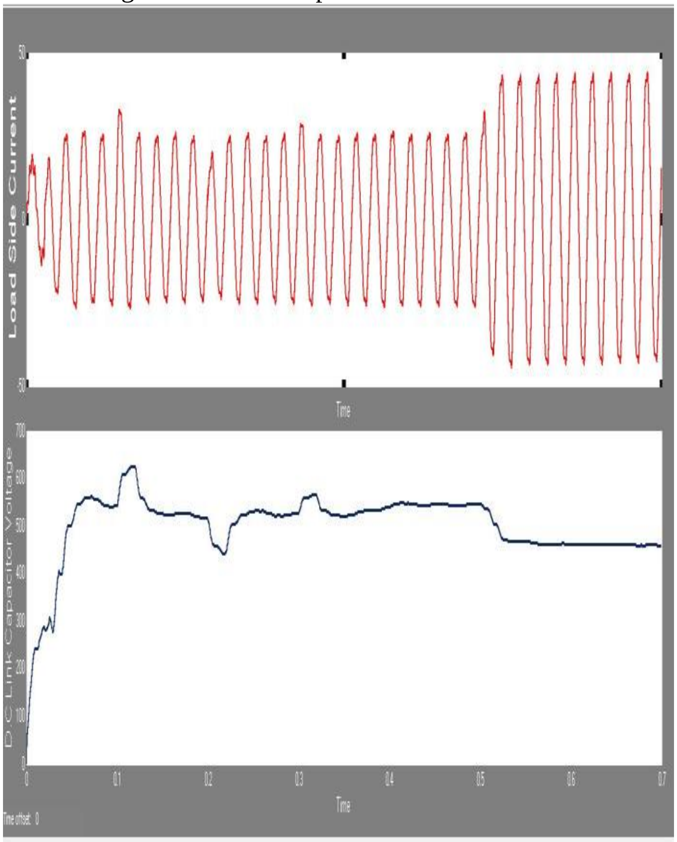

Fig.5.23- output current and D.C link capacitor Parameters

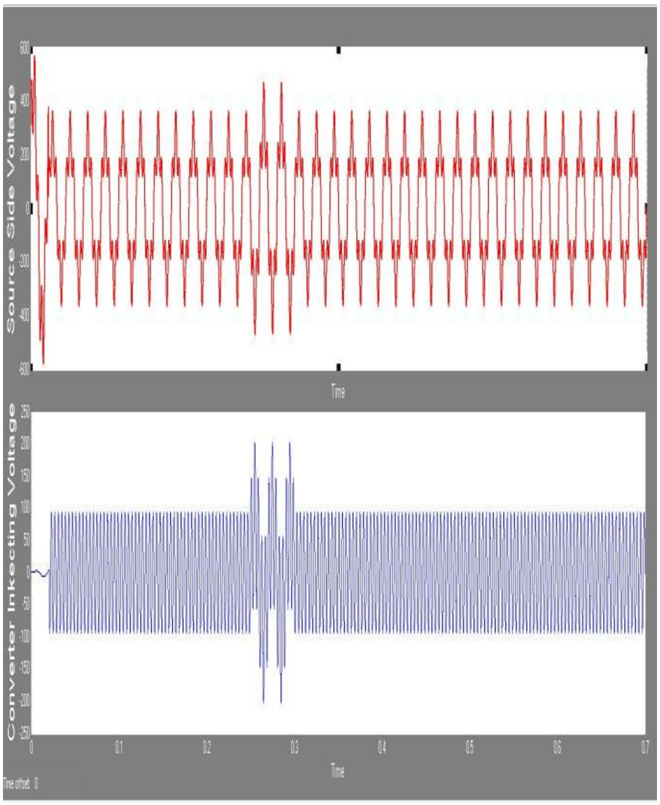

Fig.5.24- Source side and converter side voltage Parameters

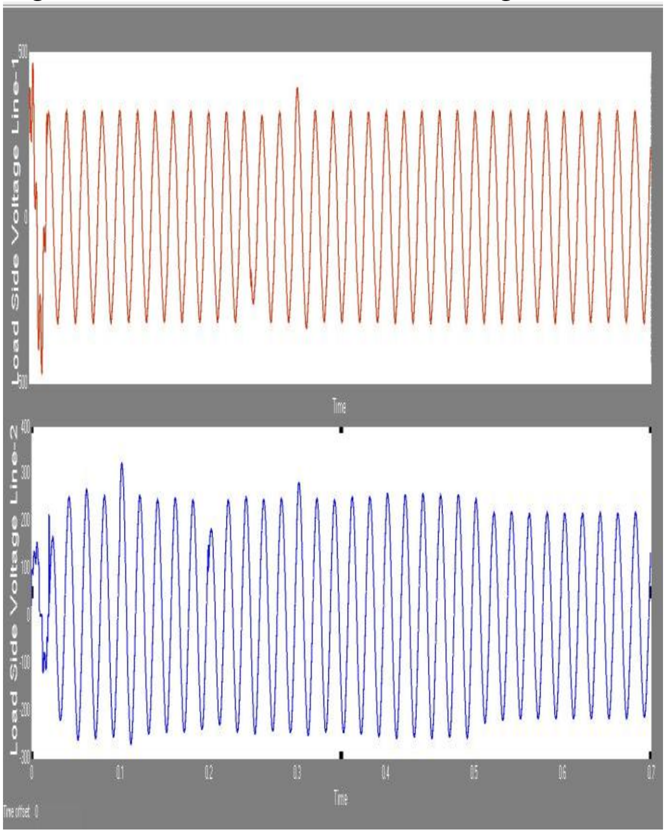

Fig.5.25- Line-1 and Line-2 output Voltage Parameters

THD Analysis for Hybrid UPQC

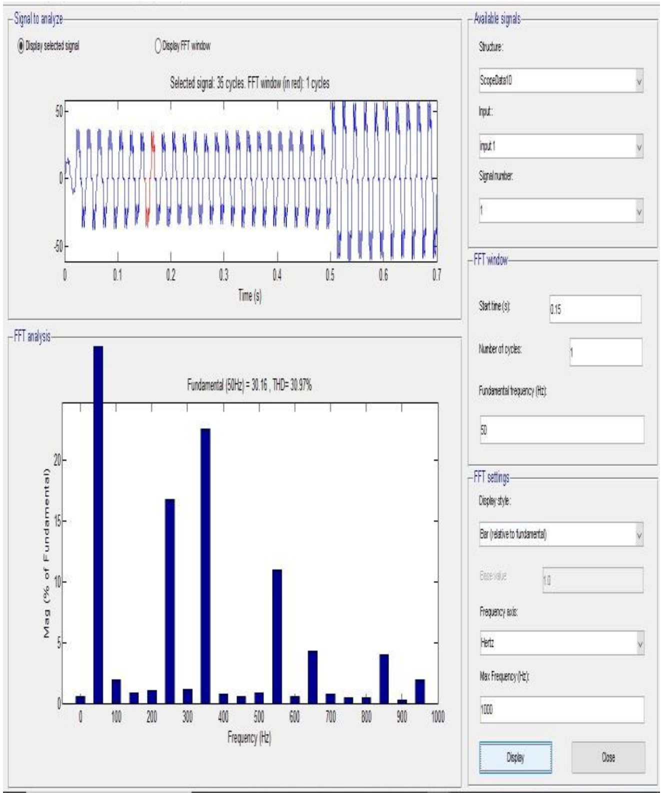

Fig 5.26- THD of Load Current without Hybrid UPQC (for Line-1)

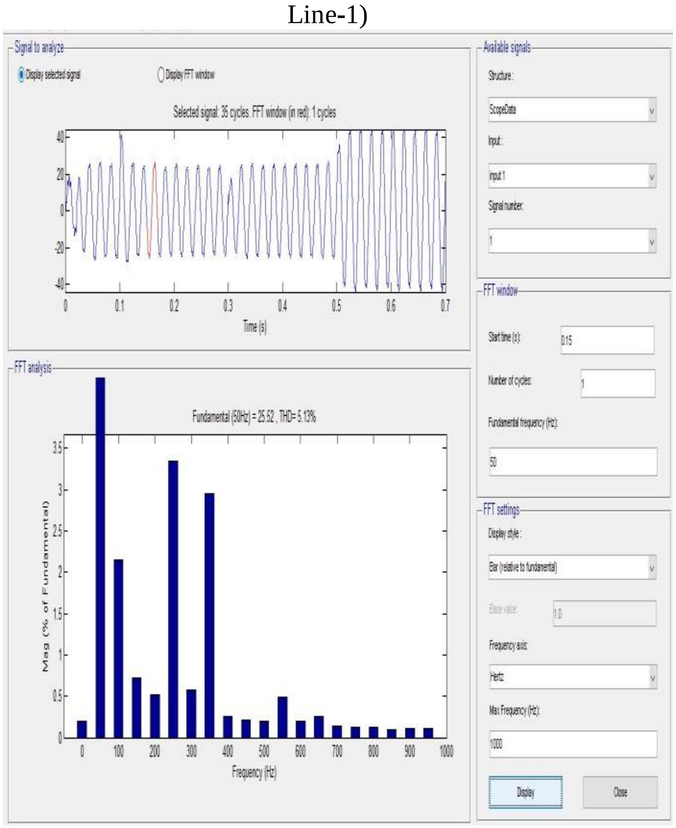

Fig 5.27- THD of Load Current with Hybrid UPQC (for Line-1)

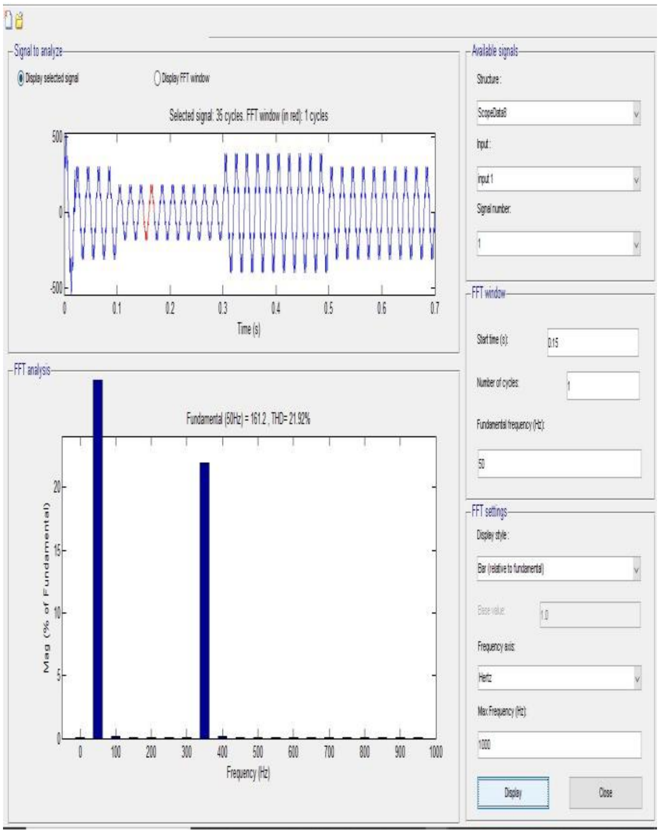

Fig 5.28- THD of Load Voltage without Hybrid UPQC (for Line-1)

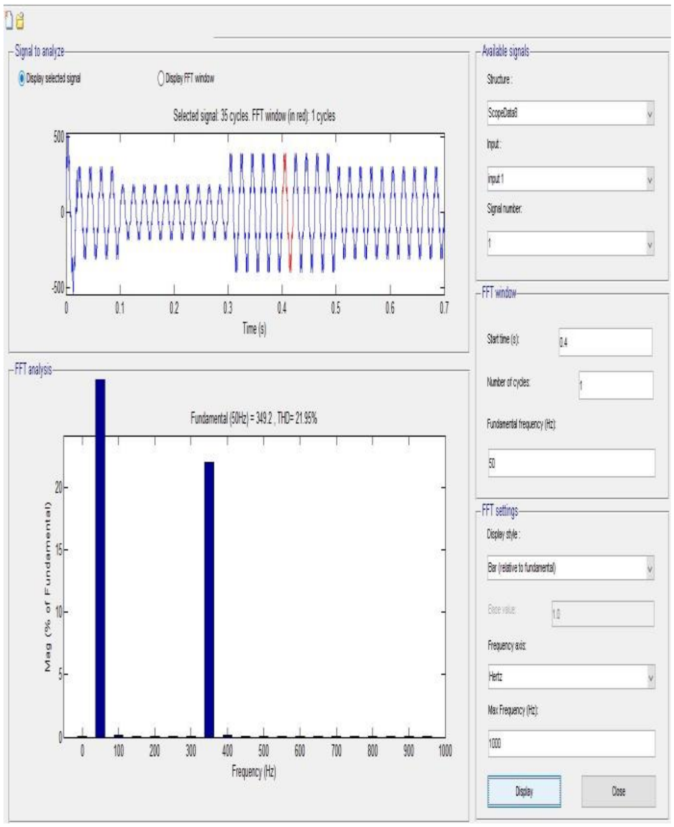

Fig 5.30- THD of Load Voltage without Hybrid UPQC (for Line-2)

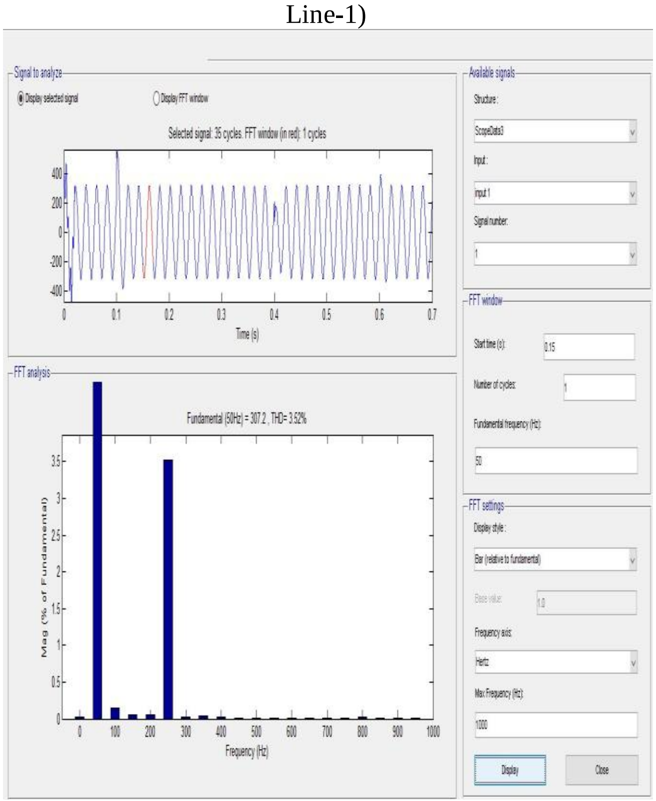

Fig 5.29- THD of Load Voltage with Hybrid UPQC (for Line-1)

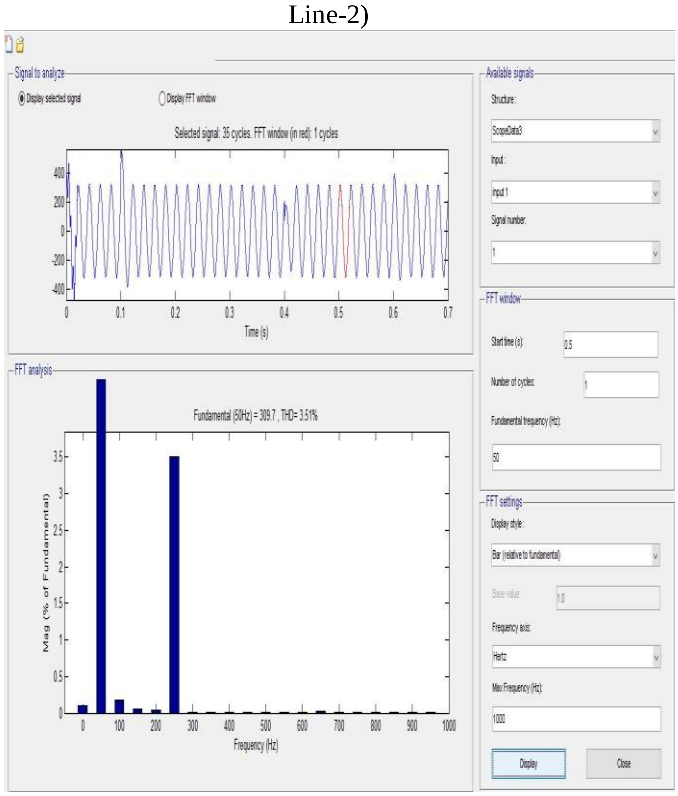

Fig 5.31- THD of Load Voltage with Hybrid UPQC (for Line-2)

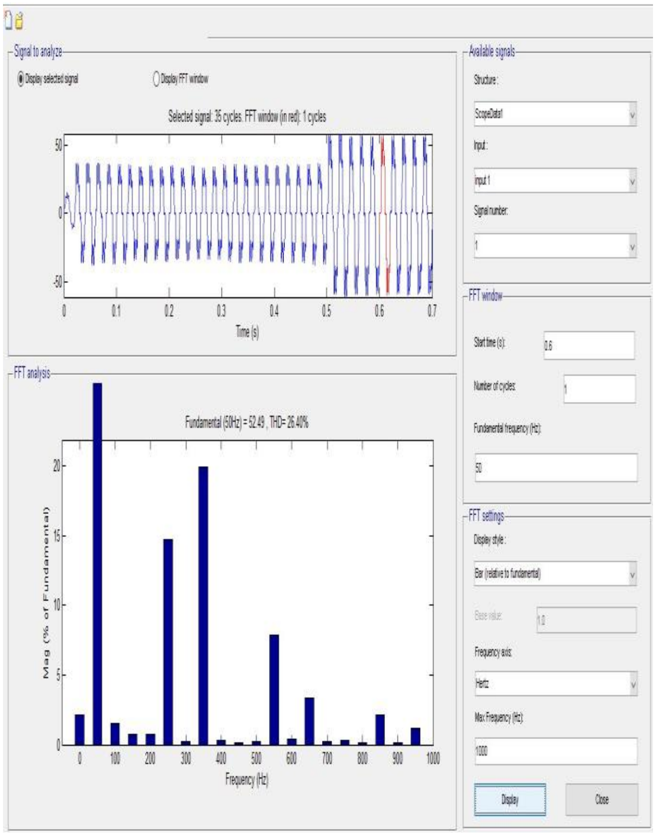

Fig 5.32- THD of Load Current without Hybrid UPQC (for Line-2)

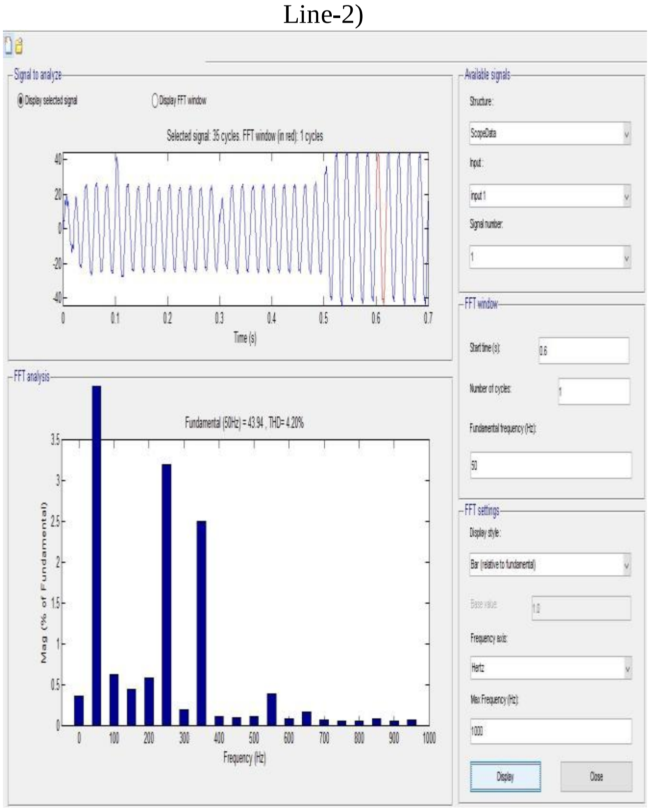

Fig 5.33- THD of Load Current with Hybrid UPQC (for Line-2)

VI. CONCLUSION

The power quality is improved using the control strategy of UPQC in three phase compensated system. The THD Analysis is done using Matlab simulation for without UPQC and With UPQC. The Voltage Sag Swell Problem mitigation also successfully done with proposed controlling of UPQC Device. This project presents a reduced rating starconnected hybrid UPQC in distribution systems forsimultaneous compensation of load currentharmonics, voltage sag/swell and source neutralcurrent. 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 performance of proposedUPQC has been investigated through extensivesimulation studies. From these studies it is observedthat the proposed scheme completely compensatedthe source current harmonics, load current harmonics,voltage sag/swell and neutral current.

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