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Three Phase PV Integrated UPQC for Power Quality Enhancement

Sidhi Vishnu Vardhana Chary[1] and Dr.C. Bhargava[2]
M. Tech Student, Department of Electrical and Electronics Engineering, Sreenidhi Institute of Science and Technology, Ghatkesar, Hyderabad, Telangana, India [1]
Associate Professor & HOD, Department of Electrical and Electronics Engineering, Sreenidhi Institute of Science and Technology, Ghatkesar, Hyderabad, Telangana, India[2].

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Active power filter (APF), power quality (PQ), photo voltaic unified power-quality conditioner (PV-UPQC), Proportional integral controller (PI), Maximum power point tracking (MPPT), Point of connection (POC).

ABSTRACT

Reliable power filters that lower current and voltage harmonics are crucial to the operation of modern power grids. In this article, we'll go through the steps you need to do to create a PV-UPQC that will enhance the quality of your electricity. Series and shunt APF are combined into a single circuit in PV-UPQC. Shunt Active Power Filters utilize the instantaneous reactive power theory (P-Q Theory) to address current harmonics, whereas series APF makes use of the dq theory to address voltage problems like voltage sag/swell. In order to power the DC-Link, a buck-boost converter is connected to the PV system through a maximum power point tracking (MPPT) algorithm. A proportional-integral (PI) controller is used to regulate the DC-link voltage. Hysteresis current control may be used to produce the gate pulses that activate the VSI switches. In this paper, we construct a full PV-UPQC in MATLAB/Simulink and test it out with a variety of nonlinear loads. If implemented, the proposed UPQC would ensure that THD remains below acceptable limits, even in the presence of severe defects like LLLG problems. The proposed filter has been shown to be effective in simulations, reducing harmonic distortion to levels much below the IEEE limitations.

1. INTRODUCTION

Recently, the importance of power quality (PQ) has grown. There are a few of the most useful items in the world, power electronics-based goods or functional prototypes Due to advancements in power electronics, a wide variety of tools for creating clean energy and enhancing power grid management are now within reach in Flexible Alternating Current Transmission Systems. One such organization is the UPQC. Block diagram depiction of the UPQCs used in this analysis is shown in Figure 1. A UPQC may be useful for addressing problems associated with reactive power [4], harmonics, and supply voltage variations or imbalances. Once again, the UPQC may be easily integrated into existing electrical distribution networks or industrial power grids to quickly improve power quality. The UPQC is generally recognized as one of the most effective technologies for shielding high-capacity loads from harm due to supply voltage flicker/imbalance. To address this gap in our understanding, this research presents a universal power quality criterion (UPQC) that may be used to any power system. For these active filters, a series-and-shunt topology is utilized. By entirely insulating the voltage at the load terminal from the voltage at the power source, a series-active filter lessens the likelihood of voltage imbalances and fluctuations. Shunt-active filters are used to reduce the harmonic current.

In order to keep the voltage stable throughout the dc-link, we haveincluded a buck-boost converter and PV. The distribution system must guarantee that the real power being consumed has the specified amplitude and frequency. PQ is the fact to standard for expressing voltage and other quantities,excellent voltage, dependability, and quality of power. Low-quality power may be raised due to non-linear loads. The distribution and transmission networks indicators of deteriorating electrical quality include power line disturbances come in numerous forms, including impulses, notches, voltage sags/swells, voltage and current imbalance, interruptions, and harmonic distortions. The distribution system has poor power quality because to harmonics [2].

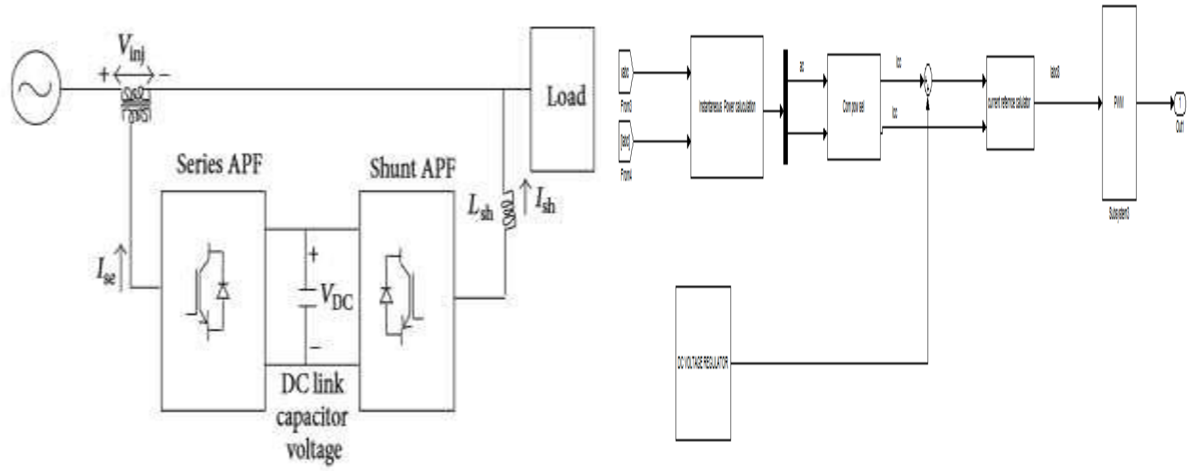

Figure. 1*:* Block diagram of UPQC

As there is increase in complexity and decrease in dependability of passive filters, high and medium voltage passive filters are seldom used. It retains some of the shortcomings of its forerunner, including the inability to be tuned, the impossibility of adjusting its mass, and a resonance that might potentially disrupt the electrical system.

UPQC CONTROL STRATEGY

A. Shunt APF Control Strategy

Active power in a shunt topology line conditioners use power electronics to create harmonic components that cancel one other out, reducing the negative effects of harmonic distortion those caused by a non-linear load. An alternating current (ac) network harmonics filter [1] consists of a power converter and a control unit, and it injects harmonics into the network that are out of phase with the harmonics of the measured load. It will detect current harmonics at POC, then generate compensating harmonics to eliminate them. The waveforms produced by the source are very certainly corrected by a feedback mechanism before being sent to the load. Both voltage and power factor are controlled by the filter. The P-Q simulation circuit of a shunt active power filter is shown in the figure.

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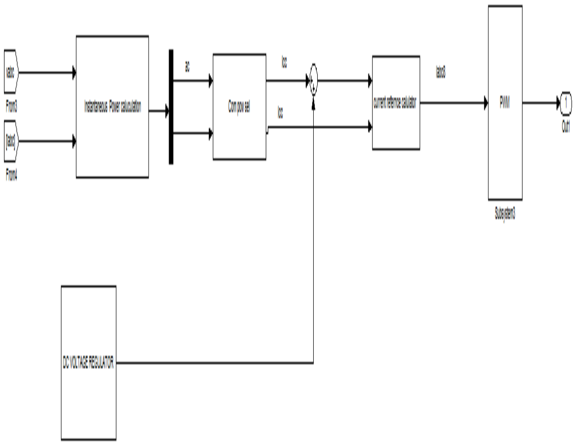

Fig. 2(a): Shunt Active Power Filter

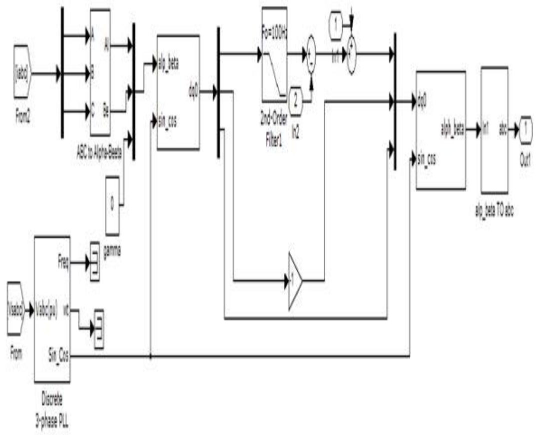

Fig. 2(b): P-Q theory-based simulation of a shunt active power filter.

The point of connection (POC) has a parallel connection between the load and the active power line conditioner. Existing compensatory approaches that function in the time domain allow for quick responses (specification). By injecting the compensating current at the parallel point, this Shunt active power filter line conditioner may eliminate the current harmonic at POC and restore the source current to sinusoidal operation.

A voltage source inverter (also called a shunt active power inverter) has its dc terminal connected to a capacitor for energy storage, while its ac terminal is connected directly to the AC bus through an interface inductor. Whether linear or nonlinear, the ac-bus can power any appliance in your home or business. A closed-loop control system actively alters the current flowing through the coupling (interface) inductor in an active power line conditioner.

The voltage across a dc-link capacitor may be managed using P-Q theory, a PI controller and phase-locked loop (PLL) circuit which is utilized vector orientation [1]. Three-phase, fixed-coordinate load currents (iLa,iLb,iLc) are converted to two-phase, rotating-coordinate direct (d) and quadratic (q) forms.

Classical P-Q theory [1] provides the theoretical foundation for the idea of instantaneous real and reactive power.Nomatter whether the input power is symmetrical or unbalanced, the extraction controller will still operate normally. With the help of an active power line conditioner, a nonlinear load current may be corrected, potentially resulting in a balanced, sinusoidal source current. The high computational cost of this controller's great performance is a trade-off.

B. Series APF Control Strategy

Connecting an active power filter in series with the power source may mitigate the consequences of harmonic distortion and power factor imbalance. The presence of fluctuations, peaks, and pulsing might be an indication of imbalance in the system.

The source voltage distortion may be eliminated by connecting APF circuits in series. An active power filter (APF) may correct voltage waveform distortions and harmonics by injecting a voltage component in series with the source voltage. Adjusting the load voltage using the series APF might be a straightforward solution to these supply voltage problemsin a place devoid of danger and strife. A series transformer is often used to link an APFC to a transmission line. The only method to know for sure whether the turns ratio of the series transformer is sufficient for the voltage injection is to take a reading. The three-phase voltage's a, b, c reference frame is converted into the dqo reference frame.

$$\begin{bmatrix} v_d \\ v_q \\ v_0 \end{bmatrix} = \begin{bmatrix} \sin(\omega t) & \cos(\omega t) & 1 \\ \sin(\omega t - \frac{2\pi}{3}) & \cos(\omega t - \frac{2\pi}{3}) & 1 \\ \sin(\omega t + \frac{2\pi}{3}) & \cos(\omega t + \frac{2\pi}{3}) & 1 \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$

The above shows the transformation between three-phase a, b, c quantities into dqo frame and from dqo to three-phase a, b, c quantities.

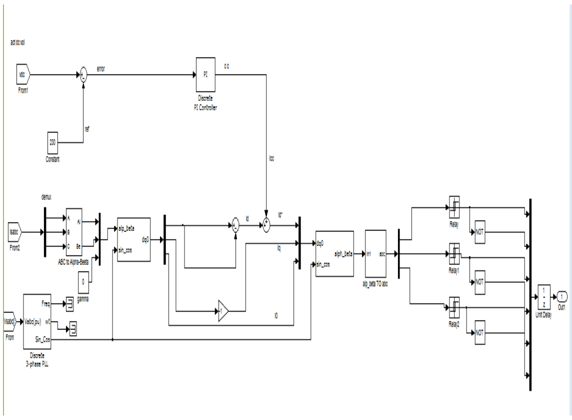

Fig. 3. Series Active Power Flight Simulation Circuit

The output voltage of the series active filter will not be equal to the compensatory value if the DC voltage is different from the rated value. To maintain a consistent voltage, the DC voltage regulator provides a command signal.

HysteresisController:

Hysteresis voltage controller gives output signal to VSI inverter whenever error is generated. Switching occurs whenever output voltage crosses hysteresis band. It is for the phase "a" operation, for "b and c" it is same. Whenever $V_{ca}= V_{ca}^{*} + HB/2$ then upper switch is OFF and lower switch is ON. And $V_{ca}= V_{ca}^{*} - HB/2$ then upper switch is ON and lower switch is OFF.

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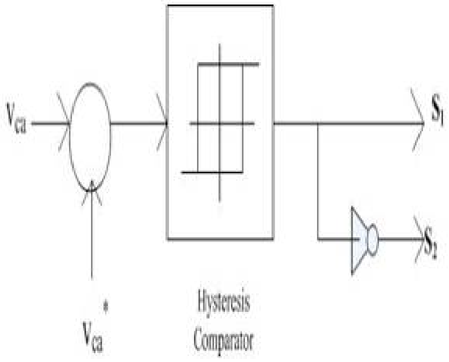

Fig. 4:HysteresisVoltageController

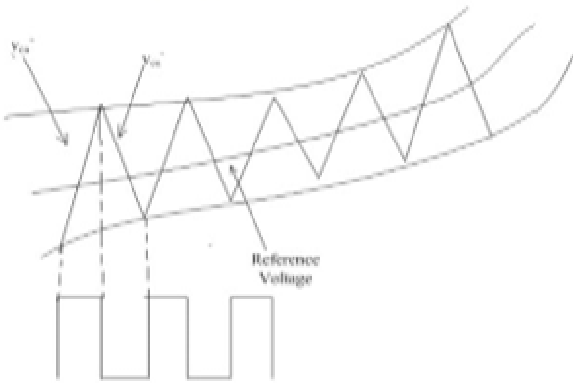

Fig.5:PrincipleofHysteresisVoltagecontroller

In Fig. 5, we see the hysteresis controller's response to an out-of-range reference voltage. (As seen by the triangle waveform, on the right). It is possible for the meter to provide false readings if the voltage is beyond the hysteresis range. The series transformer may reduce current in the series inverter and achieve ideal load-side voltage balance by injecting a compensation voltage with the right turn's ratio. A DC voltage regulator may be anything from a capacitor or battery to a whole separate device. This DC power source might be used to power VSI.

Table1:SimulationParameters

	Parameters		values
Soure	Voltage	Vsabc	400Vrms
	Frequency	f	50 Hz
Load	3 phase AC line Inductance	$L_L$abc	5mH
	1 phase AC line Inductance	L_La1	5mH
	3 phase DC Inductance	Ldc3	10mH
	3 phase DC Resistance	Rdc3	30 Ω
	1 phase DC Capacitance	Cdc1	0.24μF
	1 phase DC Resistance	Rdc1	90Ω
DC link	Voltage	V_{DC}	700V
	Twoseries Capacitor	C_1 ,C_2	2200μF
Shunt Active Filter	AC line Inductance	Lcabc	3mH
	Filter Resistance	Rcabc	5Ω
	Filter Capacitor	Ccabc	20μF
Series Active Filter	AC line Inductance	Ltabc	3mH
	Filter Resistance	Rtabc	5Ω
	Filter Capacitor	Ctabc	10μF
	Two series Transformer	S	1KVA

PROPOSED SYSTEM SIMULATION AND RESULTS

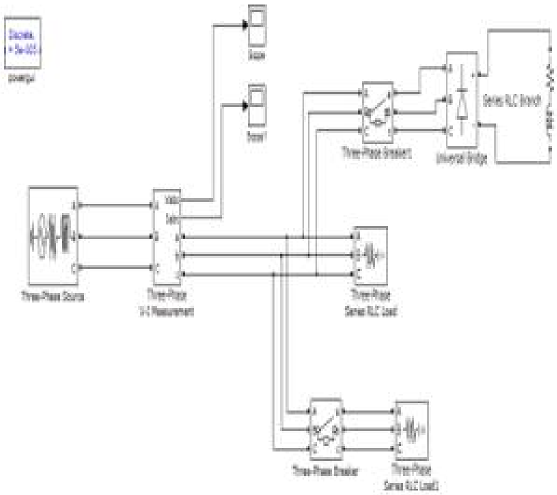

Figure. 6: without UPQC

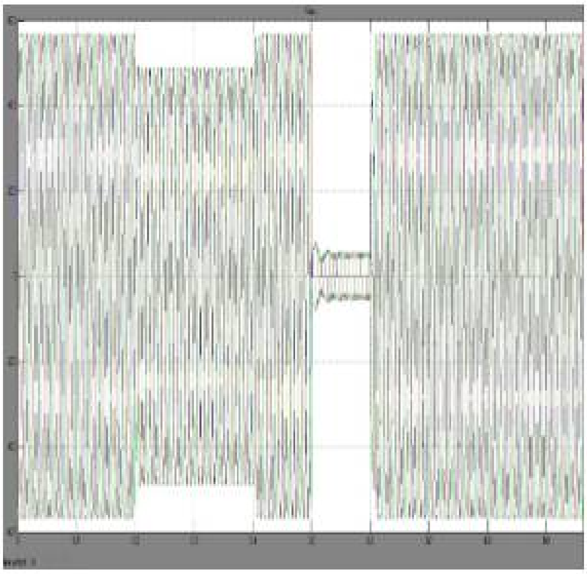

Figure. 7:Source voltage wave form

As the loading is switched ON and switched OFF at different interval, there is harmonics in source voltage and current waveforms as shown in fig 7 and 8 respectively. From figure 6 the three-phase breaker 1 will switch ON in the interval 0.5 to 0.6 seconds while the three-phase breaker will switch ON during the interval 0.9 to 0.1 seconds only. Because of the different switching action of the three-phase breaker there will be harmonics in both current and voltage.

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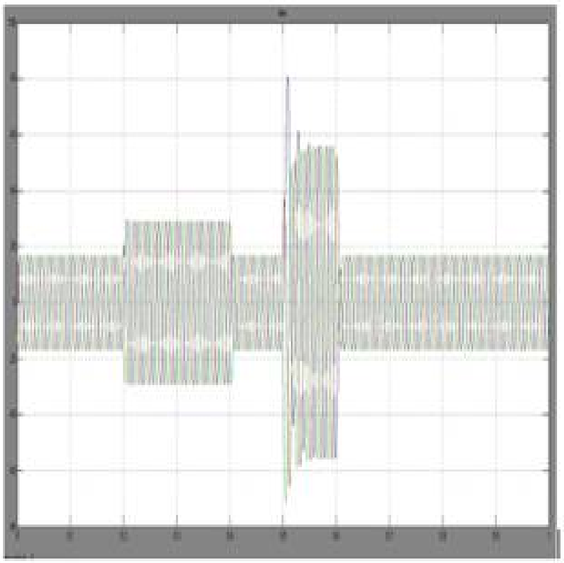

Figure.8:sourcecurrent

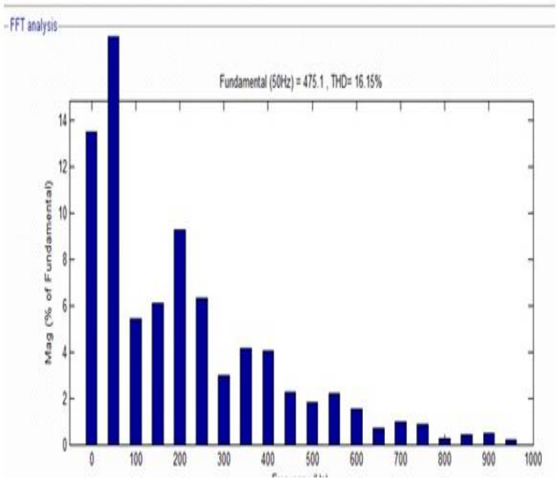

Figure. 9: for an FFT analysis of the source voltage.

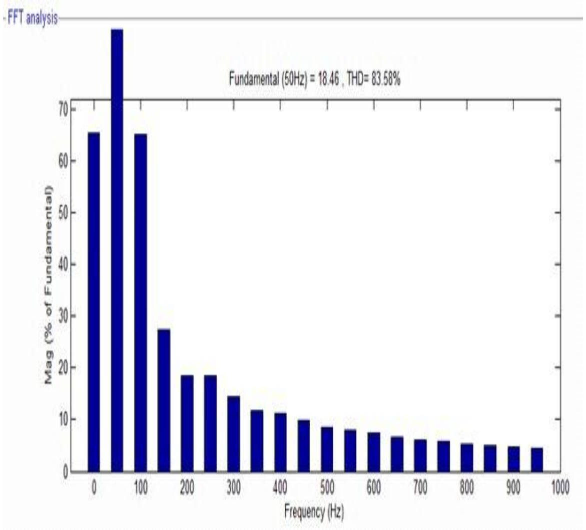

Figure. 10: Source Current FFT Analysis

Total harmonic distortion (THD) of 16.15% and 83.58%, respectively, may be expected in the voltage and current waveforms due to the switching action of the three-phase circuit breaker.

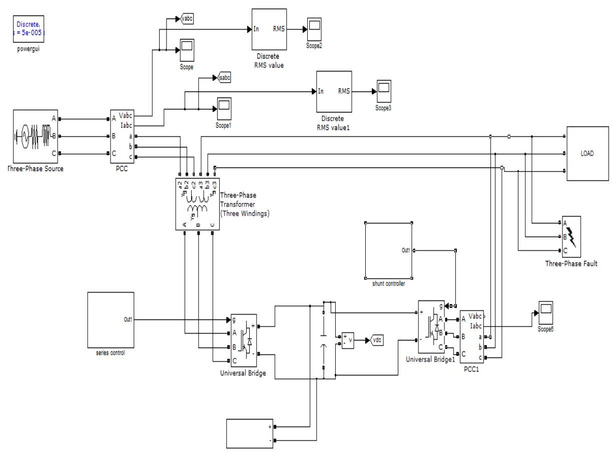

Figure. 11: UPQC Circuit Used in Simulation

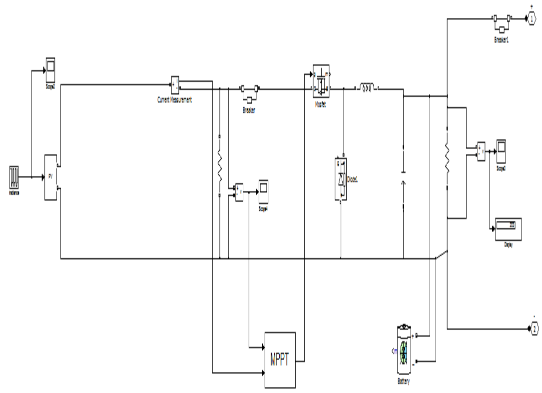

Figure. 12: PVWithBuck-BoostConverter

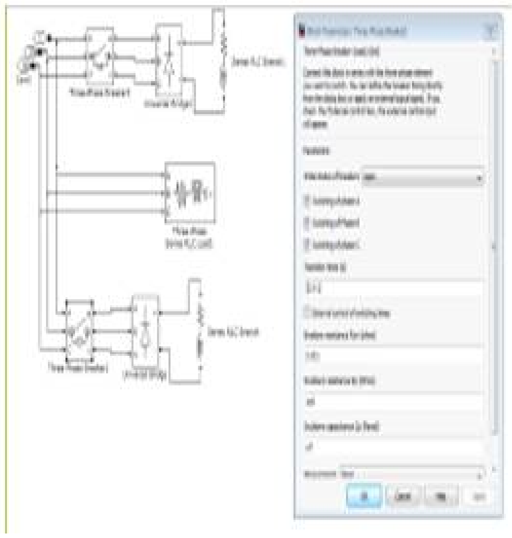

Figure.13:withmultipleload

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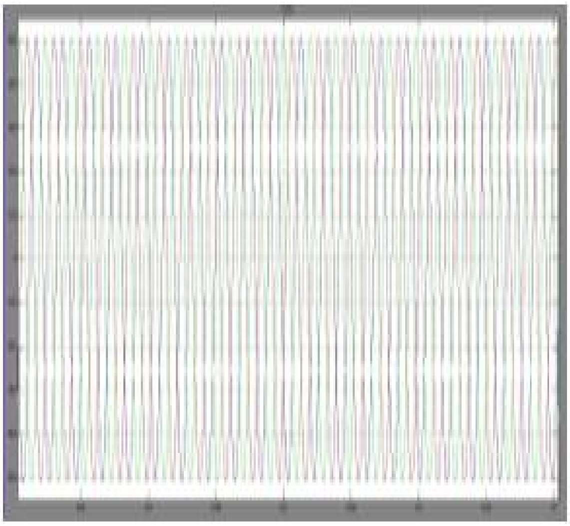

Figure.14:sourcevoltagewaveform

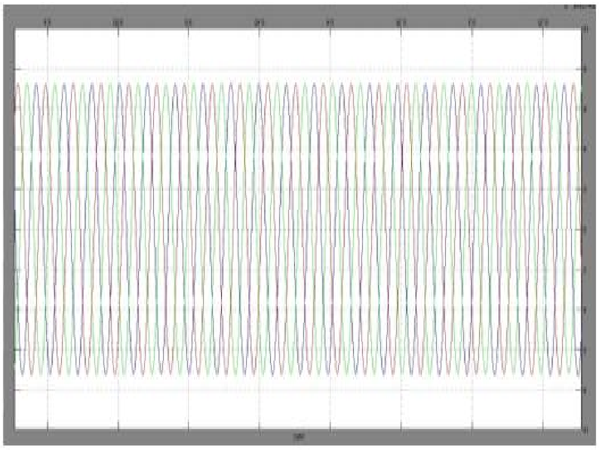

Figure. 15: Source Current Waveform

Waveforms of the currents and voltages from this source are sinusoidal, and they all have the same phase relationship. If you turn on the UPQC, the load will act as a resistance. An active shunt filter may be used to dampen the effects of harmonic current.

In spite of this, reactive current has to be cancelled out to increase power factor. The P-Q theory is the most well-known technique for regulating voltage and current, and it was proposed by Akagi.

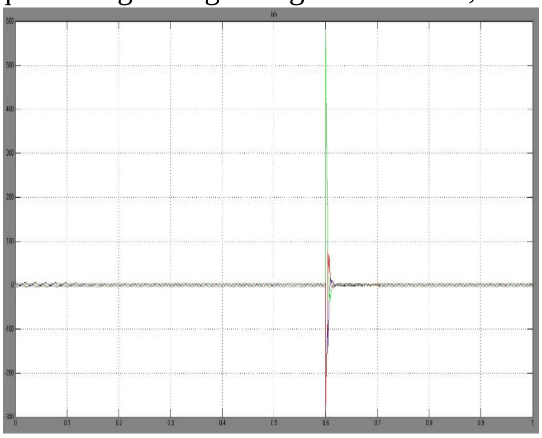

Figure.16:Injected Shunt Current

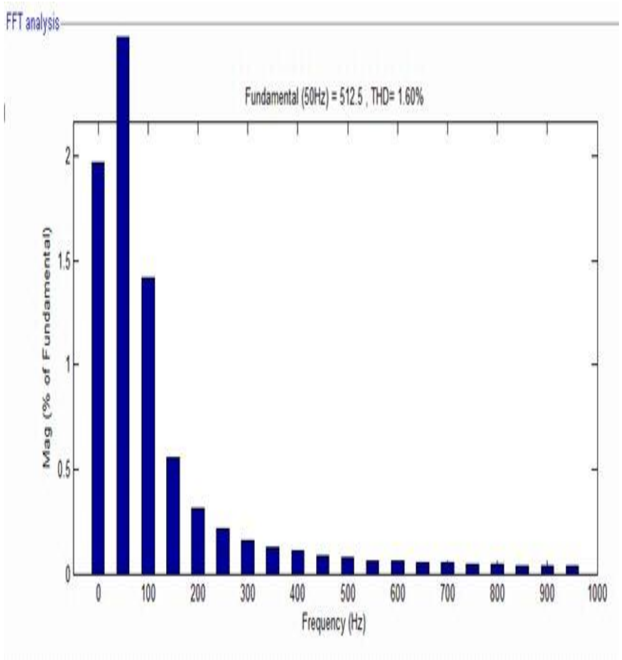

Figure. 17: FFTAnalysisofSource Voltage

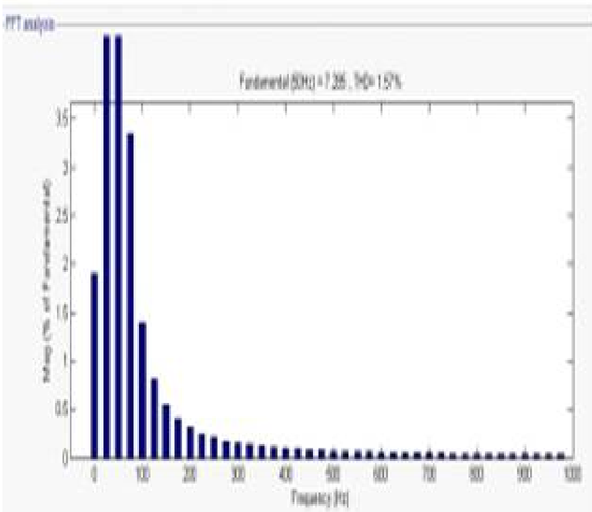

Figure.18:FFTAnalysisofSourcecurrent

In figure 11 and 13 due to multiple loading which is switched at different intervals and due to LLLG fault there is harmonics in voltage and current and also voltage imbalance in the system. Therefore, the power quality is improved by the combination of series and shunt active power filter. The shunt APF will inject the opposite harmonic current into the system as shown in the figure 16. Therefore, the voltage and current waveforms has a THD of 1.6% and 1.57% which is in the acceptable range (<5%).

Table2:COMPARISIONOFTHD:

SYSTEM CONDITION	TOTAL HARMONIC DISTORTION (THD)	
WITHOUT UPQC	For source voltage	16.15%
	For source current	83.58%
WITH UPQC	For source voltage	1.6%
	For source current	1.57%

CONCLUSION

The voltage and current harmonics in the distribution system are mitigated by the three-phase unified power quality line conditioner. The compensation process uses suitable control method to extract the reference-current while controlling dc-link capacitor voltage of the inverter. The active power line conditioner is implemented with P-Q theory which is used as a control algorithm and the switching patterns are generated by hysteresis controller. To put it simply, harmonics are the root of many of the power quality issues that plague businesses and factories. If electrical systems are often tripping due to poor power quality, costs and downtime might soon add up. The most severe problems, such LLLG failures, may be mitigated thanks to this UPQC. It has been determined that the THD values of the source voltage and source current are 16.15% and 83.5%, respectively; these figures, if reduced by UPQC, might fall below 5%.

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