

# Improved control method of UPQC for unbalanced and non linear load conditions

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*Abstract*— Nowadays more number of electronic devices is used by industries and residences in electrical system. For proper working of these devices, we have to provide high quality of power supply. But these devices inject harmonics in distribution system. This is one of the major problems in electrical system. The various power quality disturbances are transients, interruptions, voltage sag, voltage swell, voltage collapse, harmonics etc. It has been identified that power quality can be degraded both due to utility side abnormalities as well as the customer side abnormalities. To overcome the problems caused by customer side abnormalities so called custom power devices are connected closer to the load end. One modern and very promising solution that deals with both load current and supply voltage imperfections is the Unified Power Quality Conditioner (UPQC). In this dissertation, a UPQC is function of both series and shunt active power filter using P-Q Theory. This concept is introduce for mitigating different problems of power system.

*Keywords*— Power quality, Unified Power Quality Conditioner (UPQC), Custom Power, Active power filter.

## 1. INTRODUCTION

### 1.1 Problem Statement

The electrical power system is consider of three function blocks generation, transmission and distribution. For a reliable power system, the generation unit must produce sufficient power to meet customer's power demand;

transmission system is transport bulk power over long distances without overloading or jeopardizing system stability and distribution system is deliver electrical power to each customer's premises from bulk power system. Any power related problem that compromises either characteristic or related to power quality. Power quality is a term which interprets in different path for different people. Institute of Electrical and Electronic Engineering (IEEE) Standard defines power quality as "the concept of powering and grounding sensitive electronic equipment in a suitable manner for equipment". This description of power quality might be partial to "sensitive electronic equipment" only. Electrical equipment susceptible to lack of power quality would fall within a truly unlimited domain. A simpler and maybe more clear definition might state: "Power quality is a set of electrical boundaries that allows a piece of equipment to function in its intended manner without significant loss of performance or life expectancy." This definition holds two things that we demand from an electrical device: performance and life expectancy.

### 1.2 Introduction to FACTS Devices

Initially for the improvement of power quality or reliability of the system FACTS devices like static synchronous compensator (STATCOM), static synchronous series compensator (SSSC) and unified power flow controller (UPFC) etc. are introduced. These FACTS devices are design for transmission system. But now a day's more attention is on the distribution system for the improvement of the power quality, these devices are modified and known as a custom power devices. The main custom power devices which are

used in distribution system for power quality improvement are distribution static synchronous compensator (DSTATCOM), dynamic voltage restorer (DVR), unified power quality conditioner (UPQC) etc. UPQC is the integration of series and shunt active filters, connected back-to-back on the dc side, 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.

### 1.3 Objective

UPQC is the best custom power device. Which is useful in both source and load are unbalanced and distorted. UPQC is used for harmonic compensation. Series active power filter is reducing the voltage sag and shunt active power filter is reduce the current harmonics at the load side. So we use the UPQC and reduce the voltage sag at the source side and also reduce harmonics at the load side.

## 2. Introduction to Custom Power Devices

Custom power is a strategy, which is indented principally to convene the requirement of industrial & commercial consumers. The concept of the custom power device is tools of application of power electronics controller devices into power distribution system to supply quality of power demanded by sensitive users. The quality may contain following specification or combination of these:

- i. Rare power interruptions.
- ii. Magnitude and duration of over and under voltages within specified limits
- iii. Low harmonic distortion in the supply voltage.
- iv. Low phase unbalance.
- v. Low flicker in the supply voltage.

vi. Frequency of the supply voltage within specified limits.

### 2.1 Classification of Custom Power Devices

The custom power devices are generally divided into two groups: network reconfiguring type and compensating type. The complete classification of custom power devices is shown in the Fig 2.2.

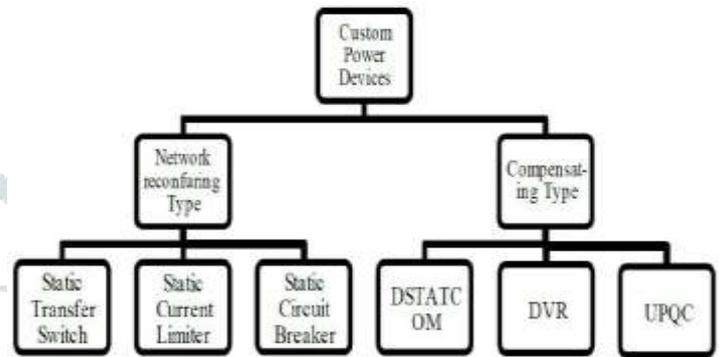


Fig 2.1: Classification of custom power devices

### 2.2 Network reconfiguration type

These are GTO and thyristor based devices, which are generally used as fast current limiting and current breaking.

The main devices are:

- i. Solid state current limiter
  - ii. Static transfer switch
  - iii. Static breaker
  - iv. UPS
- (i) Static current limiter It is a GTO based device applied for high fault current limiting. When fault is occurs, inserts a limiting inductor in the fault circuit. When the fault is cleared, removes the inductor from circuit.
  - (ii) Static transfer switch Static Transform Switch (STS) is used to protect sensitive load voltage sag or swell. It is composed of two parallel connected thyristor or GTO blocks. Each block contains of three GTO or thyristor corresponding to the three phase of the system.
  - (iii) Solid state breaker the solid state breaker is based on the GTO or Thyristor switching technology. It is a high speed switching device, which is applied for decreasing the electrical

fault and protect from large current in distribution system. It can be also used in a single switch, static transfer switch, hybrid switch or a low level fault interrupter. The voltage and current rating of the breaker defines the necessity of no. of switching devices, cost and the losses of the breaker. It performs auto reclosing function.

- (iv) Uninterruptible Power Supply Uninterruptible power supply (UPS) is the conventional device to avoid production interruption and outage costs. In UPS load receives the power from source via two stage operation: conversion (ac/dc) and inversion (dc/ac). When voltage dips or an interruption, the load voltage is made constant by energy, which is generated through battery. The performance of UPS is depending on energy storage capacity of battery.

**2.3 Compensating Type**

The compensating custom power devices are used for active filtering, load balancing; power factor improvement and voltage regulating (sag/ swell). These devices are mainly three types: shunt compensator, series and hybrid compensator. These are also called as DSTATCOM, DVR and UPQC respectively.

1. Distribution Static Compensator (DSTATCOM)
 

DSTATCOM is based on Voltage source inverter (VSI), where static compensator device (STATCOM, FACTS controller ) applied to maintain bus voltage sags at the desired level by supplying or receiving of reactive power in the distribution system. It is connected in shunt with distribution feeder by means of coupling transformer. The single line diagram of DSTATCOM is shown in shown fig 2.3. The DSTATCOM involves of a VSI, dc energy storage device, an ac filter and coupling transformer.

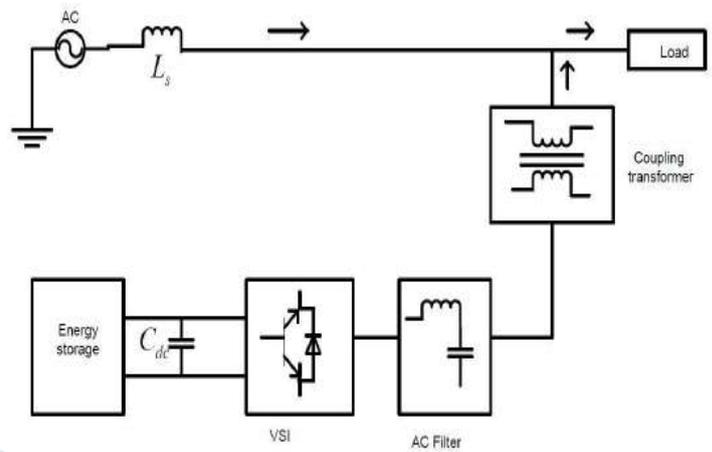


Fig 2.2: Single Line Diagram of DSTATCOM

**2. Static Series Compensator (DVR)**

Static series compensator is called as Dynamic Voltage Restorer (DVR). It is a high- speed switching device, which is controlled by power electronic devices. DVR is connected in series to inject a dynamically controlled voltage in magnitude and phase in to distribution line via coupling transformer to correct load voltage. The single line diagram of DVR is shown in the Fig 2.4.

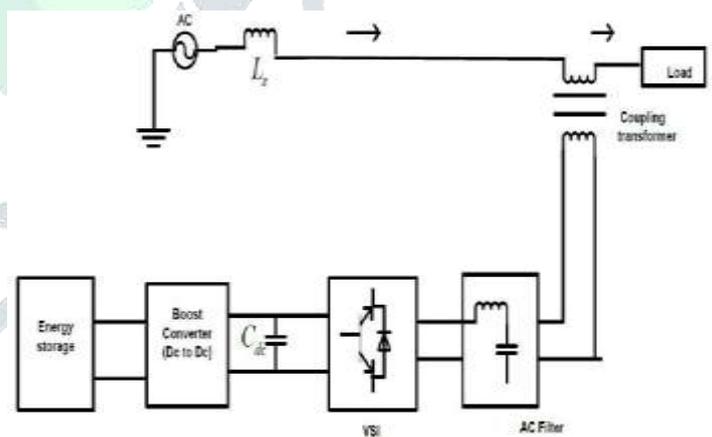


Fig 2.3: Single Line Diagram of DVR

**3. Unified Power Quality Conditioner (UPQC)**

It is the combination of back to back connected shunt and series compensators via common dc bus voltage. Capacitor is connected between two voltage source inverters for operating as combination of shunt and series compensator in this dc link. The single line diagram of unified power quality

compensator is shown in Fig 2.5. It can suppress current in shunt and voltage in series simultaneously, so it is a most flexible device. It can balance the terminal voltage and eliminate negative sequence current components at the same time.

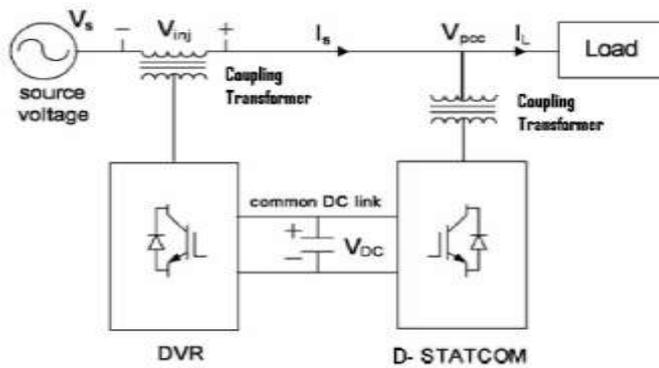


Fig 2.4: Single Line Diagram of UPQC

**2.1 Unified Power Quality Conditioner (UPQC) using PQ method.**

**2.1.1 General Introduction of UPQC**

The basic configuration of a unified power quality conditioner shows in the fig 2.7. If it is compared with the basic configuration of the unified power flow controller (UPFC), they appear to be quite similar. In that additional current measurement of the nonlinear load is needed. Unlike the UPFC, the shunt converter of the UPQC must be connected as close as possible to the non-linear load, instead of the network side. The series converter of the UPQC acts as a controlled voltage source, that is, it behaves as a series active filter, whereas the shunt converter acts as a controlled current source, as a shunt active filter. There is no power supply is connected at the dc link.

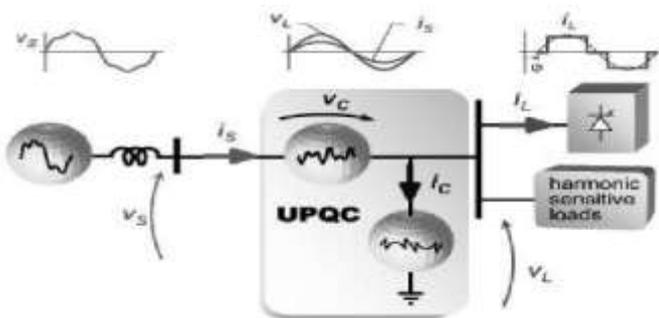


Fig 2.5: Combined series and shunt compensation (UPQC device)

It comprises only a comparatively small dc capacitor as a small energy storage element. The unified controller of the series and shunt active filters of the UPQC provide the compensating voltage reference  $V^*C$ , as well as the compensating current reference  $I^*C$  to be synthesized by the converters.

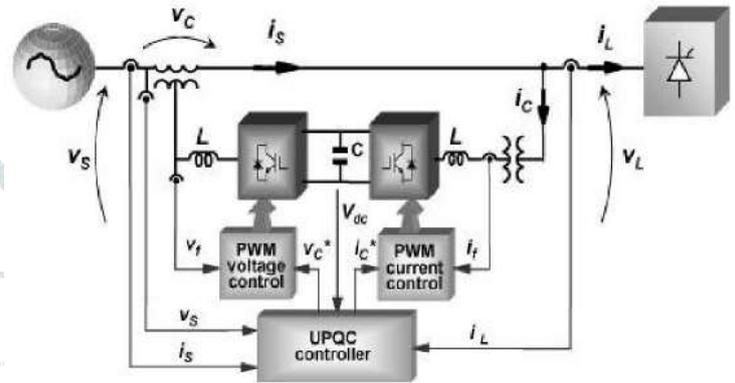


Fig 2.6: Basic configuration of the unified power quality conditioner

The UPQC method is the most powerful compensator for a situation as depicted in Fig 2.6, where the supply voltage  $V_S$  already unbalanced and/or distorted and is applied to a critical load that needs high power quality. On the other side, part of the total load comprises nonlinear loads that inject a large amount of harmonic current into the network, which should be filtered. Table 2.1 the tasks assigned to each active filter in the UPQC method.

**Table 2.1: Assignments for a combined series and shunt active power filter**

| Unified Power Quality Conditioner  |  |
|--|--|
| Series Active Filter   | Shunt Active Filter  |
| Compensates source voltage harmonics, including negative and zero-sequence components at the fundamental frequency | Compensates load current harmonics, including negative and zero-sequence components at the fundamental frequency |
| Blocks harmonic currents   | Compensates reactive   |

|  |  |
|--|--|
| flowing to the source (harmonic isolation) | power of the load                              |
| Improves the system stability (damping)    | Regulates the capacitor voltage of the dc link |

the line current of the nonlinear load that the shunt active filter has a selective compensation characteristic.

The shunt active filter can also provide harmonic damping throughout the power line to avoid “harmonic propagation” resulting from harmonic resonance between the series inductance of the power system and shunt capacitors for power factor correction.

The active filter controller consists of four functional control bloc

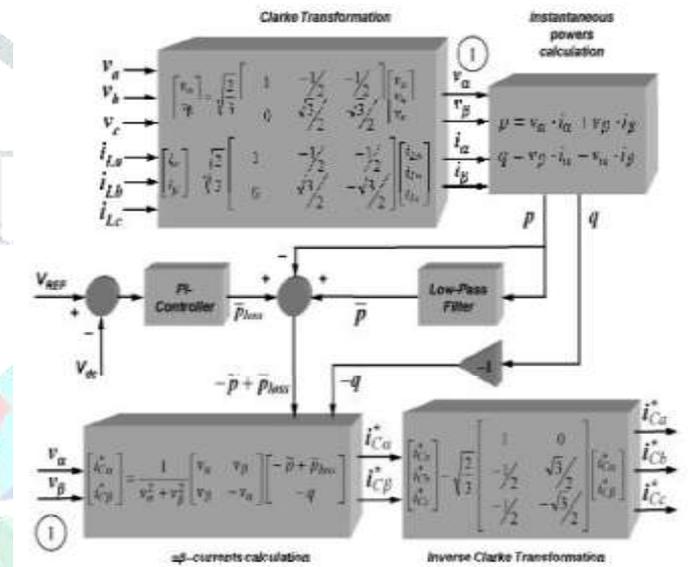


Fig 2.9: Control block for the constant instantaneous power control strategy

2.2.3 Basic Series Active power filter

2.2 Introduction of PQ theory

2.2.1 BASIC OF THE p-q THEORY

The p-q Theory is based on a set of instantaneous power defined in the time domain No restrictions are imposed on the voltage or current waveforms, and it can be applied to three phase systems with or without a neutral wire for three- phase generic voltage and current waveforms. Thus it is not valid only in the steady state but also in the transient state. This theory is very efficient and flexible in designing controller for power conditioners based on power electronics devices.

The other traditional concepts of power are characterized by treating a three phase system as three single phase circuits. The p-q theory first transforms voltages and currents from the abc to  $\alpha\beta 0$  coordinates and then defines instantaneous power on this coordinates. Hence this theory always considers the three- phase system as a unit, not a superposition or sum of three single phase circuits.

2.2.2 Three Phase – Three Wire Shunt Active Filter

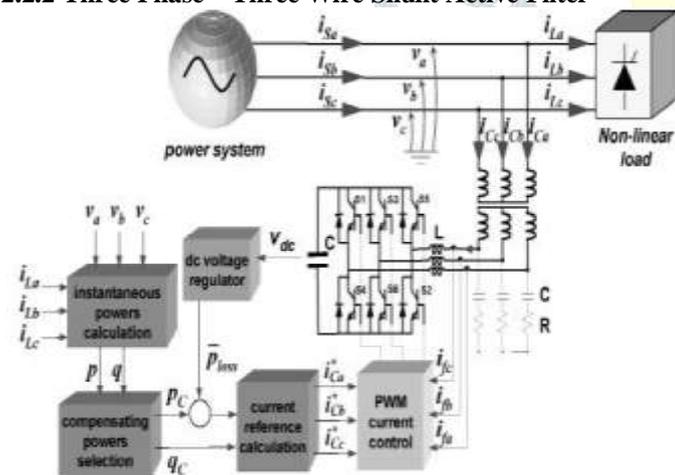


Fig 2.7: Three phase three wire shunt active power filter

Figure shows the most important parts of a three phase, three wire shunt active filter for current compensation. The control block that calculates the instantaneous power takes as inputs the phase voltages at the point of common coupling (pcc) and

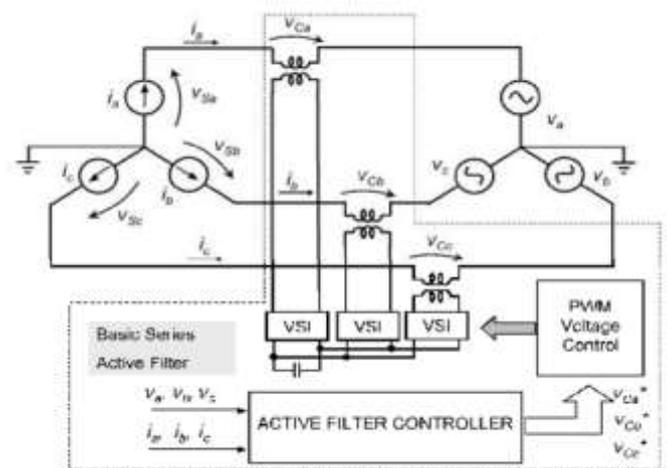


Fig 2.10 Basic Series Active power Filter

Fig. shows an example of basic series active power filter. For simplicity system A represents the source side, which has been represented by balanced sinusoidal current sources, and system B represents the load side with its voltage sources containing harmonic components moreover, it is assumed that there is no zero-sequence current.

**2.2.4 Benefits of the P-Q theory**

1. The instantaneous real and imaginary powers defined.
2. Clear physical meanings are assigned to the real power the imaginary power and the zero sequence power in P-Q theory.
3. The compensation algorithm based on the P-Q theory is very flexible.
4. The instantaneous imaginary power is calculated without time delay.

**3 Block diagram of UPQC**

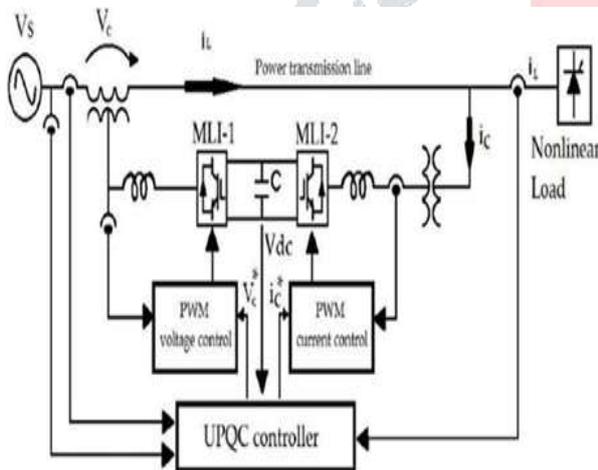


Fig 3.1: General block diagram of UPQC

UPQC is the integration of series and shunt active filters, connected back-to-back on the dc side, sharing a common DC capacitor as shown in Fig 2.16. 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.

**3.1 Experimental Parameter**

**3.1.1 Simulation Parameters of shunt active power filter**

1. Source (3-Phase)
- 2.-Voltage=400V (Ph-Ph)
- 3.-Frequency=50Hz
- 4.-Resistance=0.001 ohm
- 5.-Inductance=10-8 H

Load:

1. Unbalanced ( $R_a=200$  ohm,  $R_b=400$  ohm,  $R_c=600$  ohm)
2. Rectifier with 1000 ohm resistive load as non-linear load
3. Coupling Inductor=50 mH

**3.1.2 Simulation and Simulation Results**

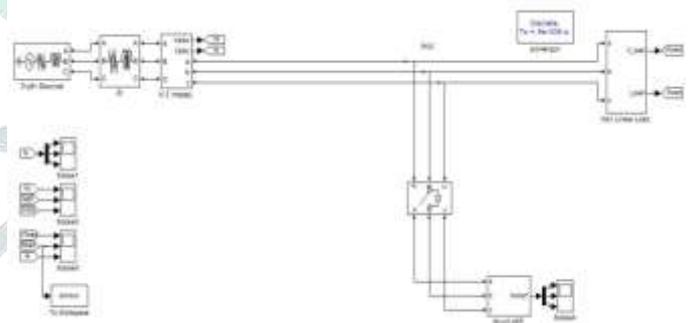


Fig 3.2: Shunt active filter

Coupling Inductor= 50 mH

**3.1.4 Simulation and Simulation Results**

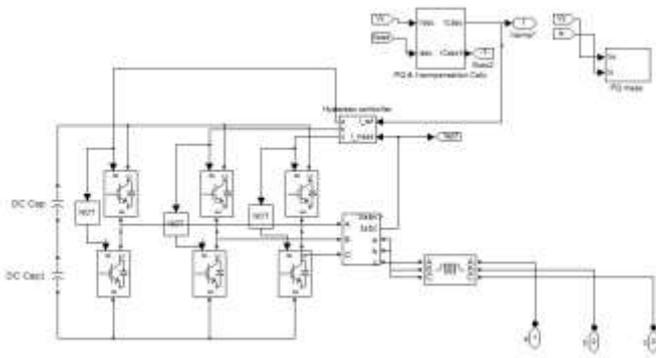


Fig 3.3: Sub system of shunt active power filter

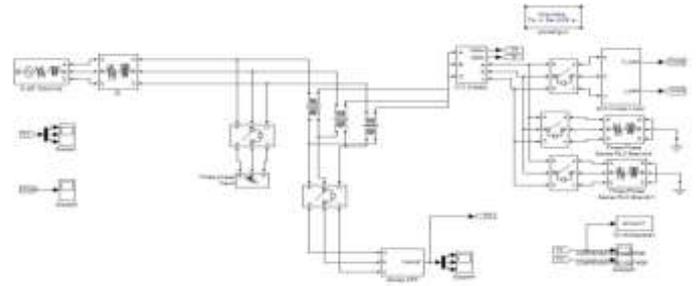


Fig : 3.6 series active filter

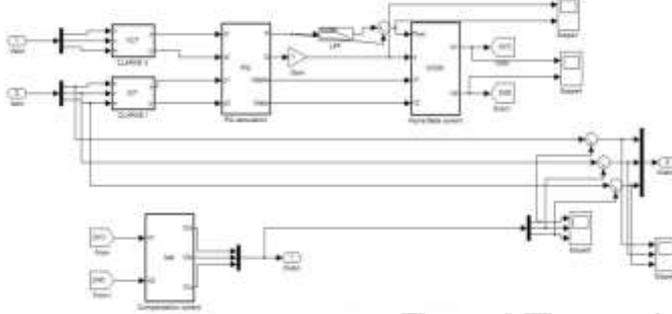


Fig 3.4: p-q calculation

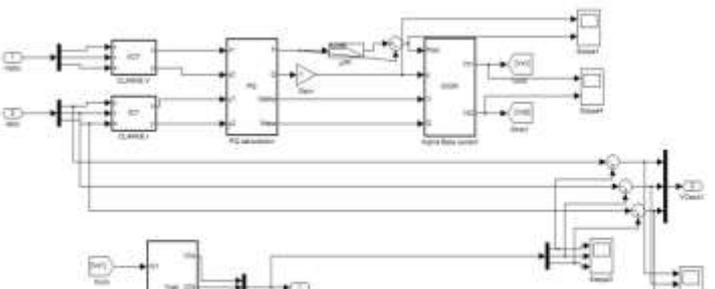


Fig 3.7: p-q calculation

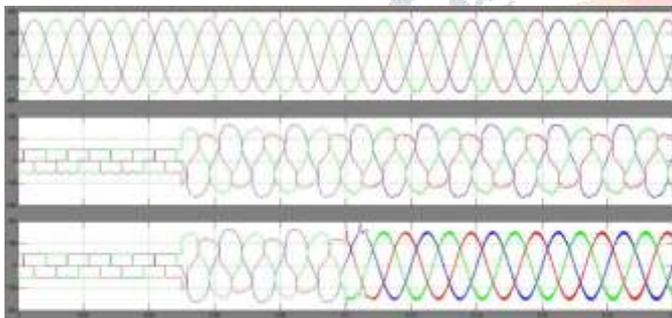


Fig 3.5: Load voltage, load current, source current

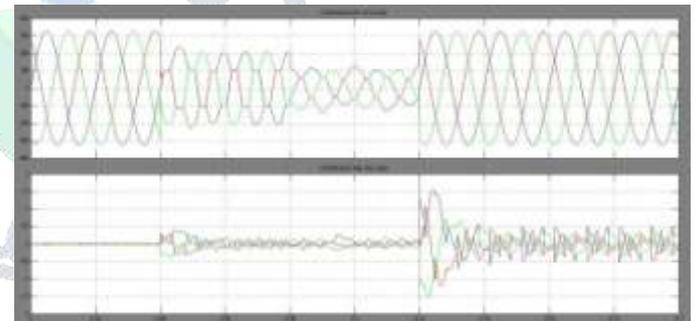


Fig 3.8: unbalanced load

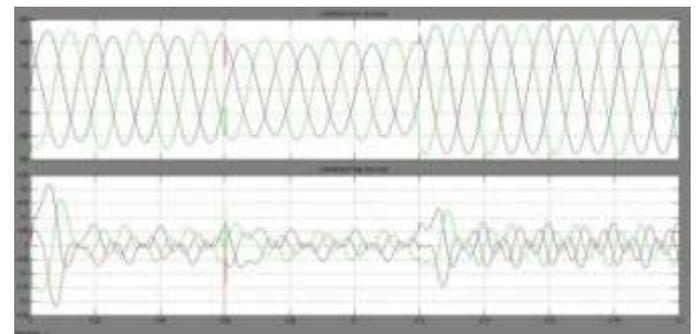


Fig 3.9: sag

**3.1.3 Simulation Parameters of series active power filter**

Source (3-Phase)

-Voltage=400V (Ph-Ph)

-Frequency=50Hz

-Resistance=0.001 ohm

-Inductance=10-8 H

Load:

Unbalanced (Ra=200 ohm,Rb=400 ohm,Rc=600 ohm)

Rectifier with 1000 ohm resistive load as non-linear load

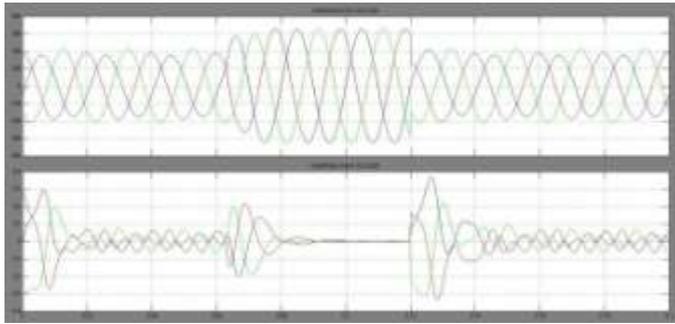


Fig 3.10:swell

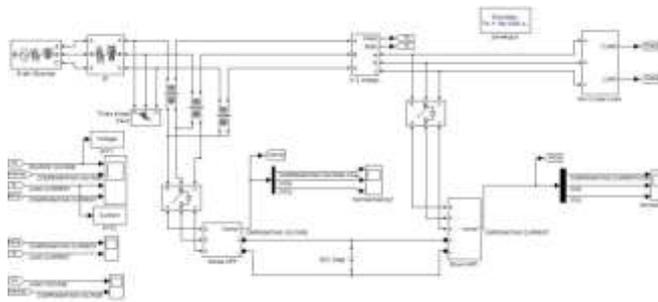


Fig 3.11:UPQC

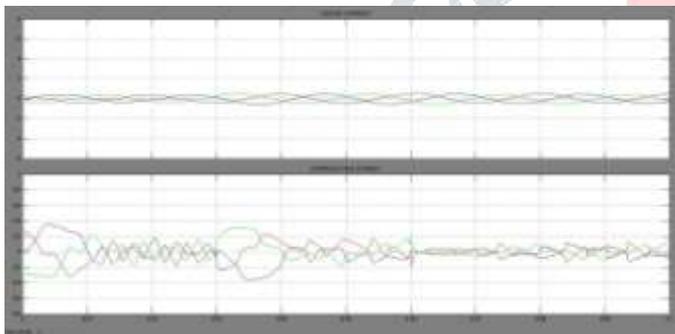


Fig 3.12:Compensated current

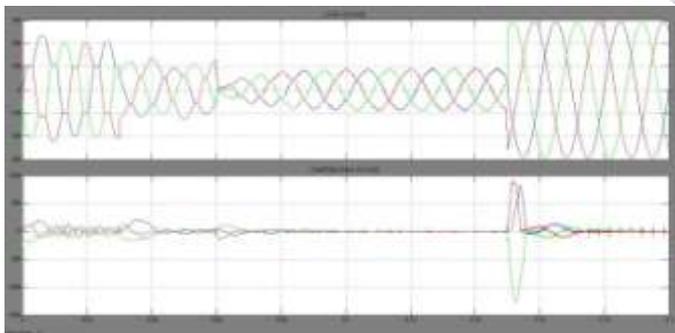


Fig 3.13:Compensated voltage

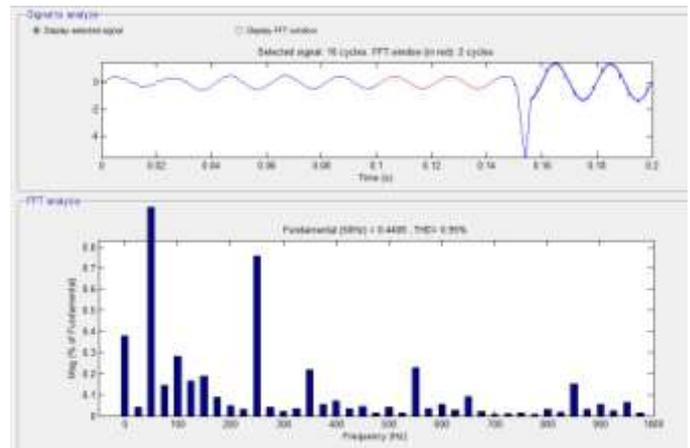


Fig 3.14:THD result of current

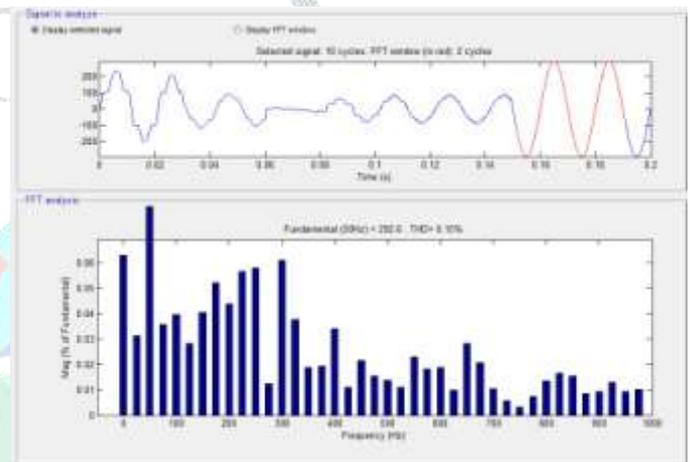


Fig 3.15:THD result of voltage

**CONCLUSION**

Custom power devices like DVR, DSTATCOM, and UPQC can enhance power quality in the distribution system. Based on the power quality problem at the load or at the choose particular custom power device with specific compensation. Unified power quality conditioner is the combination of series and shunt active power filter, which compensates supply voltage and load current imperfections in the distribution system.

**Future Enhancement:**

In the future, detail analysis of simulating result of shunt and series active power filter will be carried out and the whole simulation of UPQC will be carried out. Also analysis of UPQC will be carried out.

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