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Voltage Sag and Harmonic Compensation of PV Fed Unified Power Quality Conditioner

P. Marshall Arockia Dass[1], Omkar S Pawar[2] and A. Peer Fathima[3]

ABSTRACT

This paper demonstrates the design of PV fed Unified Power Quality Conditioner (UPQC). Nowadays due to growing applications in power electronics, the power quality problems in the grid interconnected applications take great interest. Hence, mitigation of harmonics and utilisation of clean energy related to power electronics applications became popular worldwide. PV fed UPQC is proposed in the present paper. The unique property about UPQC is it can also export active power. According to the analysis, the proposed UPQC has the capability of eliminating both the supply current distortion, which is a consequence of nonlinear loads and secondly, distortions caused due to the introduction of the fifth and seventh order harmonics to the supply voltage. Also, the proposed UPQC transfers power obtained from PV to the grid using boost converter. The simulation system gives the performance of voltage sag, voltage swell, harmonic distortions and its mitigation and also offers future outlook on UPQC.

Keywords: UPQC, Active Power Filter (APF), voltage swell, voltage sag, harmonic mitigation, power quality.

I. INTRODUCTION

The field of renewable energy resources has undergone many evolutions of the recent society, in the utilisation of clean energy. The PV system is at the zenith of all the solar energy applications because of its versatile attributes such as easy construction, maintenance, and wide applications. As a result of this characteristics, the PV system have been successfully deployed in many of the commercial usage and also some of the technical research [1-3]. The PV based outcomes have been further broadened on their interconnection to grid. Actually the enhancement in the power electronics technology have boosted the utilisation of PV supplied to inverter as that of grid interconnection capabilities efficiently [4-5]. However, the power quality has degraded by switching actions because of the propagation of nonlinear loads, due to their compactness and better controllability. Whenever these power electronics systems are connected to the utility, they cause harmonics, sub harmonics or also at times cause super harmonics in current and voltage patterns. As a consequence of which they can cause malfunctioning in the electrical equipment. To overcome this constrains, different types of filters have been introduced for filtering the harmonics and for reactive power compensation. Also there are some demerits of filter, such as they cause the system to be greater in size and resonant problems, hence gives good margin to carry out research in domain of passive filter. In order to enhance the quality of power, taking into account the voltage and current distortion limits for nonlinear load, numerous system have been proposed. Custom power devices like DVR, DSTATCOM and UPQC have been proposed in recent years for improvement of power quality in the electrical distribution system. Development in manufacturing of power semiconducting devices have led to better characteristics such as higher voltage rating, current rating and at the same time higher switching frequency. In addition to repress voltage and

1 Research Scholar

2 M. Tech student

3 Professor

School of Electrical Engineering, VIT University, Chennai- 600 12

E-mails: [1]marshall.arockiadass2013@vit.ac.in; [2]pawaromkar.subhash2015@vit.ac.in; [3]peerfathima.a@vit.ac.in

current distortions, one can also cope up with the power quality problems such as voltage sag, voltage swell, currents voltage imbalance, flickers, reactive current, frequency oscillations, interruptions and surges[6]. The basic classification is of three types: first is the UPFC, which performs power flow control, voltage regulation and reactive power compensation. Second is the UPQC, which combines series active filter for harmonic current compensation. Third one is UPLC, which sums the function of UPQC and UPFC into a signal power conditioner. Voltage sag, voltage swell are the most significant power quality problem [7-8]. Voltage sag and voltage swell can be compensated using DVR, UPQC. Among the available power quality enhancement devices, UPQC has better sag/swell compensation capability, as compared to the other custom power devices. Nowadays one comes across many voltage and current related problems frequently, as a result of which, compensation of the both is must. The UPQC is an combination of the shunt and series active power filter is one of the effective devices in this concern. UPQC handles both current as well as current related power quality problems simultaneously. To avoid extra cost and hardware for UPQC system, some studies discussed with the PV. In present paper, UPQC have been used and modelled to improve the power quality, manipulated by harmonic disturbances and to export active power to grid. The proposed system is supplied by the combination of two active power filters, one in parallel and series share a common dc link voltage generated by PV. While the parallel active power filter compensates the current distortions caused by nonlinear loads and also transfers energy generated by PV to the grid.

II. CONFIGURATION OF UPQC

UPQC consists of two important types of Active Power Filter (APF). First is the shunt APF and the second is the series APF. The shunt APF handles the current related problems, whereas, voltage related problems are overcome by series APF. Since presently modern distribution requires better quality power, installations of these APF is of utmost importance. However, installation of two APF independently, may not be a cost effective solution. Moran [9] described a system in which both series and shunt APF were connected back to back with a common dc reactor. Later Fujita and Akagi named the topology as UPQC. The back to back topology is also known as series parallel converter. In construction, UPQC is similar to a UPFC. Both the devices uses two voltage source inverters which are connected to a common dc link capacitor. UPFC is used in power transmission system and UPQC is used in power distribution system. The main aim of UPQC is to compensate for supply voltage power quality problems like, sags, swell, unbalance, flickers and harmonics. UPQC consists of two voltage source inverters. One is connected across the load, which acts as shunt APF and other one is connected in series with the line as series APF. Shunt coupling inductor L_{sh} is used to interface shunt inverter [10]. This helps in smoothing the current waveform. A common dc link capacitor is used in between the two inverters, which maintains constant self-supporting dc bus voltage. An LC filter is used to eliminate high switching ripples. Series injection of transformer which is used to connect the series inverter in the network[11].

III. DESIGN OF PROPOSED UPQC

The adding of PV to existing power system gives some technical challenges, as a result of which one has to consider problems of voltage regulation, stability and power quality problems. There are many MPPT algorithms such as the voltage feedback method, perturbation and observation method, linear approximation method, incremental conductance method, hill climbing method and actual climbing method. This paper demonstrates the incremental conductance method. For the incremental conductance method, maximum power point is obtained when the condition (dp/dv)=0 is accomplished. The slope (dp/dv) of the power can be calculated by the consecutive output current and output voltage and the formulation is given as

$$\frac{dp}{dv}(n) = \frac{P(n)-P(n-1)}{V(n)-V(n-1)}$$

where, P(n)=V(n).I(n)

If the value of instantaneous conductance and incremental conductance and incremental conductance are equal, it represents that the maximum power point is found. The UPQC has two main units. The first one is power circuit formed by series and shunt PWM converter. The series PWM acts as controlled voltage source, whereas shunt PWM converter behaves as controlled current source. The combination of series and shunt active filters made by MOSFET are connected back to back, which shares common dc voltage generated by capacitor.

Fig. 2. Manifests the block diagram of a series compensator. The proposed controlling circuit uses abc to dqo transformation. For the improvement of the operation of the series inverter, Pulse Width Modulation (PWM) technique is used. The operation of series inverter is enhanced remarkably by the application of PWM technique.

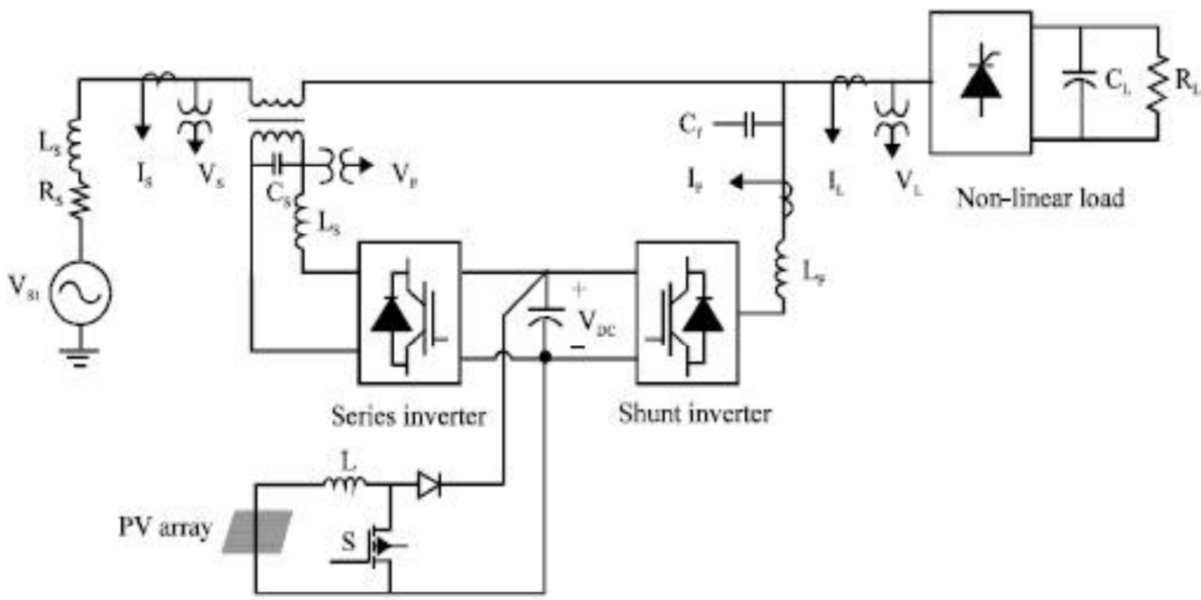

Figure 1: Block diagram of PV fed UPQC

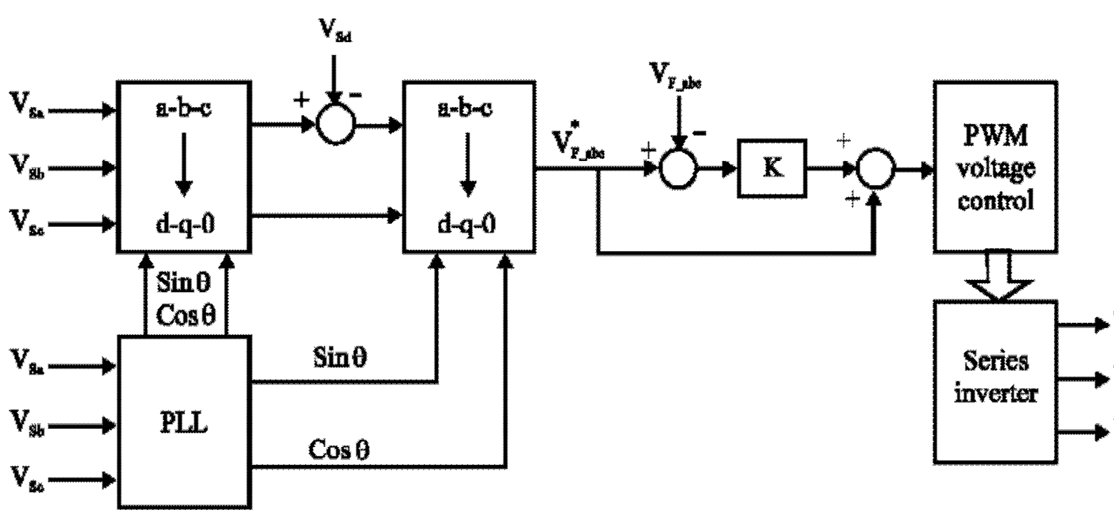

Figure 2: Block diagram of series inverter

Table 1
Parameters of the optimised circuit

Parameters		*Values*
Power supply	Rms voltage	415.34V
	Frequency (f)	50Hz
	Line impedance	
	$R_{s,}$	0.5mΩ
	Ls	19μH
Series active filter	L	16.7 mH
	C	9.6 micro farad
	Switching frequency	1kHz
Loads	Active power	10000W
	Inductive reactive	
	power	100 var
DC output voltage of PV	Vdc	750V

Table 2
Solar Panel Profile

Parameters	*Value*
Vmp	54.7
Imp	5.58
Voc	64.2
Ioc	5.96

IV. SIMULATION RESULTS

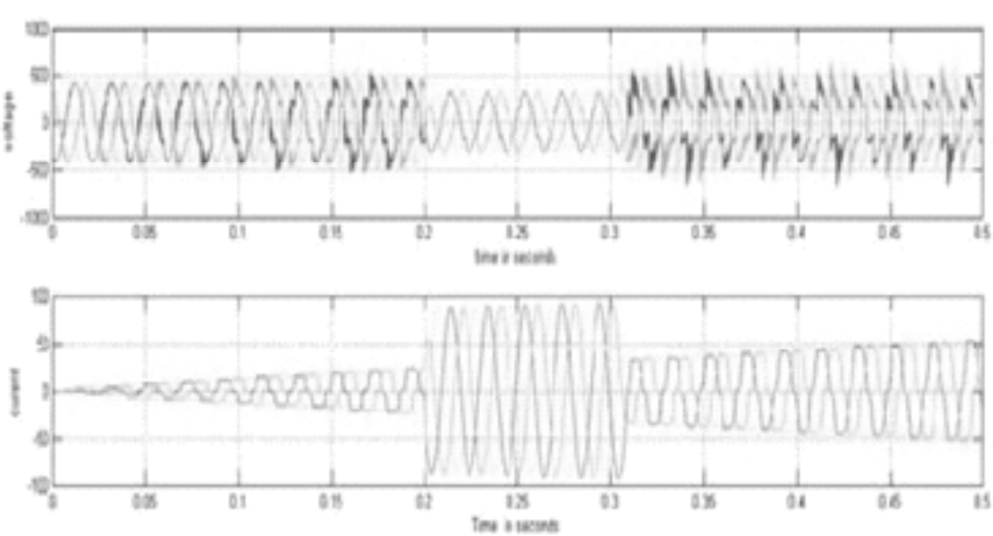

Figure 3: Source voltage and source current without UPQC -PV

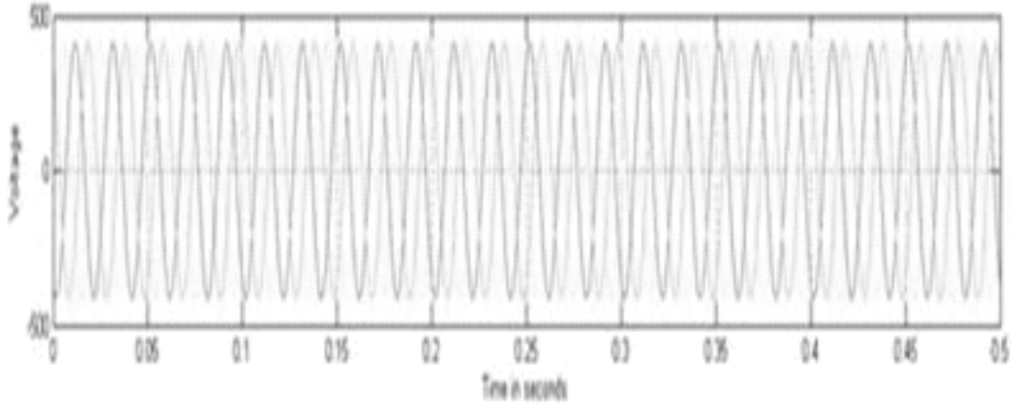

Figure 4: Source voltage with UPQC-PV

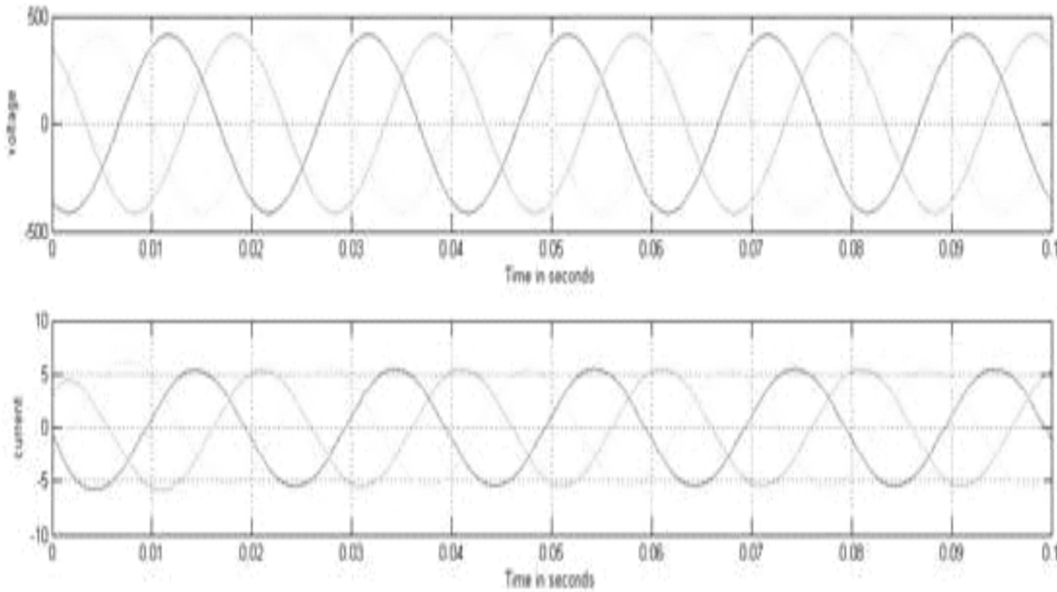

Figure 5: Harmonic compensation of source voltage and source current with UPQC-PV

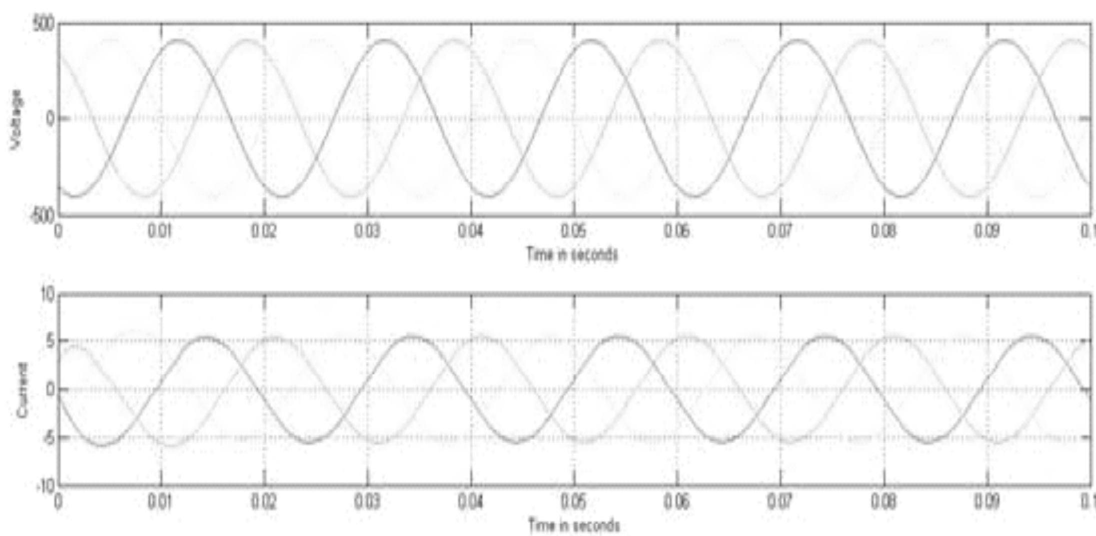

Figure 6: Harmonic compensation of Load voltage and load current with UPQC-PV

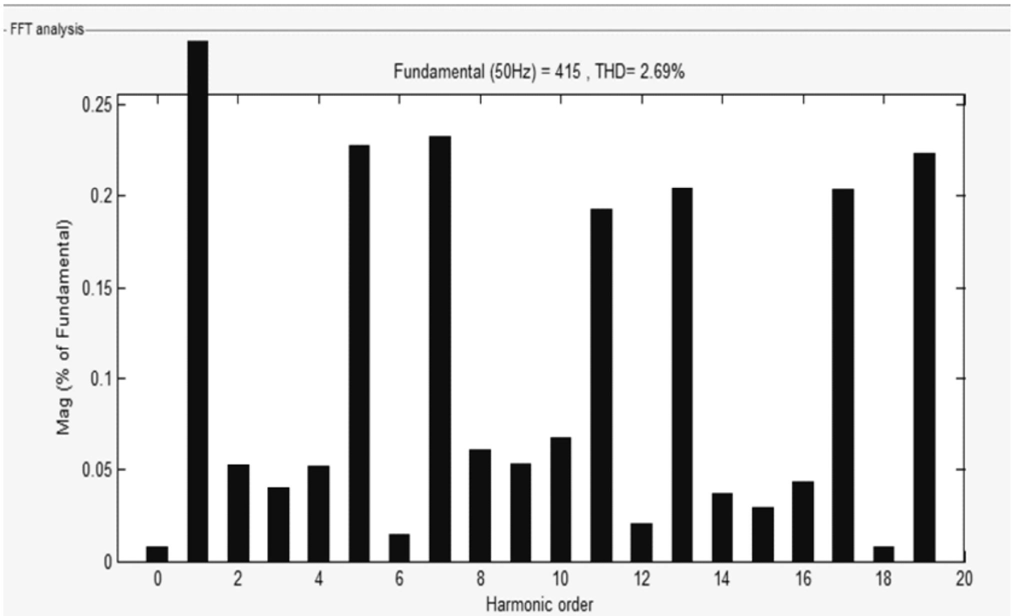

Figure 7: Harmonic spectrum of Load voltage without UPQC-PV

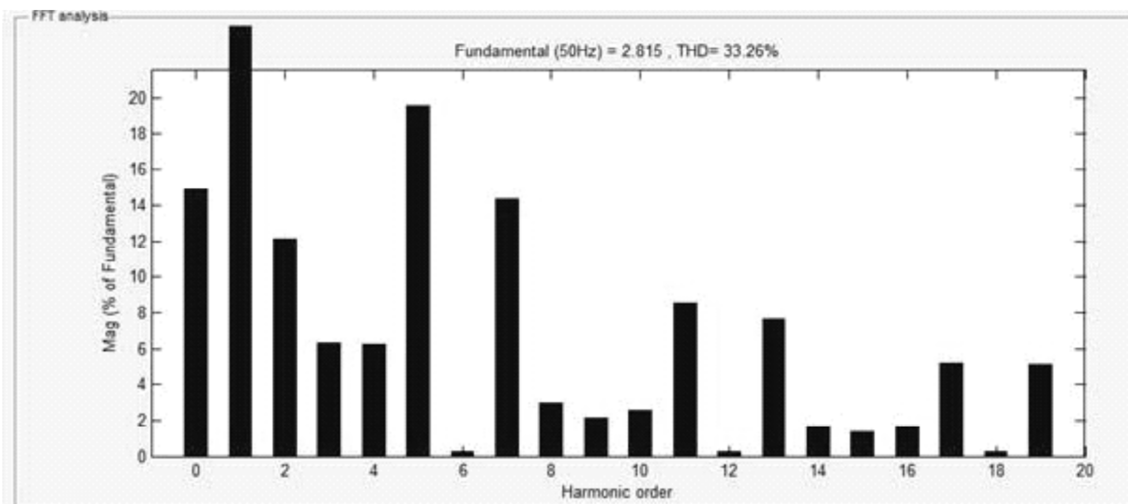

Figure 8: Harmonic spectrum of load current without UPQCPV

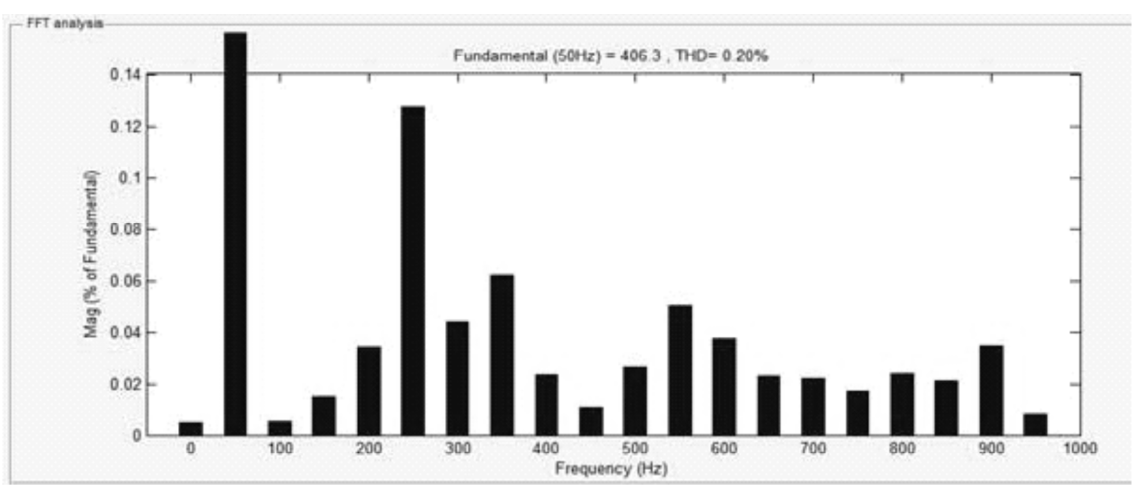

Figure 9: Harmonic spectrum of load current with UPQC-PV

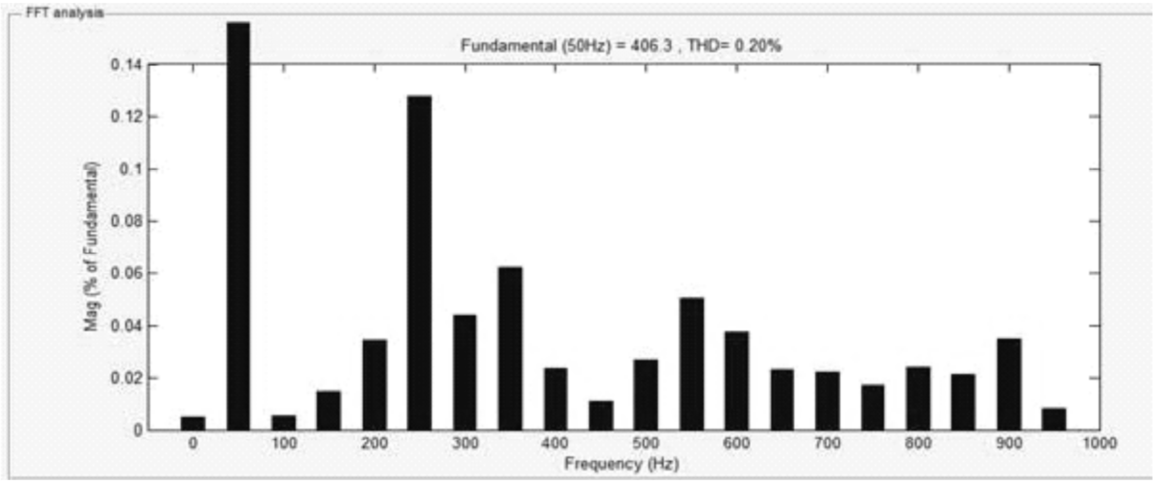

Figure 10: Harmonic spectrum of Load voltage with UPQC-PV

Table 3
THD Results

THD	*Without UPQCpv (%)*	*With UPQCpv (%)*
Source Voltage	2.644	0.04
Source Current	33.266	3.11
Load Voltage	2.699	0.20
Load Current	33.26	63.11

V. RESULTS AND DISCUSSION

To exhibit the productivity of the proposed UPQC fed by PV system, back to back combination of shunt APF and series APF has been shown in the power circuit as in the FIG 1. Table 1 gives the optimised parameters of the power circuit. Table 2 give the solar panel profile. Before the connection of UPQC-PV, the waveforms of source voltage has been totally distorted from 0 to 0.2 sec and voltage sag occurs from 0.2 to 0.3 sec as shown in FIG 3. The results for FFT analysis harmonic spectrum shows high value of THD (2.69%) in Fig. 7. The shape of the source current has also undergone some deformation, due to presence of three phase to ground fault and nonlinear load as shown in FIG 3. Harmonic spectrum analysis of load current without UPQC-PV gives the THD value =33.26% as shown in FIG 8. After connection of UPQC-PV, there has been improvement in the source voltage and source current as shown in FIG 5, It gives competent value of THD_i , which is 3.11%. as per IEEE 519-1992 standards, THD values less than 5% is adequate for signal recovery. Thus the proposed system has adequate result in terms of applicable standards. According to the results obtained, it is proved that there is good improvement in the source voltage, source current, load current and load voltage being almost sinusoidal as shown in the FIG 5 and FIG 6. The respective values for load current and load voltage are THD_i=3.11% and THD_V= 0.20%. The proposed UPQC has immaculately attained to repress the voltage and harmonic distortions and prevent the grid from disturbances. Also, as an option for green energy, the generated active power from the PV system has been sent to the grid.

VI. CONCLUSION

Recently, the energy from renewable energy system has been swiftly taking interest especially in large scale PV and wind energy system. As a result of which, new provocation to lodge these resources into the existing distribution system takes place considering the power quality indices to be within acceptable limits. An exhaustive review on the UPQC-PV for enhancement of the power quality at the distribution side has been conveyed in the paper. The proposed PV system does the dual function of supplying active power to grid and regulate the DC link to the power circuit of UPQC. The simulation is carried out in the MATLAB/ SIMULINK environment , which proves that the proposed UPQC-PV has provided favourable way to obliterate the voltage and current harmonics at the order of THD_V=0.20% and THD_I=3.11% , when the series and shunt APF are activated. As a result, the proposed UPQC fed by PV can be considered as novel method for power quality conditioner. Some laboratory modifications are required for recognition of new system for future expansion.

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