# Unified Power-Quality Conditioning in LV Distribution Networks using Multi Converter based System

Pragya Rajput[1], Prof. Aakansha Mercy Steele[2]

*[1]Mtech Scholar, [2]Research Guide*

*Department of Electrical Engineering, UIT, RGPV, Bhopal*

***Abstract- Power system is made up of three components which are very commonly known as Generation, Transmission and Distribution. These three when collectively combined is termed as Power system. A power system can't be reliable until it generate sufficient amount of power to meet consumer demand, and transmission system must be equipped for transmit mass power without losing stability and overloading and distribution system ought to convey the power from the over two phases to each consumer. Distribution system basically indicates the end of the system and is directly concerned with consumer application. Power quality is purely relies upon distribution side. So the power quality is consumer driven issue, and the reliability of a power system is a noteworthy concern. It is essential for distribution system to deliver good quality power. The power quality issue can be dictated by investigating the electrical power and assessing the equipment or load. To maintain power quality and to mitigate distortion in power supply a Unified Power-Quality Conditioning using multi level converter based System in low voltage distribution networks has been proposed in this work modeled and simulated in Matlab Simulink.***

***Keywords- UPQC, LV Distribution System, Power Quality Improvement, Multi Level Converter, Quality Conditioning, MC-UPQC, VSC.***

## I. INTRODUCTION

In today's world there is great importance of electrical energy as it is the most famous from of energy and all are massively relying on it. Without supply of electricity life cannot be imagined. At the same time the quality and continuousness of the electric power supplied is also very important for the efficient functioning of the end user equipment. Many of the commercial and industrial loads require high quality undisturbed and constant power. Thus maintaining the qualitative power is topmost important in today's world.

Power quality is a range of phenomena related to deterioration of current and voltage waveforms from ideal shape. Many definitions of power quality have been proposed, but variety of related phenomena is too wide to cover. In this investigation the term power quality is used with reference to parameters of voltage delivered to the load.

Power quality is one of the most burning issues of the present scenario. The power attributes is directly concern and have direct impact on consumers, utilities, and electrical equipment manufacturers. Resent scenario of modernization and automation of industry involves with the rapid increasing rate of use of computers, microprocessor and power electronic systems. The power electronic system involves largely on the behavior of power attributes dilemma, as the power electronics devices lead to cause of generation of harmonics. The impact of power quality dilemma may be easily felt to us customers-industrial, commercial and even by residential one.

Due to power electronics devices there is serious effect on quality and continuousness of electric supply. Because of power electronics devices there is uninterrupted power supply, flicker, harmonics, and voltage fluctuations e.tc. There is also PQ problems such as voltage rise/dip due to network faults, lightning, switching of capacitor banks. With the excessive uses of non-linear load (computer, lasers, printers, rectifiers) there is reactive power disturbances and harmonics in power distribution system. It is very essential to overcome this type of problems as its effect may increase in future and cause adverse effect.

Traditionally passive filters were used for reactive power disturbances and harmonics generation but there is many problems with them like they are large in size, resonance problem, effect of source impedance on performance.

Active Power Filters are used for power quality enhancement. Active power filters can be classified according to system configuration. Active power filters are of two types series and shunt. Combining both series APF & shunt APF a combination get a device known as UPQC. UPQC eliminates the voltage and current based distortions together.

A Shunt APF eliminates all kind of current problems like current harmonic compensation, reactive power compensation, power factor enhancement. A Series APF compensates voltage dip/rise so that voltage at load side is perfectly regulated. The Shunt APF is connected in parallel with transmission line and series APF is connected in series with transmission line. UPQC is formed by combining both series APF and shunt APF connected back to back on DC side.

In this controlling techniques used is hysteresis band controller using "p-q theory" for shunt APF and hysteresis band controller using Park's transformation or dq0 transformation for series APF. UPQC is made by combining both shunt APF and series APF. UPQC is used to eliminate all problems due to current harmonics and voltage unbalances & distortions and improve power quality of a system. UPQC is a very versatile device as at same time it mitigates the problem both due to current and voltage harmonics. In this work power quality of system is improved by using UPQC.

## II. SYSTEM MODEL

Fig.2.1 shows basic configuration of UPQC. UPQC mainly consists of following component blocks:-

*a. Series APF*

In a transmission line series APF is generally connected in series. It is connected to the transmission line with the transformer. Series APF is a voltage source inverter connected in series with transmission line. It is used to compensate or mitigate the problems which come due to voltage distortions and voltage unbalances.

*b. Shunt APF*

In a transmission line shunt APF is generally connected in parallel. Shunt APF is used to compensate for distortions & harmonics which are produced due to current. Due to non- linear load there is harmonics in load current, so to keep source current completely sinusoidal and distortion free. Shunt APF injects compensating current so that the source current is completely sinusoidal and free from distortions.

*c. Series Transformer*

The necessary voltage which is generated by series APF so that the voltage at load side is perfectly balanced and regulated i.e. Sinusoidal is injected into the transmission line with the help of these transformers. The series transformer turns ratio should be suitable so that injected voltage is suitable such that it injects a compensating voltage which will completely make the load side voltage balanced and also it reduces the current flowing through series inverter.

*d. Low Pass Filter*

Low pass filter is used at the output of series inverter so that the high frequency voltage components are removed which is produced due to switching of Voltage source inverter.

*e. High pass filter*

High pass filter is used at output of shunt inverter so that the ripples which are produced due to currents switching are absorbed.

*f. DC link capacitor*

The two voltage source inverter is connected back to back through a DC capacitor. DC capacitor is provides a DC voltage for working of both the inverter. The DC capacitor also provides a real power difference between source and load during the transient period and also acts as a energy storage elements.

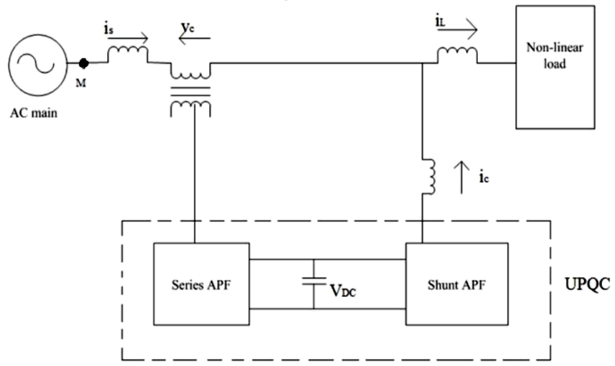


Figure 2.1 Configuration of UPQC.

*Operation of UPQC*

As given in fig.2.1 $v_s$ is source voltage, $v_c$ is series compensation voltage, $i_s$ =source current & $i_L$ is load current. The source voltage contains a positive, negative & zero & also the harmonic components. Generally UPQC can be configured in two ways by connecting unit to terminal voltage $v_t$ at PCC (point of common coupling).

## III. PROPOSED MODEL

Control method plays an important role in power electronic devices because principally a power electronic device is made by some solid state switches and without proper control method, combination of active switches could do nothing. The inverter control still is a challenging task for engineering even for the typical full bridge topology, due to inverter intrinsic characteristics, like low-impedance and quick response. Because of these characteristics, inverter current and voltage profile can change quickly and inside a fraction of cycle, those may overload, surpass the current and voltage cutoff points and cause system failure.

In this work a reliable and effective control methods based on classical control algorithm with the mode of operation of unified power quality conditioner (UPQC) with MLC has been reported.

The UPQC controller is able to

- inject power to PCC from the source at unity power factor (UPF),

- PCC and load bus voltage regulation and balancing.
- circulate excess power

The proposed controller scheme is achieved by detaching the voltage at the point of common coupling (PCC) from the load bus voltage however the UPQC. The execution and simulation of proposed work has finished on Matlab Simulink figure 3.1 has illustrate proposed Simulink Model of LV distribution network with MLC based UPQC. The sub blocks of proposed model have been described as follows.

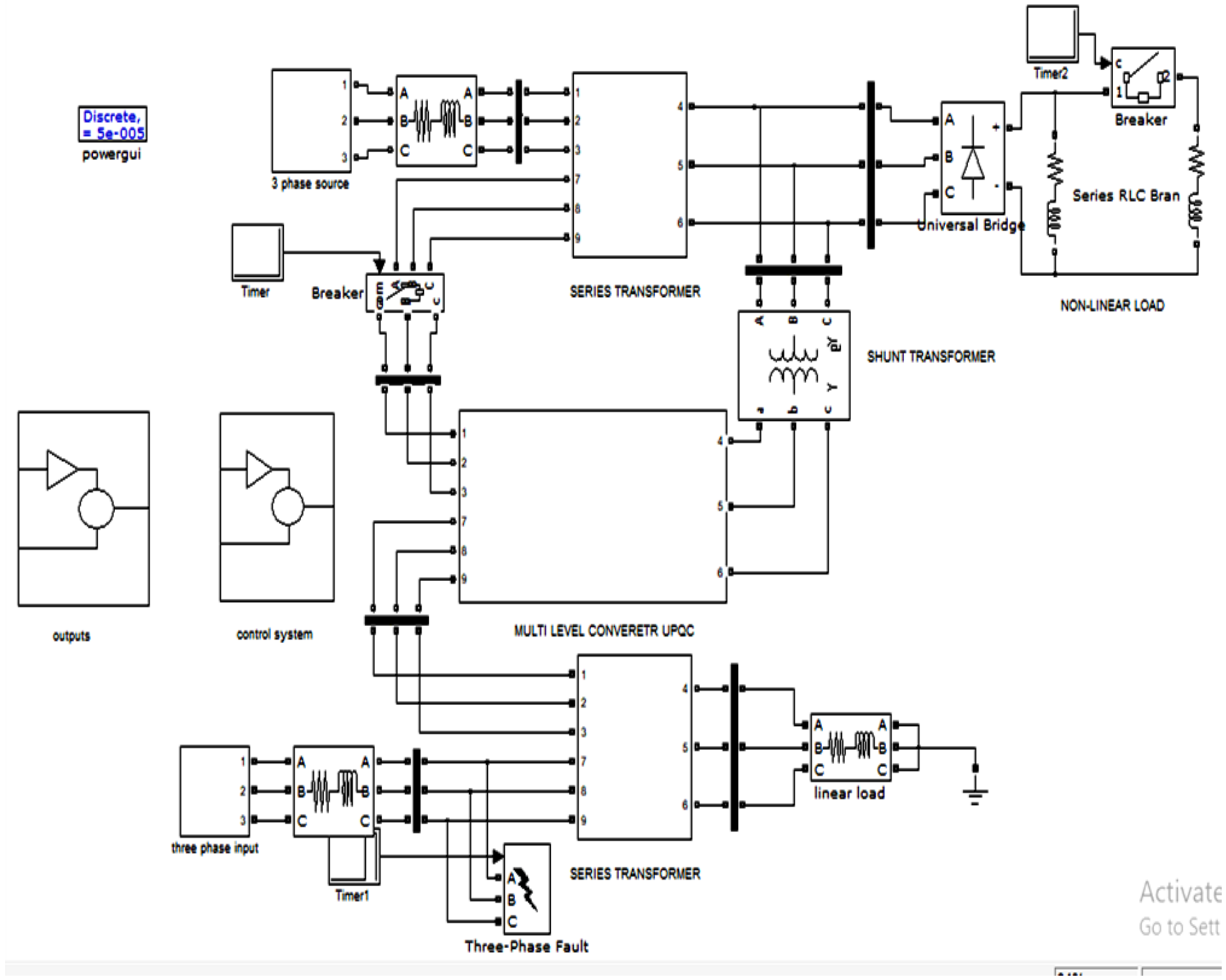


Figure 3.1 Simulink Model of LV Distribution Network with MLC Based UPQC.

*a. Multilevel Converter MLC*

The principal function of a converter is to transfer energy in a type of direct current (DC) or alternating current (AC) to either a similar frame or to the next i.e. DC to DC, AC to AC or DC to AC. Converters can likewise be worked in bidirectional mode, allowing the lessening of system parts when utilized as a part of specific applications, for example, starter-generator drive systems.

The utilization of power electronic semiconductors in such converters, nearby filtering parts (inductors and capacitors), permits proficient conversion of electrical energy. For DC-DC conversion, the input voltage might be ventured up or down both with or without the utilization of a transformer. For the instance of the DC to AC, an appropriate grouping and ON time of the switching segments is required to shape the required yield voltage.

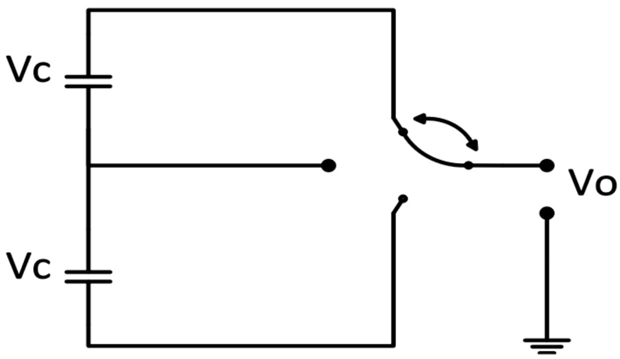


Figure: 3.2 Functional diagram of a DC to AC converter.

As appeared in Figure 3.2 the conversion from DC to AC requires the voltage taken from the DC-connect capacitors (Vc) being changed to the yield (Vo) and periodically switched at the yield to give AC and an unpleasant guess to a sinusoidal voltage yield. By utilizing all the more switching components, a fitting switching sequencing, and clipping or adjusting components, the guess to the sinusoidal yield signal can be quite enhanced and additionally improved by including more advances (or levels) to the yield to frame a staircase waveform.

Although the expanded number of levels essentially enhances the nature of the waveform, it has a negative result as far as the control of the voltage on the DC-connect and the sequencing of the switches. These days the utilization of Field Programmable Gate Array (FPGA) to control the converters enables a bounty of levels because of: the accessibility of pulse width modulation (PWM) configurable cells; the lessening in cost; and simplicity of programming. The conversion from DC to AC utilizing MLCs permits creating a low distortion yield and the upsides of decreased gadget evaluations (voltage and current) for the segments.

Based on the simulation comes about, the topology chose is the multilevel converter which delivers the yield voltage with a decreased THD, this will permit to limit the filtering size and diminish the DC to DC conversion as the yield voltage is of an indistinguishable level from the DC input.

*b. UPQC*

The MC-UPQC system comprises of two voltage source inverters, a typical DC-interface capacitor which acts as source, Three phase source and a MLC converter and load.

The rating of series APF utilized as a part of UPQC relies on the most extreme level of sag/swell that it ought to compensate. In any case, these are of little length issues. However, the shunt APF works as long as the non-linear currents are drawn from the source. It supplies the reactive power persistently, which prompts expanded usage of it contrasted with series APF. The power point control conspire is predominantly used to build the use factor of series APF without bringing on any extra weight on it. Here the series APF is utilized to share a piece of load reactive power request alongside repaying voltage sag/swell by making a power point distinction between source voltage and load voltage. The compensation of sag should be possible by active power approach or reactive approach or by both of these in UPQC.

The useful block representation of the UPQC controller is outlined in Fig. Generation of compensating voltage and current for Series and Shunt APF depends on the instantaneous p-q principle. What's more, it is appeared in Fig that the UPQC controller requires a positive-sequence detector, a PWM voltage controller for voltage compensation, a hysteresis current controller for reactive harmonic current compensation and a dc-link voltage controller. The phase voltages at the load terminal comprises mostly of the positive succession segment (V+1), however can be unequal (containing negative-and zero arrangement parts at major frequency), and can likewise contain harmonics from any grouping segment.

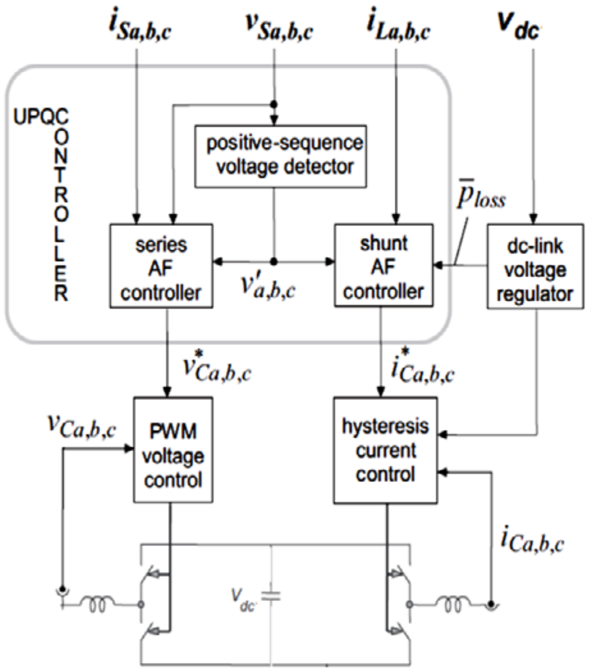


Figure: 3.3 A functional Block representation of UPQC Controller.

The detection of the fundamental positive-sequence component of vsa, vsb, and vsc is necessary in the sinusoidal current control strategy. The PWM voltage controller should allow the series active filter to generate compensating voltages according to their references v*Ca, v*Cb, and v*Cc, which can vary widely in frequency and amplitude.

## IV. SIMULATION RESULTS

The MLC based UPQC controller has been modeled tested based on Simulation in a LV substation and LV Network. Therefore, to understand functionalities of proposed UPQC controller, the whole model has been introduced briefly then the field network has been described and some preliminary analysis of the network have been reported in order to understand reliability of the system.

The implementation and simulation of proposed model has completed on Matlab Simulink. Some experimental Studies are carried out using MATLAB to find the effect of power quality using proposed approach based on simulation conducted on Matlab Simulink. Both the design and controlling mechanism for MLC UPQC for LV distribution network system has been reviewed and discussed here as a part of the design and control of a complete UPQC system that can minimize the disturbance of supply voltage as well as cancel the reactive and harmonic part of the load current. The Simulation waveform on Matlab Scope has shown in figure 4.1 to figure 4.7.

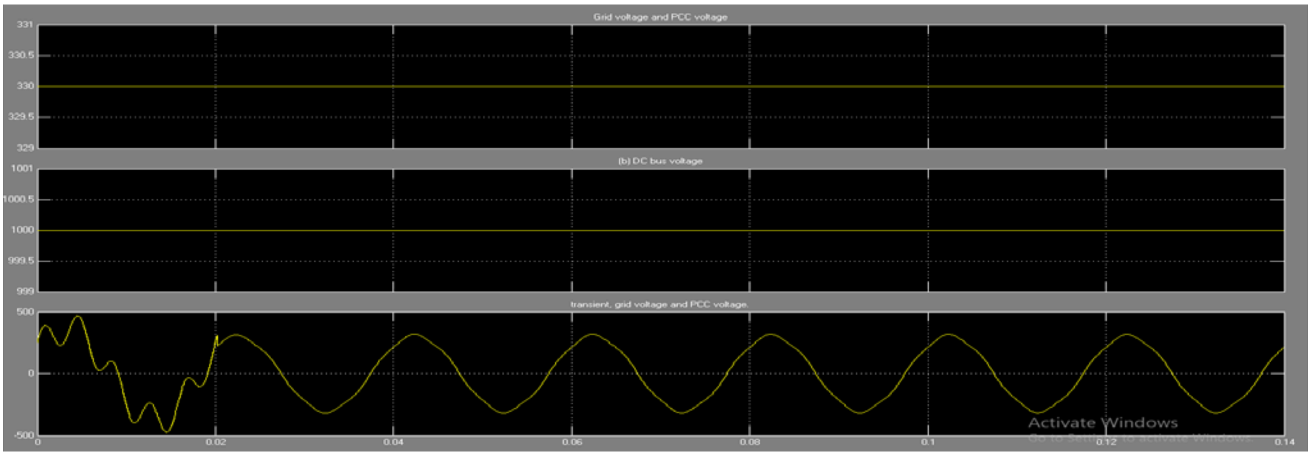


Figure: 4.1 Grid, PCC Voltage, DC Bus Voltage and Transient Voltage.

Switching functionality has been studied to develop the relation between the design parameters and the switching frequencies. This is also verified by simulation. Power losses due to conduction and switching are also co-related with the design parameters and maximum switching frequency.

Figure 4.1 shows the Grid, PCC Voltage, DC Bus Voltage and Transient Voltage waveform taken from Matlab Scope. The reactive power (Q) injection and effects on voltage regulation, for 10 samples per hour has shown in figure 4.2.

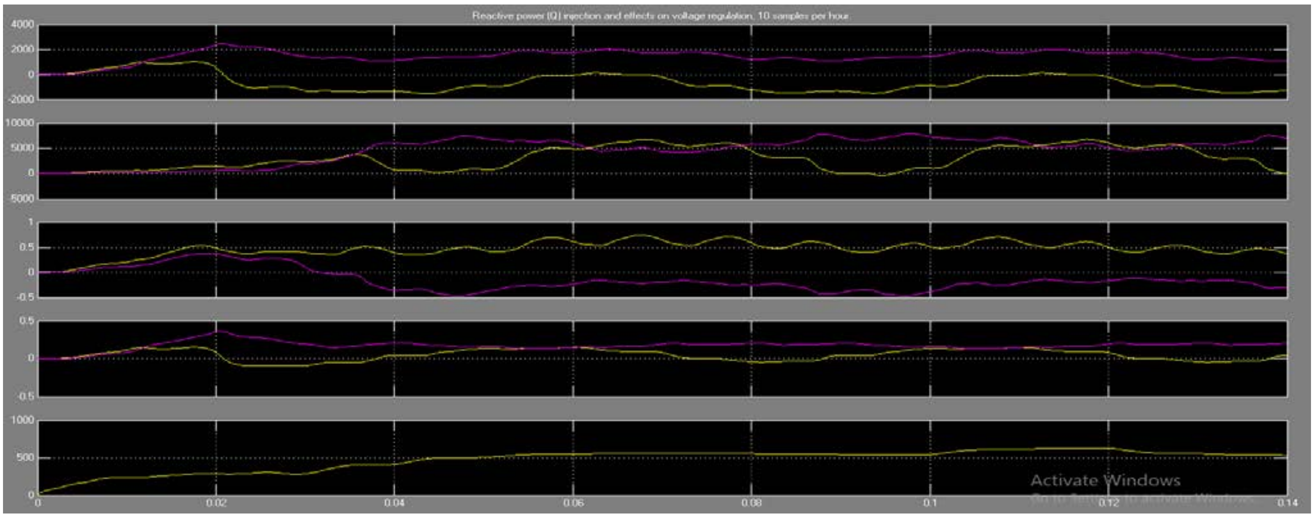

Figure: 4.2 Reactive power (Q) injection and effects on voltage regulation, 10 samples per hour.

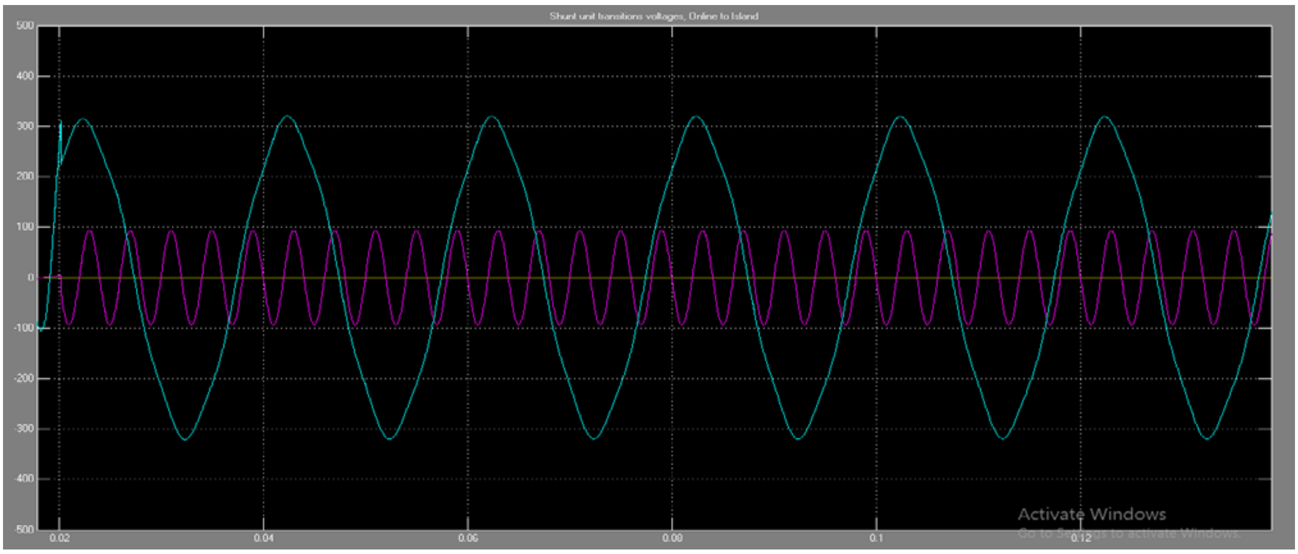

Figure: 4.3 Shunt unit transitions, Online to Island.

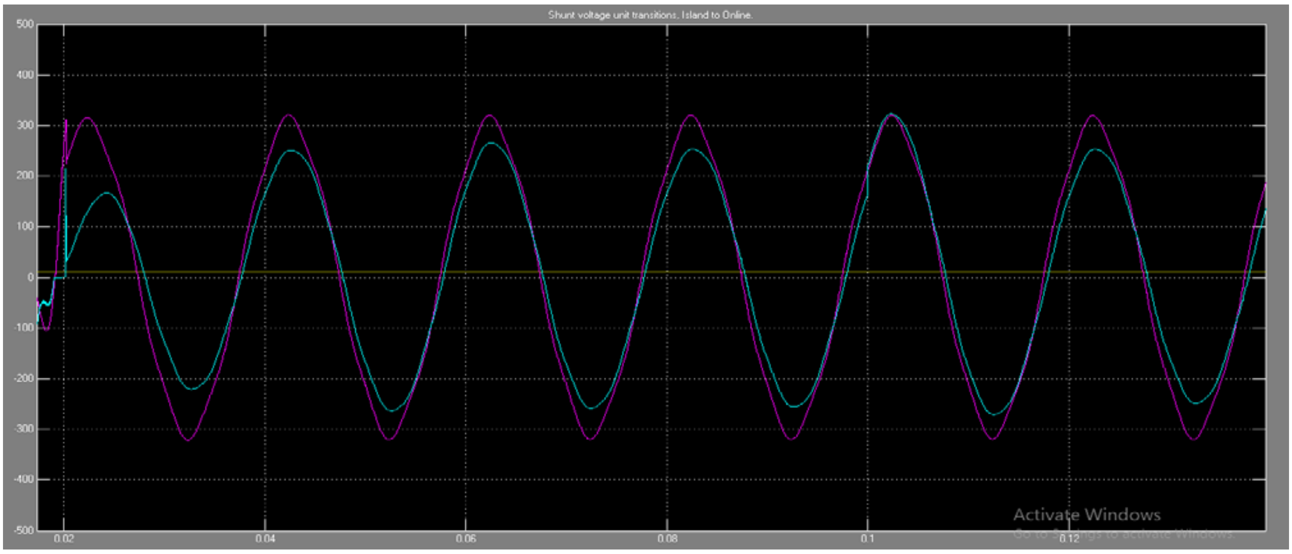


Figure: 4.4 Shunt unit transitions, Island to Online.

As the UPQC can compensate for almost all existing PQ problems in the transmission and distribution grid, integration of a UPQC in the distributed generation network can be multipurpose. Figure 4.3 shows the Shunt unit transitions, Online to Island. And Figure 4.4 shows Shunt unit transitions, Island to Online. 50% more load has added to test Series unit transient behavior. Figure 4.5 shows the Series unit transient behavior, adding 50 % load.

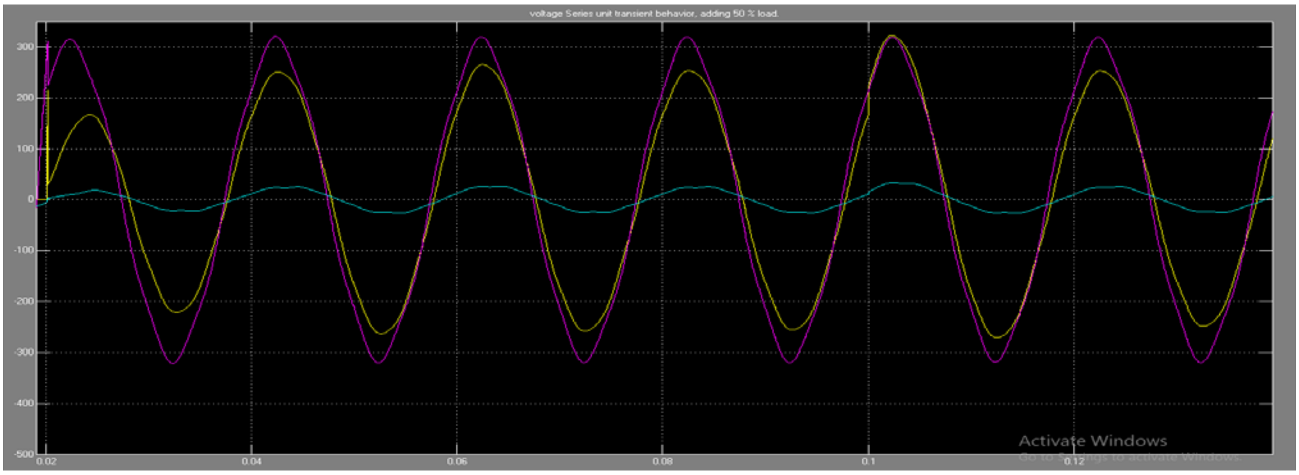


Figure: 4.5 Series unit transient behavior, adding 50 % load.

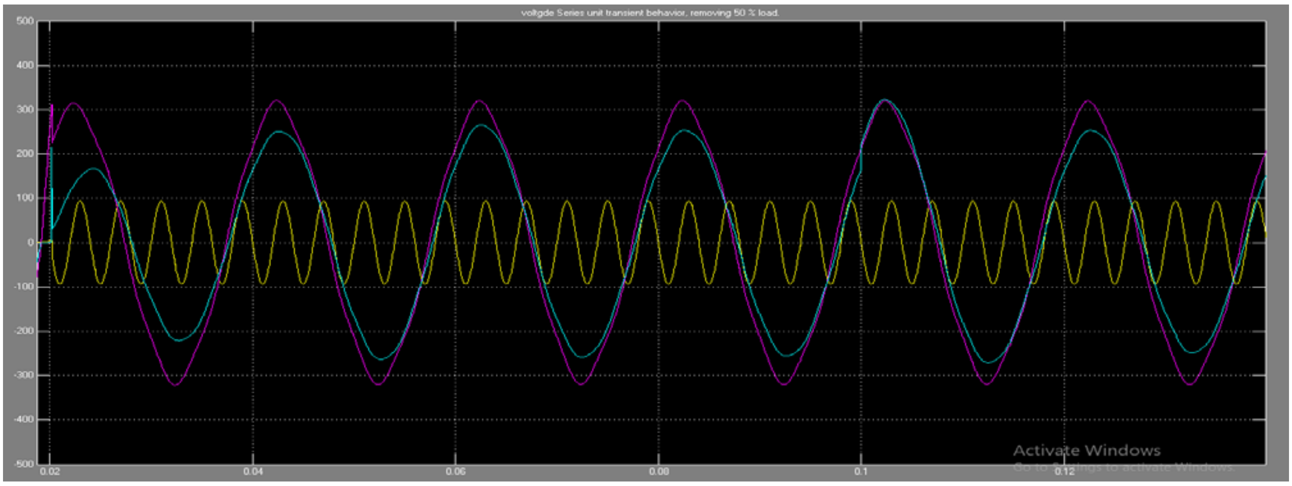


Figure: 4.6 Voltage Series unit transient behavior, removing 50 % load.

Again 50% additional from proposed system has removed and again tested for transient behavior. The waveform of Voltage Series unit transient behavior, removing 50 % load has been shown in figure 4.6.

Finally to achieve proposed objective the THD of the proposed system has been calculated and displayed in figure 4.7 THD calculation at Fundamental (50Hz)=263.5, THD=1.89%.

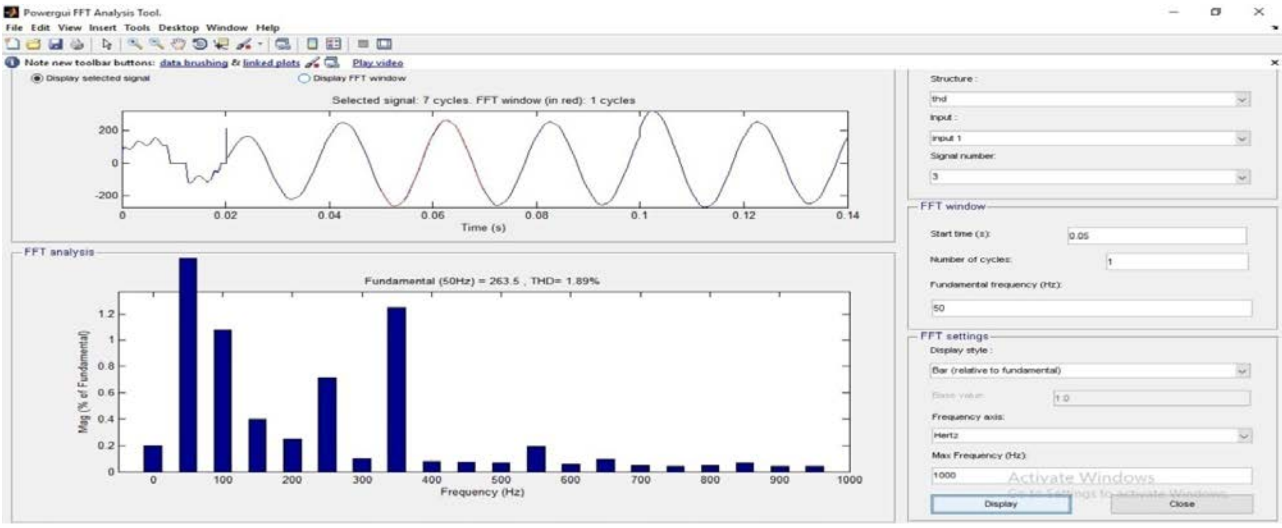


Figure: 4.7 THD calculation.

## V. CONCLUSION

This work mainly focuses on conditioning of power quality. The quality is the “analysis, measurement and improvement of bus voltage” to maintain that voltage at specified potential quantity & amplitude of current Or Frequency. Power quality is a provision of system design and voltage for the end users that they can hold electrical energy from the power system network without any disturbance or interference. In this investigation various issues which are concern with power quality, and its mitigation technique are discussed. A model based on Matlab Simulink has been implemented and simulated to mitigate THD and to improve quality of power.

As the distribution system analyses the end of power system & connected to consumer premises. Thus the reliability of power supply majorly depends upon distribution system. The consumer requirement is increases rapidly that means reliability on system is also increased. Research shows that proposed system is able to mitigate THD from simulation outcome at Fundamental (50Hz) =363.5, THD=1.89% which is better enough compared to previous work.

For future work the following point may be consider for the given circuit:

- The use of multi-level DVR can be carried to establish its behavior.
- The other controller like fuzzy logic and adaptive PI fuzzy logic may be introduced in the DVR compensation strategy.

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