Analysis & Function of Unified Power Quality Conditioner for Power Quality Improvement of Distributed Network

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Abstract--- In this paper a technical review of the integration of a Unified Power Quality Conditioner (UPQC) in a distributed generation network is presented.. The increasing use of the Nonlinear devices, such as power electronics converters, inject harmonic currents in the AC system and increase overall reactive power demanded by the equivalent load. Also, the number of sensitive loads that require ideal sinusoidal supply voltages for their proper operation has increased. This paper deals with the shunt APF, series APF and the unified power quality conditioner (UPQC) which aims at the integration of series and shunt active filters. The main purpose of a UPQC is to compensate for voltage flicker/imbalance, reactive power, negative sequence current and harmonics. In other words, the UPQC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems. & reduce the THD of voltage & current level.

Keywords: Active power filter (APF), harmonic compensation, power quality, reactive power compensation, unified power quality conditioner (UPQC), voltage sag and swell compensation.

I. INTRODUCTION

This paper represent about that It has been always a challenge to maintain the quality of electric power within the acceptable limits. Poor power quality may result into increased power losses, abnormal and undesirable behavior of equipment's, interference with nearby communication lines, and so forth. The widespread use of power electronic based systems has further put the burden on power system by generating harmonics in voltages and currents along with increased reactive current. So by reduce the voltage sag, voltage swell, and harmonic distortion by these custom power devices. The term active power filter (APF) is a widely used terminology in the area of electric power quality improvement .So by reduces the power quality problem like a voltage sag voltage swell, harmonic distortion by these custom power devices. Custom power devices like SOLID STATE TRANSFER SWITCH, D STATCOM, DYNAMIC VOLTAGE RESTORER, UNIFIED POWER QUALITY CONDITIONER devices.

II. SUPERIORITY OF UPQC OVER OTHER DEVICES

Each of Custom Power devices has its own benefits and limitations. The UPQC is expected to be one of the most powerful solutions to large capacity loads sensitive to supply voltage and load current disturbances imbalance. The most effective type of these devices is considered to be the Unified Power Quality Conditioner (UPQC). There are numerous reasons why the UPQC is preferred over the others. UPQC is much flexible than any single inverter based device. It can simultaneously correct for the unbalance and distortion in the source voltage and load current whereas all other devices either correct current or voltage distortion. Therefore the purpose of two devices is served by UPQC only.

III. UNIFIED POWER QUALITY CONDITIONER (UPQC)

The best protection for sensitive loads from sources with inadequate quality, is shunt-series connection i.e. unified power quality conditioner (UPQC) .Recent research efforts have been made towards utilizing unified power quality conditioner (UPQC) to solve almost all power quality problems for example voltage sag, voltage swell, voltage outage and over correction of power factor and unacceptable levels of harmonics in the current and voltage The basic configuration of UPQC is shown in fig1.The main purpose of a UPQC is to compensate for supply voltage flicker/imbalance, reactive power, negative-sequence current, and harmonics .In other words, the UPQC has the capability of improving power quality at the point of installation on power distribution systems or industrial power systems. The UPQC, therefore, is expected as one of the most powerful solutions to large capacity sensitive loads to voltage flicker imbalance.

Unified Power Quality Conditioner (UPQC) for non-linear and a voltage sensitive load has following facilities:

- It eliminates the harmonics in the supply current, thus improves utility current quality for nonlinear loads.
- 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 necessary.
- UPQC maintains load end voltage at the rated value even in the presence of supply voltage sag.
- The voltage injected by UPQC to maintain the load end voltage at the desired value is taken from the same dc link, thus no additional dc link voltage support is required for the series compensator.

The UPQC consists of two three phase inverters connected in cascade in such a manner that Inverter I is connected in series with the supply voltage through a transformer inverter II is connected in parallel with the load. The main purpose of the shunt compensator is to compensate for the reactive power demanded by the load, to eliminate the harmonics and to regulate the common dc link voltage. The series compensator is operated in PWM voltage controlled mode. It injects voltage in quadrature advance to the supply voltage (current) such that the load end voltage always maintained at the desired value. The two inverters operate in a coordinated manner.

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.

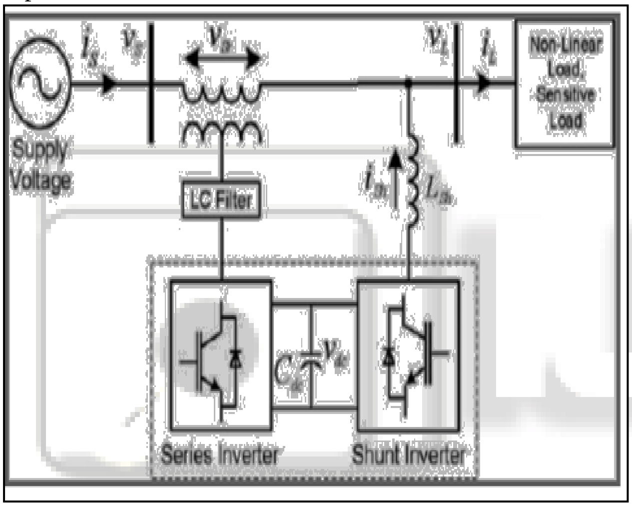

Fig. 1: Configuration of UPQC.

The Unified Power Quality Conditioner is a custom power device that is employed in the distribution system to mitigate the disturbances that affect the performance of sensitive and/or critical load. It is a type of hybrid APF and is the only versatile device which can mitigate several power quality problems related with voltage and current simultaneously therefore is multi functioning devices that compensate various voltage disturbances of the power supply, to correct voltage fluctuations and to prevent harmonic load current from entering the power system.

Fig1 shows the system configuration of a single-phase UPQC. 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. The series converter connected in series to the load provides voltage compensation. Thus UPQC improves the power quality by preventing load current harmonics and by correcting the input power factor.

IV. BASIC CONFIGURATION OF UPQC

The main components of a UPQC are series and shunt power converters, DC capacitors, low-pass and high-pass passive filters, and series and shunt transformers:

Series converter It is a voltage-source converter connected in series with the AC line and acts as a voltage source to mitigate voltage distortions. It is used to eliminate supply voltage flickers or imbalance from the load terminal voltage and forces the shunt branch to absorb current harmonics generated by the nonlinear load. Control of the series converter output voltage is usually performed using sinusoidal pulse-width modulation (SPWM). The gate pulses required for converter are generated by the comparison of a fundamental voltage reference signal with a high-frequency triangular waveform.

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

Midpoint-to-ground DC capacitor bank It is divided into two groups, which are connected in series. The neutrals of the secondary transformers are directly connected to the DC link midpoint. As the connection of both three-phase transformers is Y/Yo, the zero-sequence voltage appears in the primary winding of the series-connected transformer in order to compensate for the zero-sequence voltage of the supply system. No zero-sequence current flows in the primary side of both transformers. It ensures the system current to be balanced even when the voltage disturbance occurs.

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

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

Series and Shunt transformers These are implemented to inject the compensation voltages and currents, and for the purpose of electrical isolation of UPQC converters. The UPQC is capable of steady-state and dynamic series and/or shunt active and reactive power compensations at fundamental and harmonic frequencies. However, the UPQC is only concerned about the quality of the load voltage and the line current at the point of its installation, and it does not improve the power quality of the entire system.

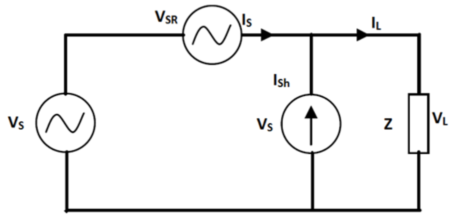

Fig. 2: Equivalent circuit for UPQC

In this circuit,

VS represent the voltage at power supply

VSR is the series-APF for voltage compensation,
VL represents the load voltage and
ISh is the shunt-APF for current and VSR compensation.

Due to the voltage Distortion, the system may contain negative phase sequence and harmonic components.In general, the source voltage in Figure 2 can be expressed as:

$$Vs + Vsr = VL$$

To obtain a balance sinusoidal load voltage with fixed amplitude V, the output voltages of the series-APF should be given by;

$$Vsr = (V - V1p)\sin(\omega t + \theta 1P) - VLn(t) - \sum_{K=2}^{\infty} Vk(t)$$

where,
V1P: positive sequence voltage amplitude fundamental frequency $\theta 1P$: initial phase of voltage for positive sequence
V1n: negative sequence component

The shunt apf acts as a controlled current source and its output component should included harmonic,reactive negative sequences components in order to compensate these quantities in the load current,when the output current of shunt apf Ish is kept to be equal to the component of the load as given in the following equation.

$$iL = I1p\cos(\omega t + \theta 1P)\sin\varphi 1P + ILn + \sum_{k=2}^{\infty} Ilk$$

$$\phi 1P = \varphi 1P - \theta 1P$$

where,
φ1P: initial phase of current for positive sequence

As seen from the above equations that the harmonic, reactive and negative sequence current is not flowing into the power source. Therefore, the terminal source current is harmonic-free sinusoid and has the same phase angle as the phase voltage at the load terminal

V. FUNCTIONS OF UPQC

- Reactive Power Compensation
- Voltage Regulation
- Compensation for voltage sag and swell
- Unbalance Compensation for current and voltage (for 3-phase systems
- Neutral Current Compensation (for 3-phase 4-wire systems).

VI. CONTROL STRATEGY OF UPQC

The control strategies are proposed here to generate reference signals for both shunt and series APFs of UPQC. An approach based on two closed loop PI controllers for shunt APF utilization and other strategy UTT is exploited to get reference voltage signals for the series APF. Fig.4 shows the reference voltage generation for series and shunt.

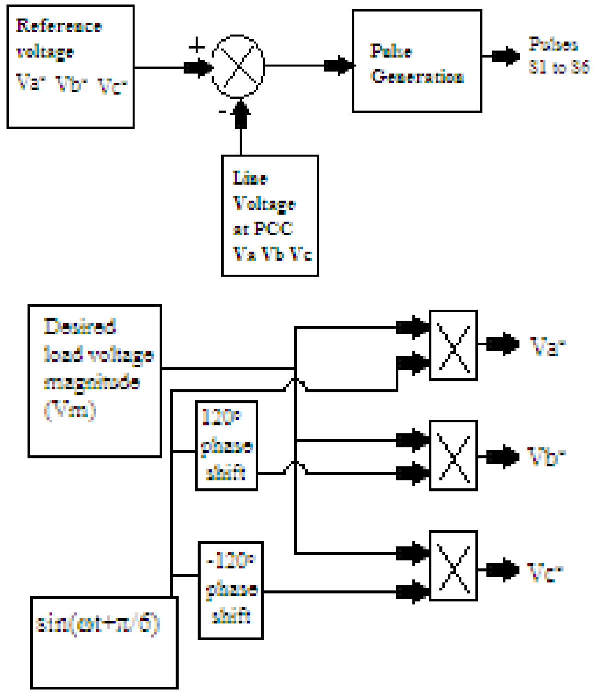

Fig. 3: Control strategy for Series Active Power Filter

A. *Reference voltage signal generation for series APF:*

The extraction of three-phase voltage reference signal for series APF is based on Unit Vector Template Generation, and this is achieved with the help of PLL. These Unit Vector Templates are multiplied with the desirable peak amplitude (Vm) of load voltage to obtained reference load voltages denoted by va*, vb* and vc*.

Va*=Vm*ua
Vb*=Vm *ub
Vc*=Vm *uc

B. *Reference current signal generation for shunt APF*

The control strategy for shunt APF is based on the utilization of closed loop PI controllers. These PI controllers are used to get the amplitude of the in-phase components of reference supply currents (Im), The PI controller is realized on the sensed and reference values of DC bus voltage of back-back VSI capacitor of UPQC. To regulate the voltage at PCC the three-phase reference supply currents have component and this component of reference supply currents in-phase with the voltage at PCC. It is very essential to feed active power to the load and the losses of UPQC. The second component is in quadrature component which is quadrature with the voltage at PCC. From above mentioned constrained, the algorithm for control of the shunt APF of UPQC is made flexible to achieve good voltage regulation. The multiplication of amplitude of the in-phase components of reference supply currents (Im) with in-phase unit current vectors(ua, ub and uc) results in the in-phase components (ia*, ib* and ic*) of three-phase reference supply currents. (ia*, ib* and ic*).

C. *Pulse generation for shunt and series APFs*

For the generation of gating pulses of MOSFET.s of shunt APF, a carrier-less hysteresis current controller is employed over the reference and sensed supply currents similarly for generation of gating pulses of MOSFET.s of series APF again a carrier-less hysteresis voltage controller is employed over the reference and sensed voltages at PCC. In this control scheme, the fast changing APF current/voltages is replaced by the current and voltage control is applied over the fundamental components, which reduces the computational delay and the number of required sensors.

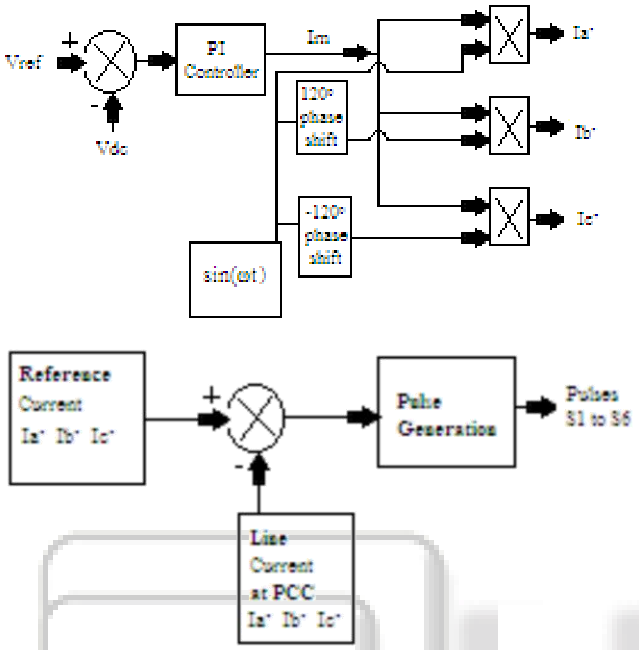

Fig. 4: Control strategy for Shunt Active Power Filter

VII. ADVANTAGE & DISADVANTAGE

To eliminate the offset, should be adjusted and reach a constant value when error becomes zero.

- The integral mode will change the bias value until the error becomes zero eliminate offset.
- The action is not immediate until the integral becomes significant. Also, the integral mode tends the system to be more oscillatory, even unstable.
- Advantages are Fast action, eliminate the offset.
- Disadvantage are Oscillatory or unstable with integral control, one more parameter to tune.

VIII. RESULT AND DISCUSSION

Technical Parameters for field oriented control induction motor load for Test

S. No.	System Quantities	Standards
1	Source	3-phase, 13kV, 50Hz
2	Inverter parameters	IGBT based, 3-arm, 6-Pulse Carrier Frequency=1080 Hz, Sample Time=5 μs
3	PI controller	KP=0.5, Ki=1000 for series control Kp=0.5, Ki=1000 for shunt control, Sample time=50 μs
4	RL load	Active power = 1kW, Inductive Reactive Power=400 VAR
5	Motor load	Voltage Vrms=11kV, Frequency 50 Hz
6	Transformer1	Y/Δ/Δ 13/115/115kV
7	Transformer2	Δ/Y 115/11kV

Table 1: Technical Parameters for field oriented control induction motor load for Test

The proposed model of a three-phase four-wire UPQC and the proposed control scheme are developed in the MATLAB/SIMULINK environment first the reference voltages and the reference currents are generated and then the reference voltages are compared with the actual load voltages and the reference currents are compared with the actual source currents and then the error signals are given to the hysteresis controllers for generating the switching signals for the switches of series active power filter and the shunt active power filter. And the generated pulses are then given to the series and shunt APF.s and accordingly the switches are turned on and off to compensate for the voltage and current harmonics.

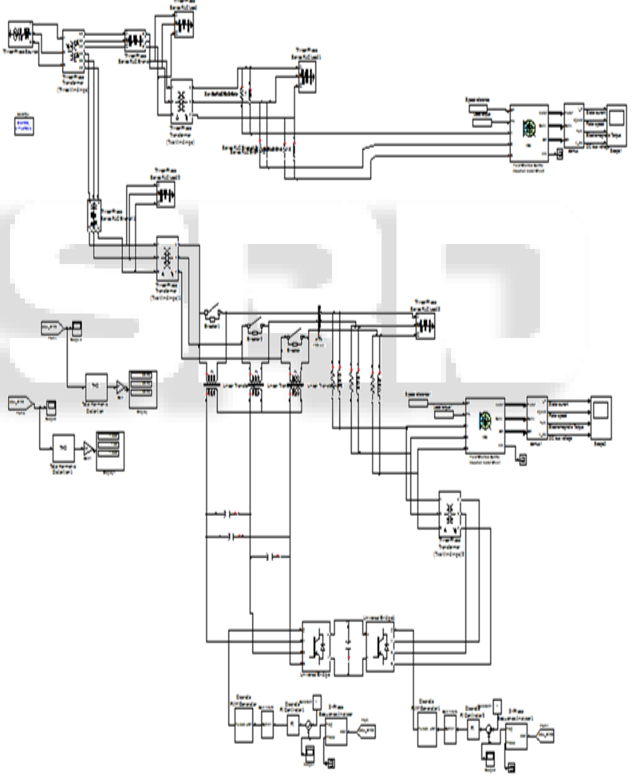

Fig. 5: Matlab Simulink Model Of Upqc Using Foc Induction Motor Drive

IX. RESULTS WHEN FIELD ORIENTED CONTROL INDUCTION MOTOR DRIVE IS USED AS LOAD

An ideal three-phase sinusoidal supply voltage is applied to the non-linear load (Field oriented control Induction motor drive) injecting current and voltage harmonics into the system. Figure 6(a) shows load current in three-phase before compensation Figure 6(b) shows THD level for uncompensated load current. Figure 7(a) shows the load current for compensated system Figure 7(b) shows THD level for compensated load current. Figure 8(a) shows load voltage in three-phase before compensation Figure 8(b) shows THD level for uncompensated load voltage. Figure 9(a) shows the load voltage for compensated system Figure 9(b) shows THD level for compensated load voltage.

The Total Harmonic Distortion (THD) for load current which was 6.35% in Figure 6(b) before compensation and effectively reduces to 3.59 % in Fig.7(b) after compensation using PI controller. Shunt inverter is able to reduce the harmonics entering into the system. The Total Harmonic Distortion (THD) for load voltage which was 29.30% in Fig.8(b) before compensation and effectively reduces to 29.19 % in Fig.9(b) after compensation using PI controller. The voltage compensation is small because system consists of transformers which are already doing compensation for voltage.

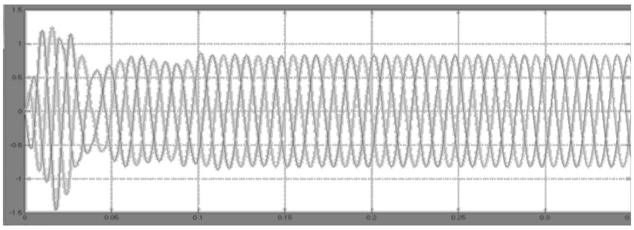
Fig. 6:(a): Current waveform without UPQC

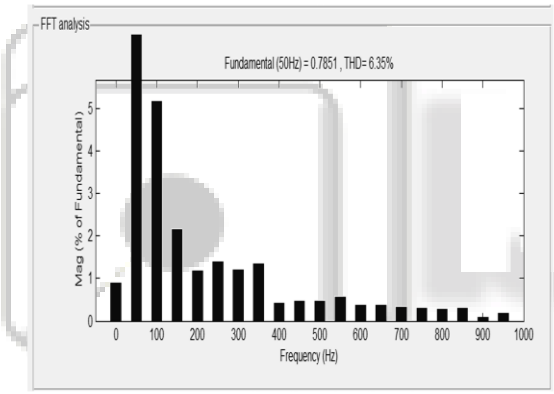

Fig. 6(b): Total harmonic distortion without UPQC for current

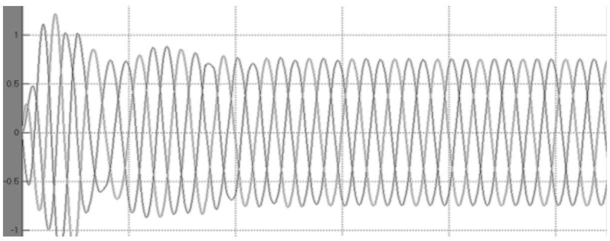
Fig. 7(a): Current waveform with UPQC

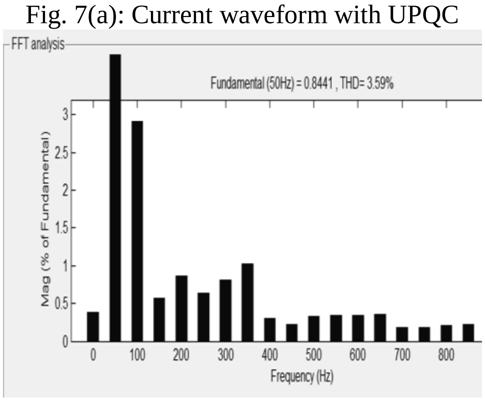

Fig. 7(b): Total harmonic distortion with UPQC for current

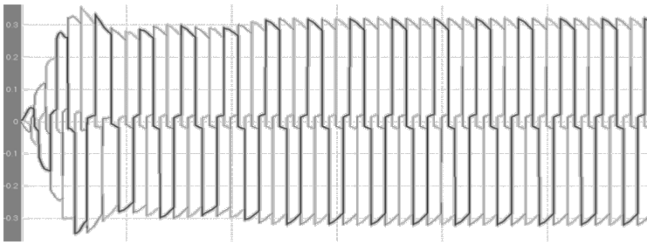
Fig. 8(a): Voltage waveform without UPQC

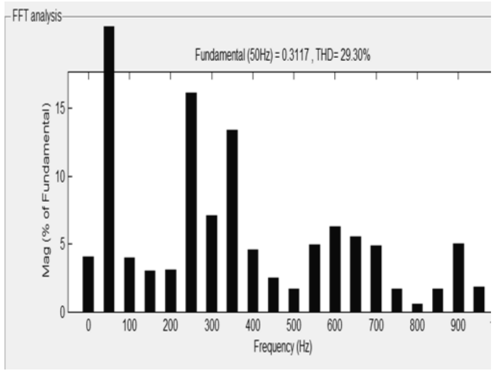

Fig. 8(b) Total harmonic distortion without UPQC for voltage

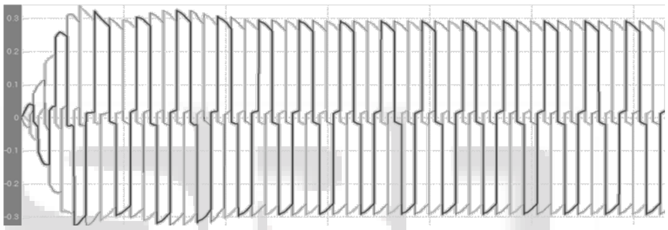
Fig. 9(a): Voltage waveform with UPQC

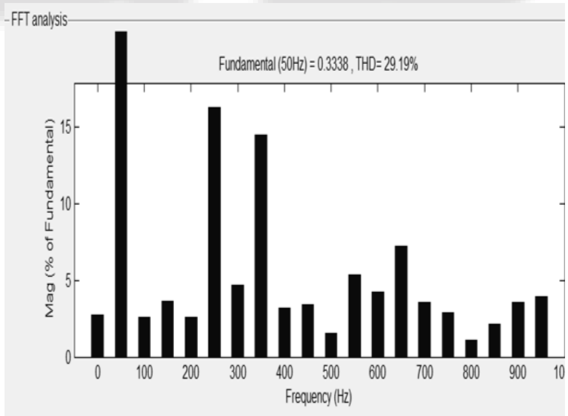

Fig. 9(b): Total harmonic distortion with UPQC for voltage

X. CONCLUSION

The MATLAB/SIMULINK were used to carry out extensive simulation studies on unified power quality conditioner and for the controlling purpose the proportional integral controller is used and adjustable speed drive is used as a load . Therefore, UPQC is considered to be an efficient solution. Unified power quality conditioner is capable of reducing the level of THD in the case of networks which are connected to the harmonics generating load (like ASD).

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