ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 5, May 2016

Enhancing Power Quality of Distributed Power Network with Unified Power Quality Conditioner & FLC

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ABSTRACT: The growth of electricity demand and the increased number of non-linear loads in power grids, providing a high quality electrical power should be considered. A new component within the flexible AC-transmission system (FACTS) family, called unified power quality conditioner (UPQC) is presented in this paper. The UPQC is derived from the unified power flow controller (UPFC). The unified power quality conditioner (UPQC) is being used as a universal active power conditioning device to mitigate both current and voltage harmonics at a distribution side of power system network. The active power exchange between the shunt and series converters, which is through the common dc link in the UPFC, is now through the transmission lines at the third-harmonic frequency. In this paper, the capability of UPQC with fuzzy logic controllers (FLC) is observed for the power system network. The proposed fuzzy logic controller (FLC) in UPQC is capable of providing good static and dynamic performances. On comparing with and without UPQC, the performance is observed. Application of UPQC with fuzzy logic controller in power quality enhancement is simulated in Matlab/Simulink environment which show the effectiveness of the proposed structure**.**

KEYWORDS: Unified Power Quality Conditioner, Fuzzy Logic Controllers, FACTS, UPFC.

I. INTRODUCTION

Power Quality (PQ) has become an important issue to electricity consumers at all levels of usage. The PQ issue is defined as “Any power problem manifested in voltage, current, or frequency deviations that results in failure or miss-operation of customer equipment.” The development of power electronic based equipment has a significant impact on quality of electric power supply. The switch mode power supplies (SMPS), dimmers, current regulator, frequency converters, low power consumption lamps, arc welding machines, etc, are some out of the many vast applications of power electronics based devices. The operation of these loads/equipments generates harmonics and thus, pollutes the modern distribution system. The growing interest in the utilization of renewable energy resources for electric power generation is making the electric power distribution network more susceptible to power quality problems. In such conditions both electric utilities and end users of electric power are increasingly concerned about the quality of electric power. Many efforts have been taken by utilities to fulfil consumer requirement, some consumers require a higher level of power quality than the level provided by modern electric networks. This implies that some measures must be taken so that higher levels of Power Quality can be obtained.

the increment of non-linear load power quality problems like voltage sag, swell, flicker are increased. LC passive filter are use to solve that type of problems. However, this kind of filter cannot solve random variations in the load current waveform and voltage waveform. Active filters can resolve this problem, however the cost of active filters is high, and they are difficult to implement in large scale. as well, they also present lower efficiency than shunt passive filters. FACTS device are use to solve the Power quality problems like sag, swell, harmonics etc. There are many types of FACTS device some of the device include active power filter, surge arrestor, battery storage system, SVR, SVC, DSTATCOM, UPS and UPQC. DVR is the series connected Power quality improvement device and it response time is quick and it is very reliable device for power quality improvement. DSTATCOM is the shunt connected device which is use to solve out power quality problems. It is use to eliminate current distortion problem and harmonic so it is normally connected in parallel to eliminate this type of problems. The UPQC is one of the APF family members which solve both shunt and series power quality problems. The UPQC is a combination of series and shunt active filters

DOI:10.15662/IJAREEIE.2015.0505125

connected through a common DC link capacitor. The main purpose of a UPQC is to solve supply voltage power quality issues such as, sags, swells, unbalance, flicker, harmonics, and for load current power quality problems such as, harmonics, unbalance, reactive current and neutral current.

The UPQC performance mainly depends upon how accurately and quickly reference signals are derived. After efficient extraction of the distorted signal, a suitable dc-link current regulator is used to derive the actual reference signals. The controller is the most significant part of the active power filter and currently various control strategies are proposed by many researchers. There are two major parts of the controller; one is the reference current However, the conventional PI controller requires precise linear mathematical model of the system, which is difficult to obtain under parameter variations and nonlinear load disturbances. Another drawback of the system is that the proportional and integral gains are chosen heuristically. Recently, Fuzzy Logic Controllers (FLCs) have been used in various power electronic applications and also in active power filters. The advantage of FLCs over the conventional controllers is that it does not need an precise mathematical model. It is capable of handling nonlinearity and is more robust than conventional PI or PID controllers.

II. UNIFIED POWER QUALITY CONDITINOR

Unified Power Quality Conditioner (UPQC) is a multifunction power conditioner that can be used to compensate various voltage disturbance of the power supply, to correct voltage fluctuation, and to prevent harmonic load current from entering the power system. It is a custom power device designed to mitigate the disturbances that affect the performance of sensitive and/or critical loads. UPQC has shunt and series compensation capabilities for (voltage and current) harmonics, reactive power, voltage disturbances (including sag, swell, flicker etc.), and power-flow control. Normally, a UPQC consists of two voltage-source inverters with a common dc link designed in single-phase, three-phase three-wire, or three phase four-wire configurations. One inverter is controlled as a variable voltage source in the series active power filter (APF). The other inverter is controlled as a variable current source in the shunt active power filter (APF). The series APF compensates for voltage supply disturbances (e.g., including harmonics, imbalances, negative and zero sequence components, sag, swell, and flickers). The shunt APF converter compensates for load current distortions (e.g., caused by harmonics, imbalances) and reactive power, and perform the dc link voltage regulation.

III. CONFRIGATION OF UPQC

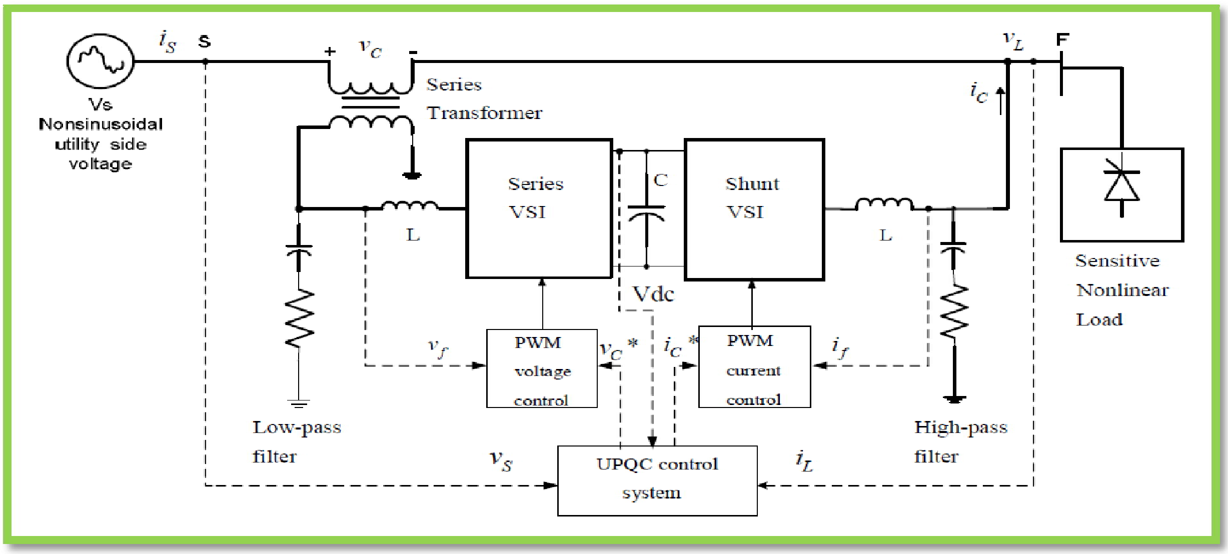


Fig.3.1: Detailed configuration of UPQC

Fig. 3.1 shows system configuration of a three-phase UPQC. The key components of UPQC are as follows:

Series inverter: It is a voltage-source inverter connected in series with AC line through a series transformer and acts as a voltage source to mitigate voltage distortions. It eliminates supply voltage flickers and imbalances from the load terminal voltage. Control of the series inverter output is performed by using pulse width modulation (PWM). Among the various PWM technique, the hysteresis band PWM is frequently used because of its ease of implementation. Also, besides fast response, the method does not need any knowledge of system parameters. In this work hysteresis band PWM is used for the control of inverters. The details of the hysteresis control technique are analysed in the subsequent sections.

Shunt inverter: It is a voltage-source inverter connected in shunt with the same AC line which acts to cancel current distortions, compensate reactive current of the load and improve the power factor of the system. It also performs the DC-link voltage regulation, resulting in a significant reduction of the DC capacitor rating. The output current of shunt converter is adjusted using a dynamic hysteresis band by controlling the status of the semiconductor switches such that output current follows the reference signal and remains in a predetermined hysteresis band.

DC link capacitor: the two VSIs are connected back to back with each other through this capacitor. The voltage across this capacitor provides the self-supporting DC voltage for proper operation of both the inverters. With proper control, the DC link voltage acts as a source of active as well as reactive power and thus eliminates the need of external DC source like battery.

Low-pass filter is used to attenuate high-frequency components of the voltages at the output of the series converter that are generated by high-frequency switching of VSI.

High-pass filter is installed at the output of shunt converter to absorb ripples produced due to current switching.

Series transformer: The necessary voltage generated by the series inverter to maintain a pure sinusoidal load voltage and at the desired value is injected in to the line through these series transformers. A suitable turns ratio is often considered to reduce the current flowing through the series inverter.

IV.OPERATION OF UPQC

As shown in Fig. 3.1 v_s, v_c, i_c, v_L are the supply voltage, series compensation voltage, shunt compensation current and load voltage respectively. The source voltage may contain negative, zero as well as harmonic component. The system (utility) voltage at pint S can be expressed as:

$$v_S = v_{1p}(t) + v_{1n}(t) + \sum_{k=2}^{\infty} 1 v_k(t) \tag{1}$$

Equation (1) can also be written as:

$$v_S = v_{1p} \sin(\omega t + \theta 1p) + v_{1n} \sin(\omega t + \theta 1n) + \sum_{k=2}^{\infty} 1 v_k (k\omega t + \theta_k) \tag{2}$$

Where v_{1p} is the fundamental frequency positive sequence components, v_{1n} is the fundamental frequency negative sequence components respectively. The last term of equation represents the harmonic content in the voltage and θ1p, θ1n , and θ*k* are the corresponding voltage phase angles.

Usually, the voltage at the load at point of common coupling (PCC) is expected to be sinusoidal with fixed amplitude *VL*:

$$v_L = V_L \sin(\omega t + \theta 1p) \tag{3}$$

Hence the series inverter will need to compensate for the following components of voltage:

$$v_c = (V_L - V_{1p}) \sin(\omega t + \theta 1p) - v_{1n(t)} - \sum_{k=2}^{\infty} 1 v_k(t) \tag{4}$$

In the subsequent sections, it will be shown how series-APF can be designed to operate as a controlled voltage source whose output voltage would be automatically controlled using the above described logic.

To provide load reactive power demand and compensation of the load harmonic and negative sequence currents, the shunt-APF acts as a controlled current source and its output component should include harmonic and negative sequence components in order to compensate these quantities in the load current.The distorted non-linear load current can be expressed as:

$$i_L = l_{1p} \sin(\omega t + \delta 1p) + i_{1n}(t) + \sum_{k=2}^{\infty} 1 i_k(t) \tag{5}$$

It is usually desired to have a certain phase angle (displacement power factor angle), φ_L , between the positive sequence voltage and current at the load terminal:

DOI:10.15662/IJAREEIE.2015.0505125

$$\varphi_L = \delta_{1p} - \theta_{1p} \quad or \quad \delta_{1p} = \theta_{1p} + \varphi_L \tag{6}$$

Substituting equation (6) into equation (5) and simplifying yields

$$i_L = l_{1p} \sin(\omega t + \theta 1p) \cos(\varphi_L) + l_{1p} \cos(\omega t + \theta 1p) \sin(\varphi_L) + i_{1n}(t) + \sum_{k=2}^{\infty} 1 i_k(t) \tag{7}$$

In order to compensate harmonic current and reactive power demand, the shunt active filter should produce the following current:

$$i_C = l_{1p} \cos(\omega t + \theta 1p) \sin(\varphi_L) + i_{1n} + \sum_{k=2}^{\infty} 1 i_k \tag{8}$$

Then the harmonic, reactive and negative sequence current will not flow into power source. Hence, the current from the source terminal will be:

$$i_S = i_L - ic = l_{1p} \sin(\omega t + \theta 1p) \cos(\varphi_L) \tag{9}$$

here are also some switching losses in the converter, and hence the utility must supply a small overhead for the capacitor leakage and converter switching losses in addition to the real power of the load. The total current supplied by the source is therefore

$$i_S = i_S + i_{Sl} \tag{10}$$

Where i_{sl} is the current drawn due to switching loss.

Hence, for accurate and instantaneous compensation of reactive and harmonic power it is necessary to estimate the harmonic component of the load current as the reference current of shunt APF.

V. UPQC WITH FUZZY LOGIC CONTROLLER

Modelling and control of dynamic systems belong to the fields in which fuzzy set techniques have received considerable attention, not only from the scientific community but also from industry. Many systems are not amenable to conventional modelling approaches due to the lack of precise, formal knowledge about the system, due to strongly nonlinear behaviour, due to the high degree of uncertainty, or due to the time varying characteristics. To improve the efficiency of UPQC in the system an intelligent control strategy, namely fuzzy control mechanism is proposed for the power system engineer. The controlled strategy implemented by the engineers are prepared as set of rules that are simple to carry out manually but difficult to implement by using conventional control strategy.

In this proposed fuzzy controller approach the inputs are error (e) and change in error (Δe) generates required control signal. The design procedure of FLC consists of the following modules: 1) Fuzzification 2) Fuzzy Rule-base 3) Fuzzy Inference Engine (*Decision Making Logic*) and 4) Defuzzification. A Fuzzy controller operates by repeating a cycle of following four steps. First, measurements are taken of all variables that represent relevant conditions of the controlled process (*Universal Discourse*). Next, these measurements are converted into appropriate fuzzy sets to express measurement uncertainties (*Fuzzification*). Fuzzy models can be seen as logical models which use "if-then" rules to establish qualitative relationships among the variables in the model. Fuzzy sets serve as a smooth interface between the qualitative variables involved in the rules and the numerical data at the inputs and outputs of the model. The rule-based nature of fuzzy models allows the use of information expressed in the form of natural language statements and consequently makes the models transparent to interpretation and analysis. At the computational level, fuzzy models can be regarded as flexible mathematical structures that can approximate a large class of complex nonlinear systems to a desired degree of accuracy. The *fuzzified measurements* are the used by the inference engine (*Decision Making Logic*) to evaluate the control rules stored in *fuzzy rule base*. The result of this evaluation is a *output fuzzy set* (or several fuzzy sets) defined on the universe of possible actions and the degree of membership of the *output fuzzy set* can be calculated by using *Root Sum Square Method*. This fuzzy set is then converted, in the final step of the cycle, into a *crisp* (single) value that, in some sense, is the best representative of the fuzzy set (*Defuzzification*). The *defuzzified value* represents the actions taken by the fuzzy controller in individual control cycles. Now, in the following Sections we develop the various components of FLC to solve power quality problem. Fuzzy controller is developed to generate required control signal it receives the input signal from the system and processing the data in different stages and generate required output.

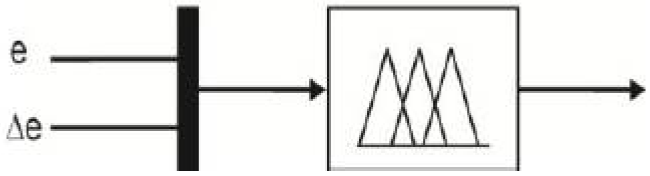


Fig. 5.1: Fuzzy Logic Controller

VI. SIMULATION AND RESULTS

This chapter discusses the simulation results of shunt active power filter (APF), series active power (APF) filter and the unified power quality conditioner to evaluate the proposed control strategy. The simulation models have been developed in MATLAB/SIMULINK environment. The models have been operated for non-linear load. In order to introduce nonlinear load a three phase diode bridge with RL load on dc side is used. Here, the fuzzy controller is implemented. In model, the dc link voltage (voltage across the dc capacitor) that feeds both the shunt and series inverters. Drawing the charging current from the supply, the capacitor is effectively charged to the reference voltage (Vdc). Fuzzy controller holds Vdc constant once the capacitor is charged to required value. Further there is drop in the capacitor voltage when it feeds shunt inverter is not significant, because shunt inverter compensating the load current harmonics, supply only reactive power. The simulation results under voltage distorted condition are presented.

An ideal three-phase sinusoidal supply voltage of 100 MVA, 50Hz is applied to the non-linear load injecting current harmonics into the system. The parameters used for the simulation model are shown in appendix.

TABLE I
SIMULATION PARAMETERS

Parameter	Value
Source Impedance	R= 0.1 Ω; L= 0.11e-3 H
DC link	Capacitor C = 2200e-6
Shunt Inverter Filter	Rs = 1e5 Ω; C=inf , Ron = 1e-3 Ω
Series Inverter Filter	Rs = 1e5 Ω; C=inf , Ron = 1e-3 Ω

The Simuink model is given below.

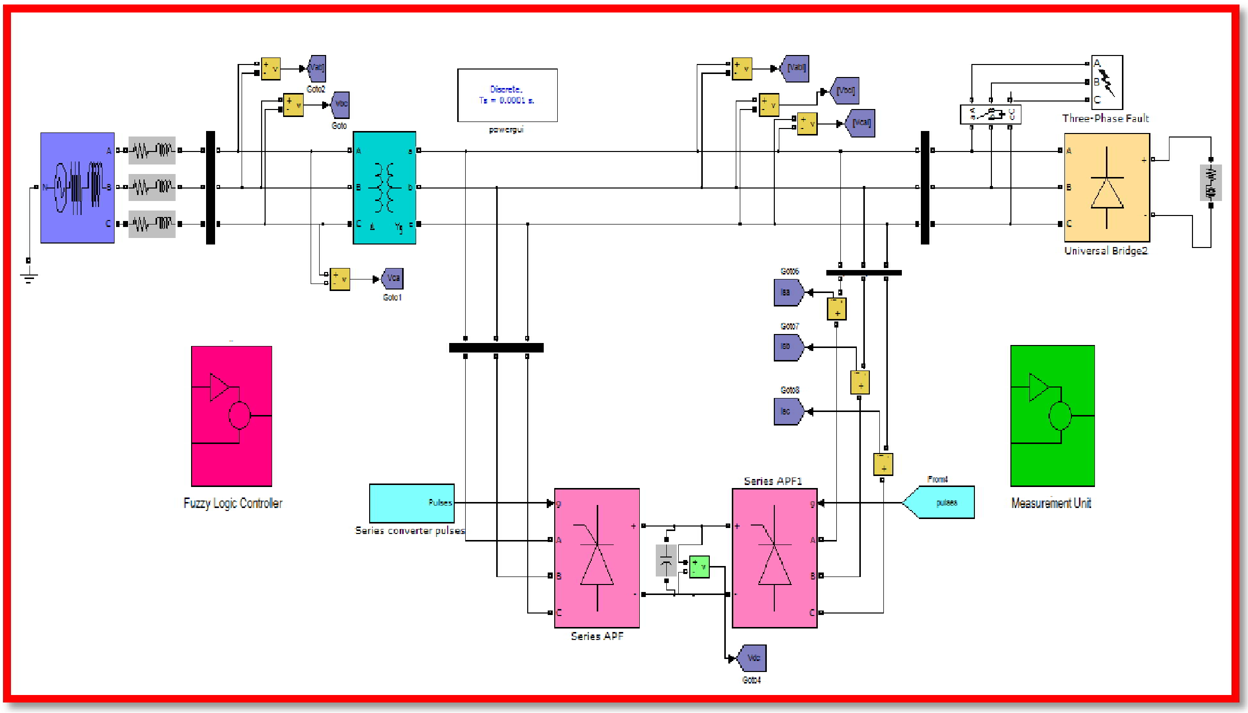


Figure 6.1: Model of Distributed Power Network with Unified Power Quality Conditioner & FLC

DOI:10.15662/IJAREEIE.2015.0505125

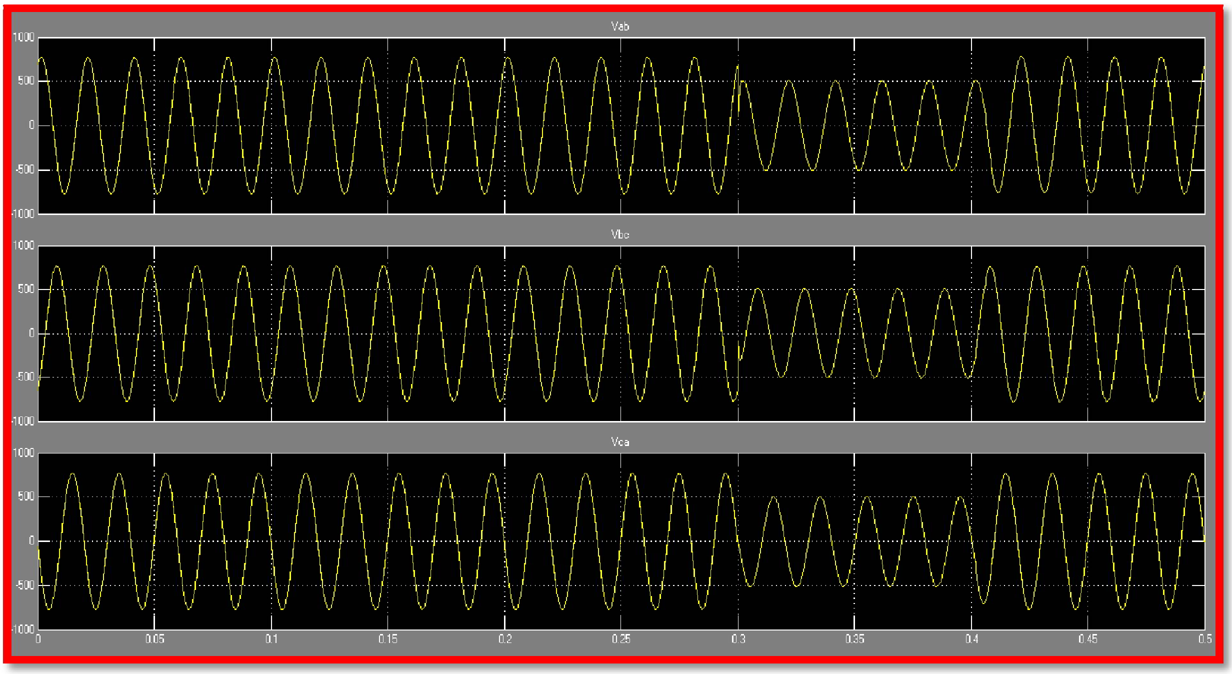


Figure 6.2: Three phase voltage waveform of distributed power network without UPQC & FLC

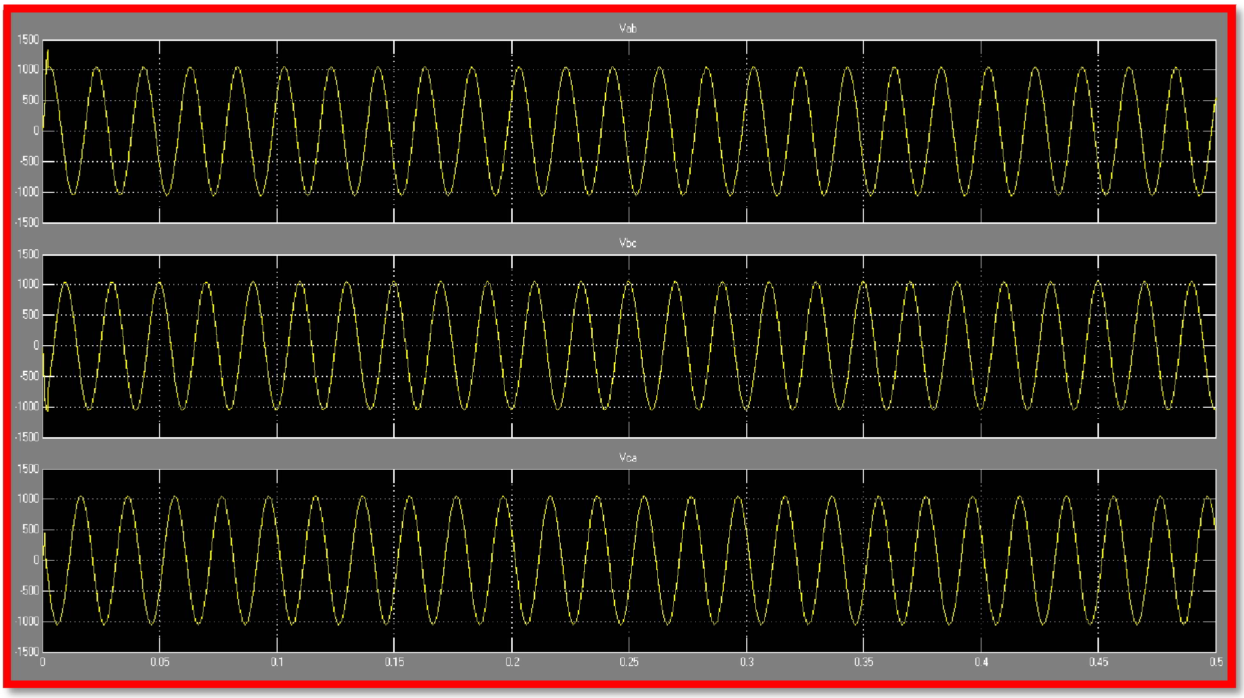


Figure 6.3: Three phase voltage waveform of distributed power network with UPQC & FLC

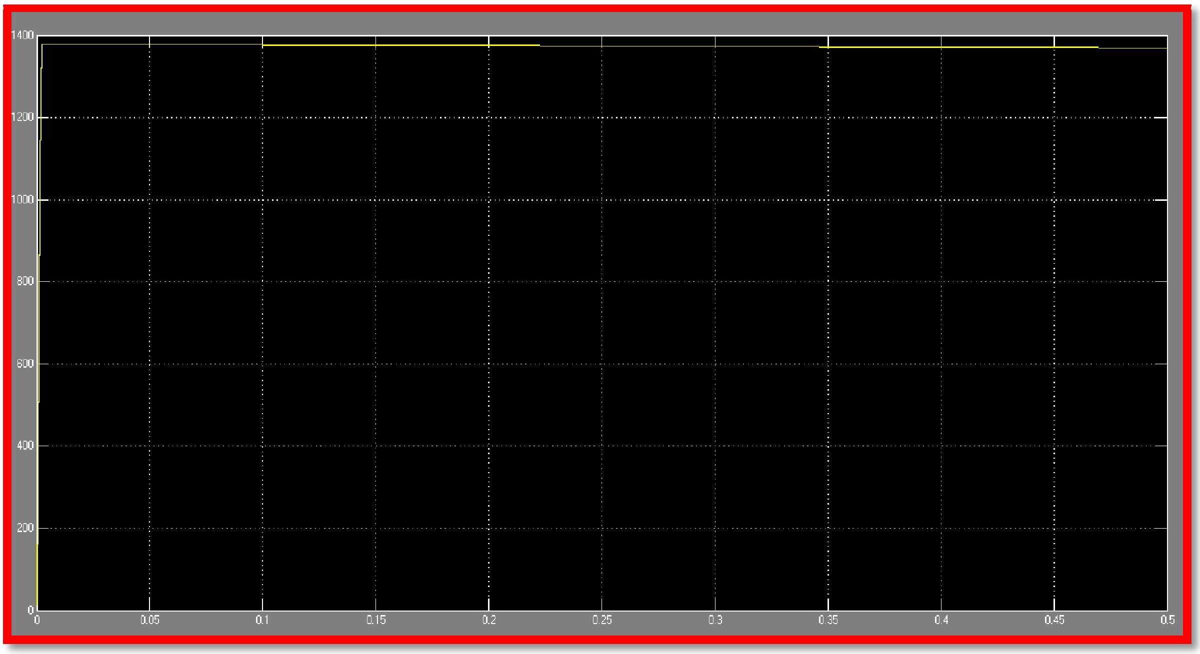
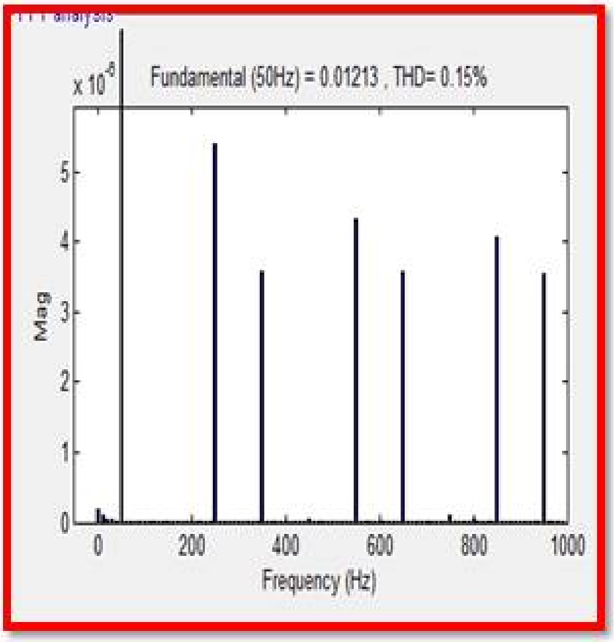


Figure 6.4: DC-link voltage rating of UPQC.



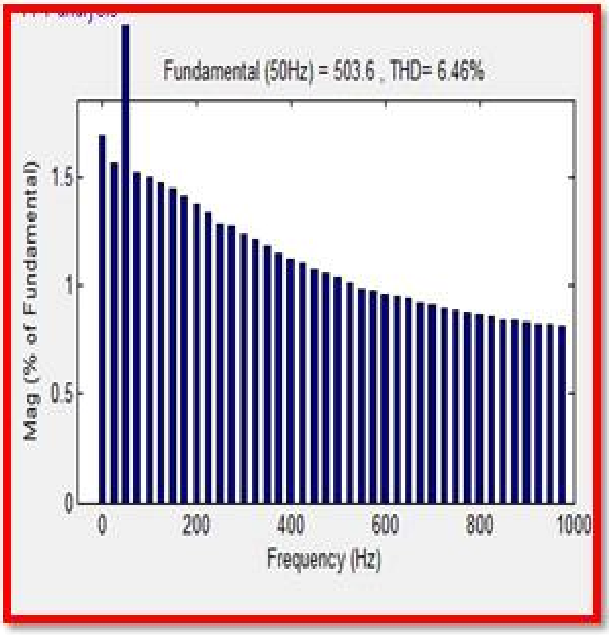


Figure 6.5: THD of distributed power network with UPQC & FLC

Figure 6.6: THD of distributed power network without UPQC & FLC

VII.CONCLUSION

In this paper, a distributed power network with Unified Power Quality Conditioner & FLC has been investigated for power quality enhancement. UPQC is an advanced hybrid filter that consists of a series active filter (APF) for compensating voltage disturbances and shunt active power filter (APF) for eliminating distortions. the obtained results from the simulation show better performance of modified UPQC with fuzzy logic controller in power system network compare than without UPQC & FLC. The THD of distributed power network with Unified Power Quality Conditioner & FLC is below without UPQC & FLC. The THD is 0.15 % and 6.46 % respectively.

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BIOGRAPHY

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