Enhancement of Power Quality under the Condition of No-Linear Loading using PV-UPQC

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Abstract— There has been a tremendous increased in non-linear loads in the grid like microprocessor and power electronics based gadgets and control units. The non-linear loads distorts the grid profile and increase the power quality (PQ) issues like voltage and current perturbation, swell and sag in voltages, harmonics, etc. If these PQ issues are not rectified at load end, it may distort the grid profile hence other system too connected to the grid. The need of the time is to increase the use of renewable resources in order to meet the load demand and reduce the carbon emission. To eliminate the PQ issues generated due to non-linear loading and grid connected PV-system a versatile UPQC controller is preferred in the distribution system. Photovoltaic (PV) tied Unified Power Quality Conditioner (UPQC) are connected back to back through dc-link capacitor and have been proposed in this paper for simultaneous mitigation of both current related and voltage based power quality issues.

Keywords: Grid-Integrated Solar Photovoltaic, Photo Voltaic (PVP), Phase Lock Loop, and Feed Forward Control Loop

I. INTRODUCTION

The technological evolution has changed the load pattern of the present day deregulated power system. There has been a tremendous increased in non-linear loads in the grid like microprocessor and power electronics based gadgets and control units. The non-linear loads distorts the grid profile and increase the power quality (PQ) issues like voltage and current perturbation, swell and sag in voltages, harmonics, etc. If these PQ issues are not rectified at load end, it may distort the grid profile hence other system too connected to the grid. There are numerous controllers available in literature which can be employed to mitigate the numerous PQ issues. One such controller is Unified Power Quality Conditioner.

Another need of the time is to increase the use of renewable resources in order to meet the load demand and reduce the carbon emission. PV system finds application in supplying local loads or connected to the distribution system or operate as a microgrid where local generation is carried out [1, 2].

There are other roles which PV system can play such as; provide regulated, balanced, and harmonic-free output voltages [3]. The above mentioned roles can be utilized by designing PV system as PV-UPQC (Photo Voltaic-Unified Power Quality Conditioner) [5, 6] compensator to mitigate power quality issues which is the objective of the research.

PV systems can provide clean power for small or large applications. Hence they could be installed as standalone or grid connected system. PV systems are preferred as stand-alone systems, where it is difficult to connect to the grid or where there is no energy infrastructure. Electricity can be imported from the network when there is no sunlight. Such small installations are also easy to set up and connect to the grid. The rules about grid connection vary from country to country, but almost in all countries it is compulsory to contact the local network system operator.

A lot of ongoing research has been reported in literature for auxiliary services on power quality improvement through proper control of converters. These converters can perform dual work of interfacing solar system with the grid and also conditions the power at point of common coupling.

In this paper to eliminate the PQ issues generated due to non-linear loading and grid connected PV-system a versatile UPQC controller is preferred in the distribution system. Photovoltaic (PV) tied Unified Power Quality Conditioner (UPQC) are connected back to back through dc-link capacitor and have been reported for simultaneous mitigation of both current related and voltage based power quality issues. The UPQC has its own supply system which is energized through PV system. The PV-UPQC can mitigate PQ related issues and can integrate PV with to utility system.

II. SYSTEM CONFIGURATION AND DESIGN

The state-of-art of the PV-UPQC is shown in Fig.1. For a three-phase system to PQ issues caused by non-linear loading, unbalanced loading or the condition of voltage fluctuations a PV-UPQC system is designed using dual compensating structure of series-shunt converters. The both the converters are connected via Dc-bus. The shunt compensator is connected at the load side. The solar array is connected across the DC-link capacitor between the series and shunt converter of UPQC. The mode of series compensator operation is voltage controlled and compensates for the grid voltage disturbances. The two converters of the UPQC are inter-linked to the grid through interfacing inductors. A series injection transformer is used to inject voltage generated by the series compensator into the grid.

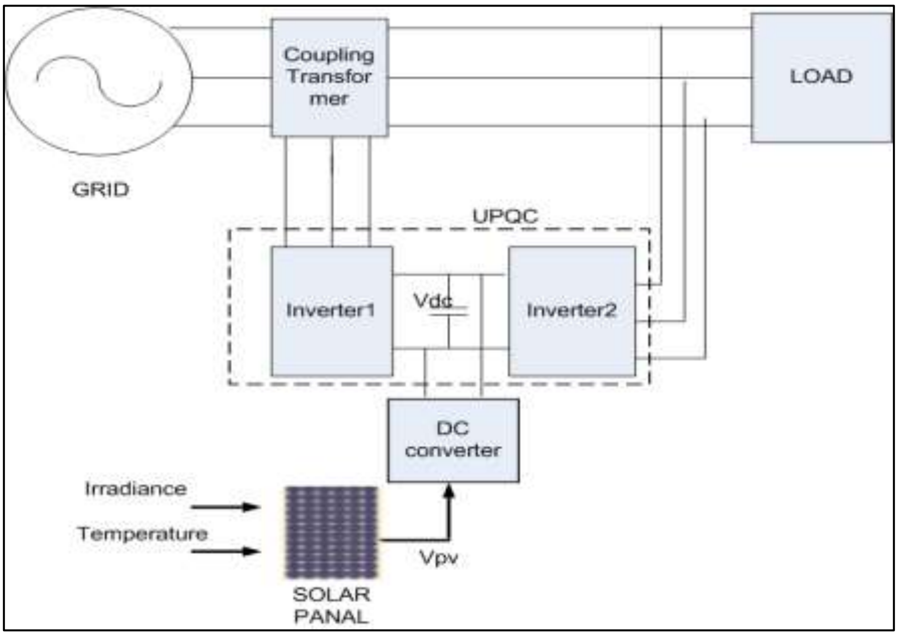


Fig. 1: Block diagram of the proposed system.

A. *Proposed Controller Design*

A UPQC controller is designed, which comprised of two converter one is in series which operates as a sinusoidal current source; another is in parallel operating as sinusoidal voltage source. Impedance of series converter must be high enough to isolate the harmonic currents generated by the nonlinear loads. Impedance of parallel converter must be sufficiently low to absorb the load harmonic currents. The converter is designed using Enhanced PLL and PI controller and an analog low pass filter is designed to mitigate the system harmonics. A conventional three leg full bridge universal inverter is used. To generate the gate pulses for inverter, 2-level PWM is used whose output is controlled by PI. The PI is referenced using grid current. For three phase system to reduce complexity an abc-dq transform is used as shown in Figure 2. The Kp and Ki gain for PI is 001 and 500.

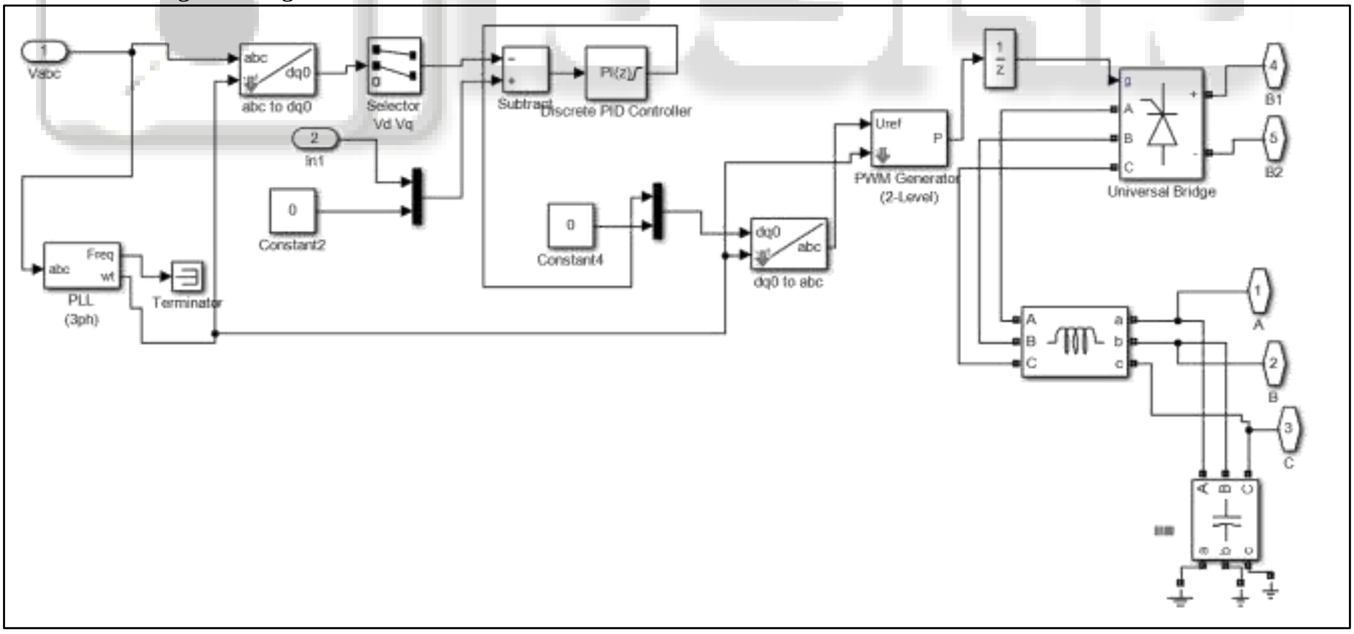


Fig. 2: Proposed PLL-PI controller

B. *Filter Design*

A low-pass filter (LPF) is a filter that passes signals with a frequency lower than a selected cutoff frequency and attenuates signals with frequencies higher than the cutoff frequency. The exact frequency response of the filter depends on the filter design. In utility system filters has tremendous utilization since the harmonics present in the voltage and current can be eliminated with the help of filters. The basic configuration of LPF is presented in figure 3.

$$L = \frac{0.03V_{in}}{2\pi f I_{Lmax}}$$

$$C = \frac{1}{(2\pi f)^2 L}$$

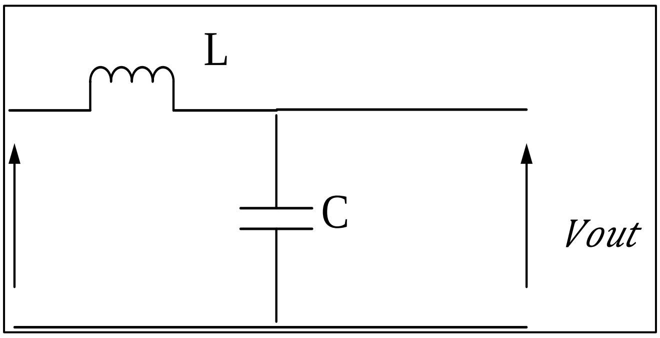


Fig. 3: schematic of analog LPF

III. PROPOSED WORK

To eliminate the PQ issues generated due to non-linear loading and grid connected PV-system a versatile UPQC controller is preferred in the distribution system. Photovoltaic (PV) tied Unified Power Quality Conditioner (UPQC) are connected back to back through dc-link capacitor and have been reported for simultaneous mitigation of both current related and voltage based power quality issues. The UPQC has its own supply system which is energized through PV system. The PV-UPQC can mitigate PQ related issues and can integrate PV with to utility system. A 150 KW PV system with 600 V PV Dc output. The parameter design selection is presented in table -1. The complete simulation model of the system designed is presented in figure 3. The proposed system is analysed under two operating conditions;

1) Under dynamic conditions with variable irradiance and non-linear loading.
2) Under the condition of fault.

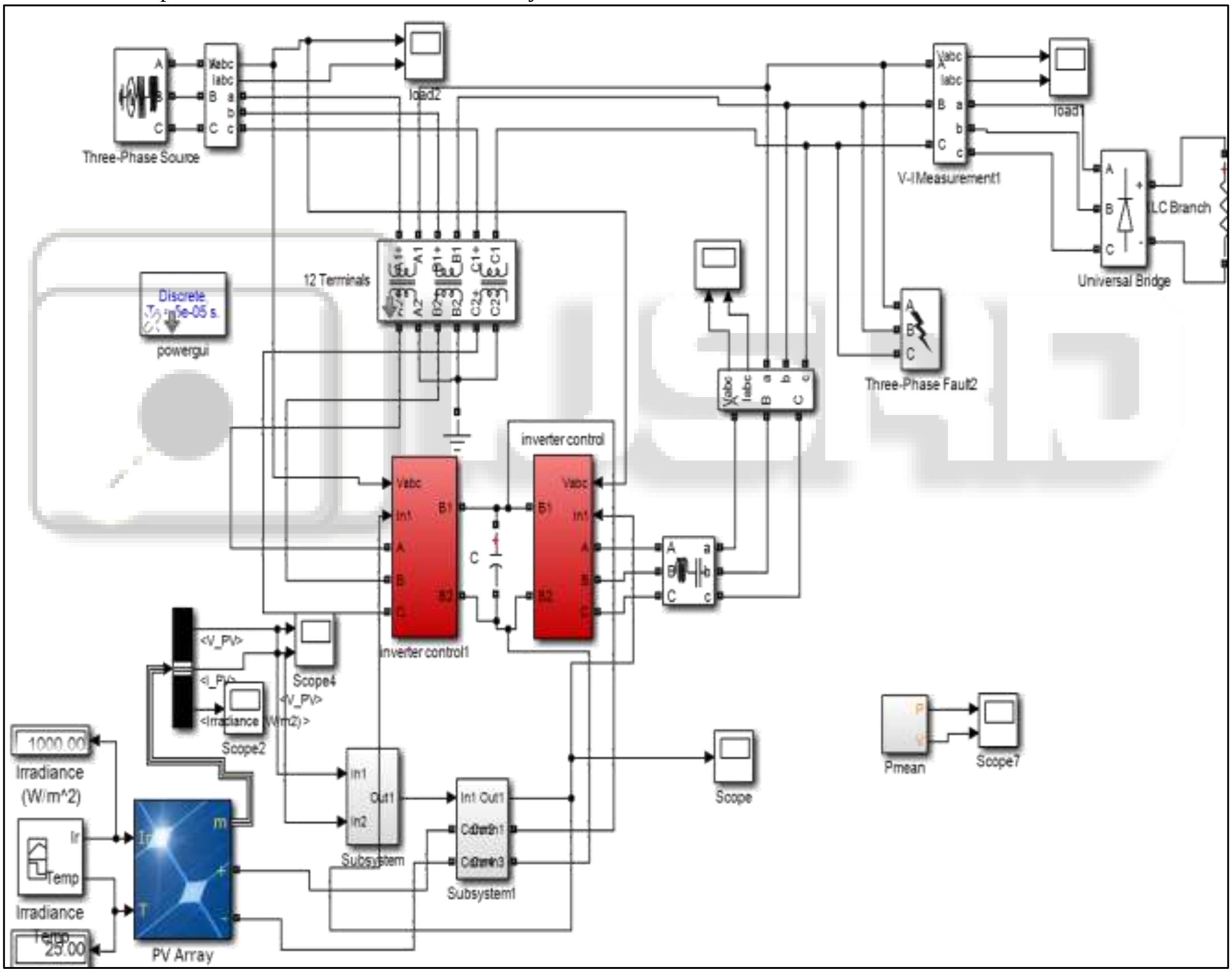


Fig. 3: Matlab model of PV-UPQC

IV. SIMULATION

A matlab simulink model of the solar panel has been developed whose DC output is regulated using DC-DC boost converter. Three phase voltage source is considered as an AC bus, replica of grid with short circuit capacity of 100MVA.

The basic functionality of UPQC is to maintain grid profile at all adverse operating conditions like non-linear loading, unbalanced loading or the condition of voltage fluctuations. UPQC has its own source to energize the converters connected. Generally theses power source is DC-batteries. In the work done these batteries are energized using solar power. Hence making it eco-friendly. In the figure 4. Output voltage and current source side for variable irradiance when non-linear load is connected is presented. Figure 5 presents the voltage and current waveform load side. From figure 4 and 5 it is evident that, the non-linearity of load is not propagated to the source hence source constant profile is maintained. Figure 6 and 7presents the voltage and current waveforms for source and load side when a three phase fault occurs grid side. From these figure it can be evidenced that the source un-balanced is not propagated to the load side and supplying a constant voltage, hence safe-guarding the connected equipments at consumer end from getting damaged due to supply fluctuations.

The THD analysis of the work done is presented in figure 8. From the THD spectrum it can be seen that the proposed PV-UPQC system successfully mitigate the Power quality issues by eliminating source current harmonics and regulating load voltages.

Parameter	Symbol	Value
Nominal utility voltages (rms)	V	415
Nominal Frequency	ω	50Hz
Inverter inductance	L	45mH
Filter Capacitance	C	60e-6 F
Filter Inductance	L_f	10.45e-3 H
linear Load 1	Three phase load resistive load	R=100 ohms
Non-linear Load 2	Three phase load through rectifier	R=20 ohms
Dc-link Voltage	Vdc	1200 V

Table 1: Parameter & its value

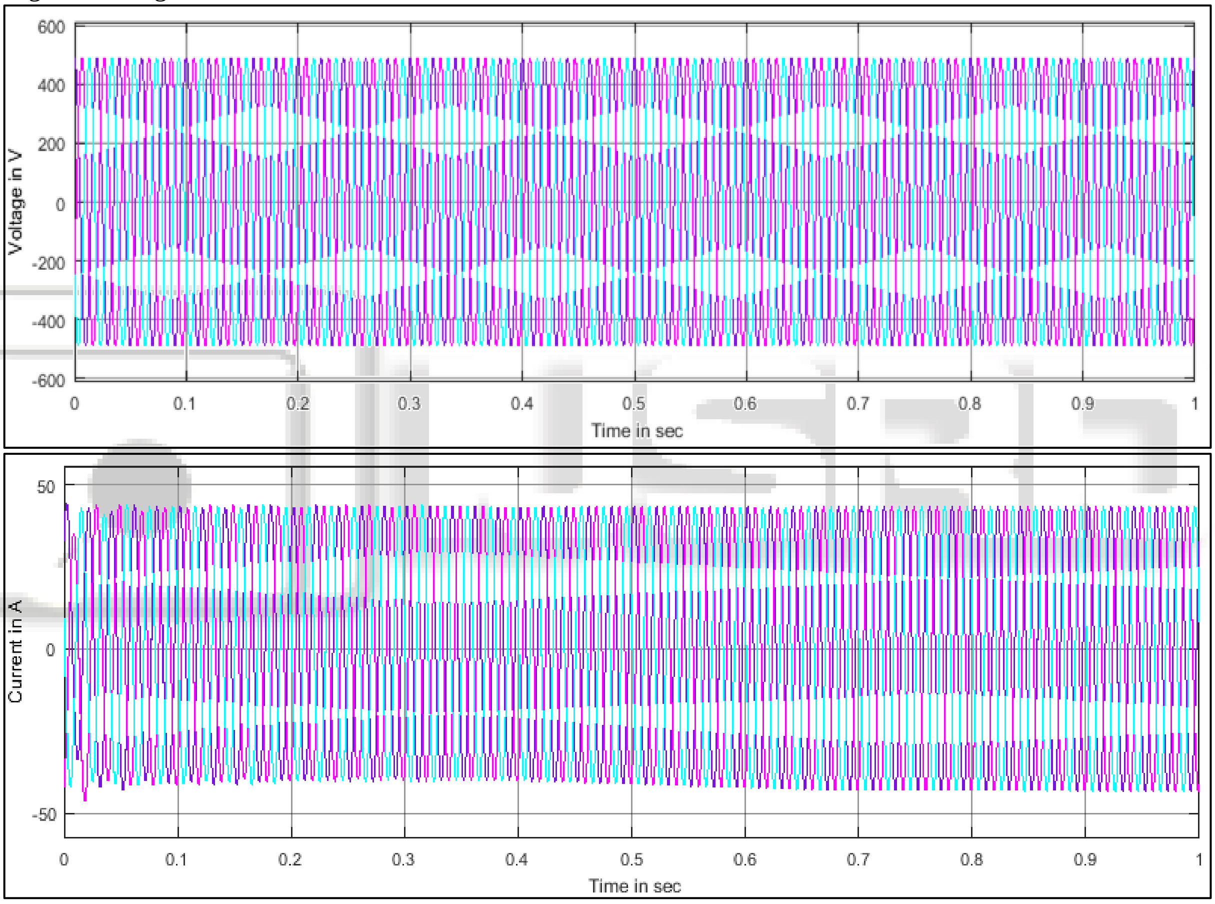
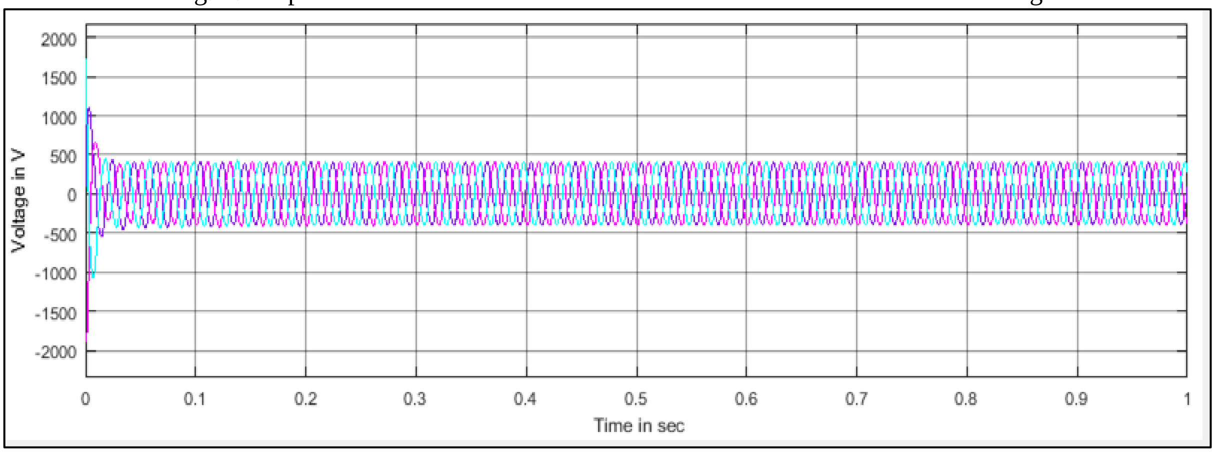


Fig. 4: Output waveform Grid side for variable irradiance with non-linear loading



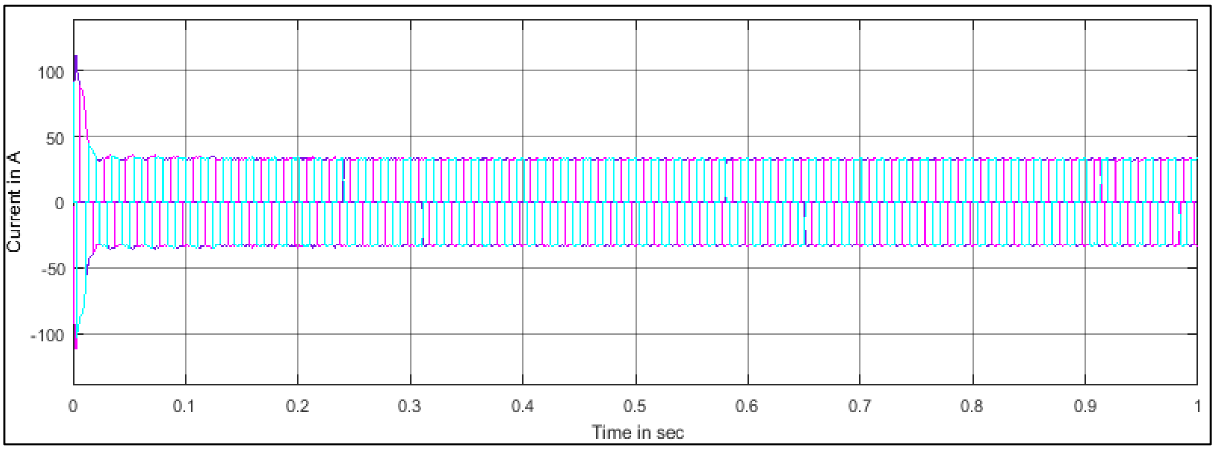


Fig. 5: Output waveform load side for variable irradiance with non-linear loading

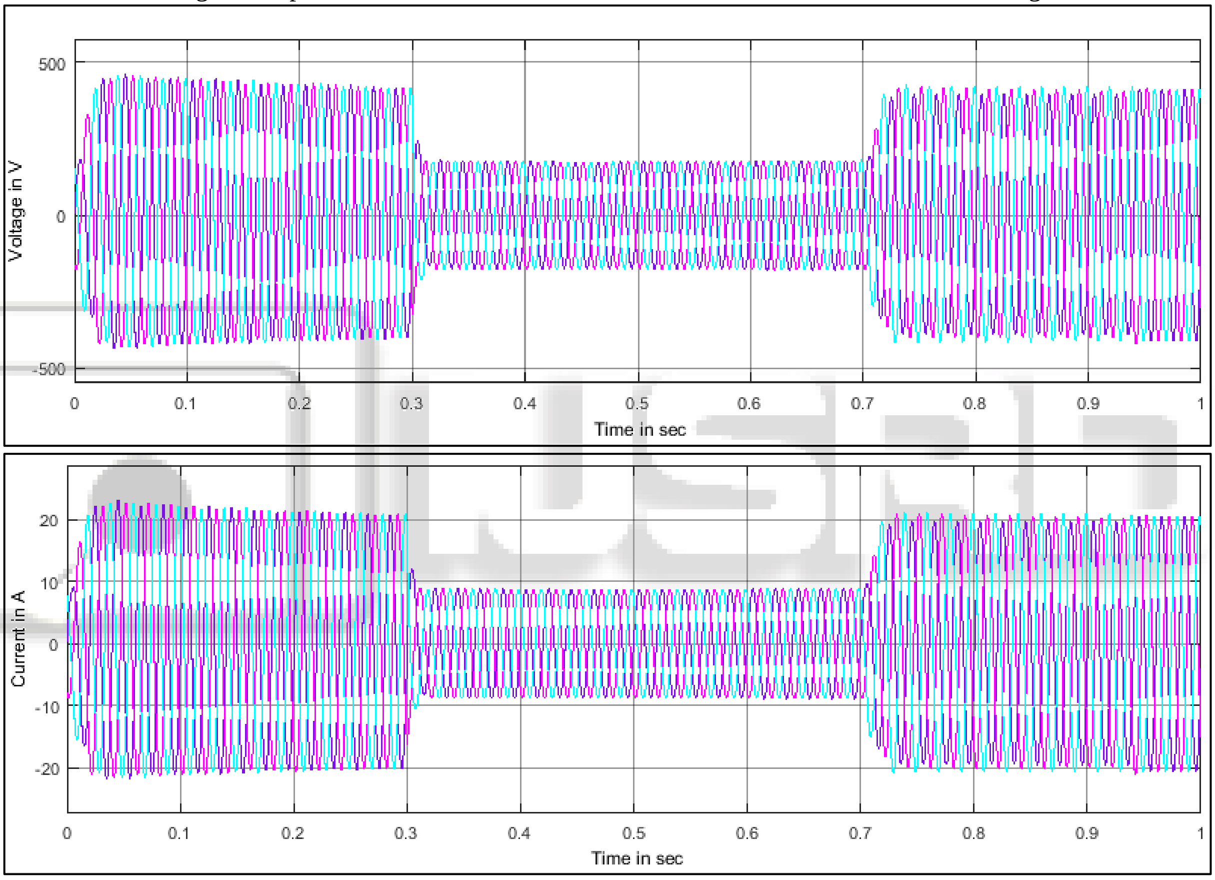
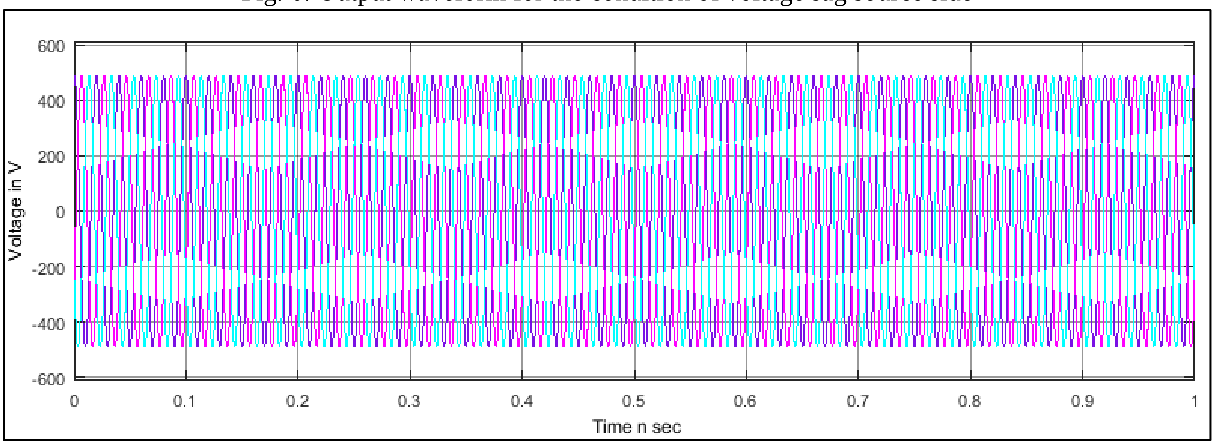


Fig. 6: Output waveform for the condition of voltage sag source side



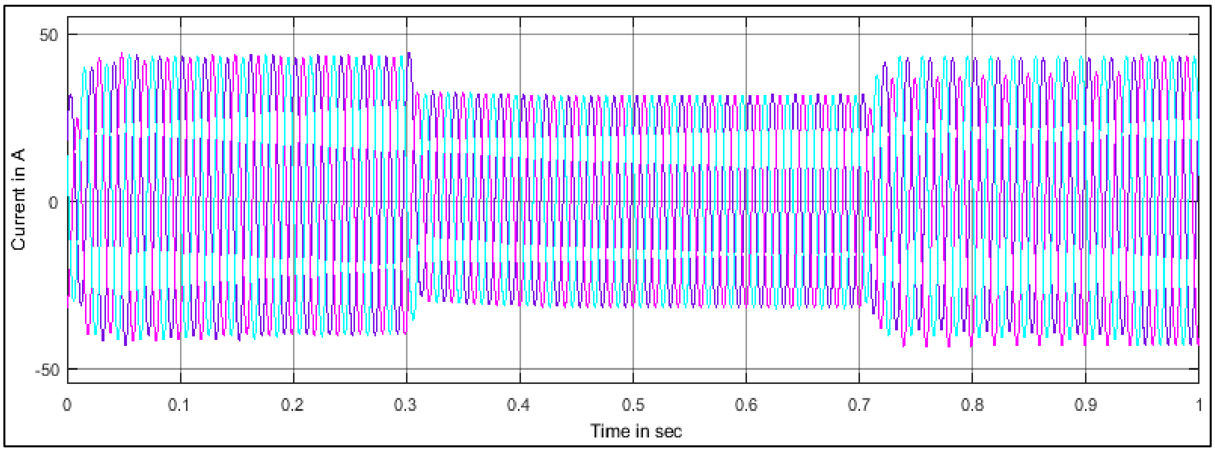
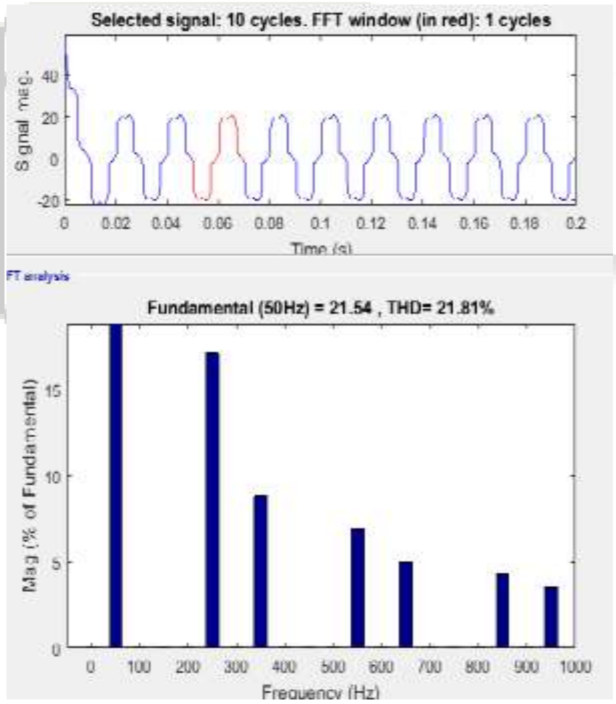


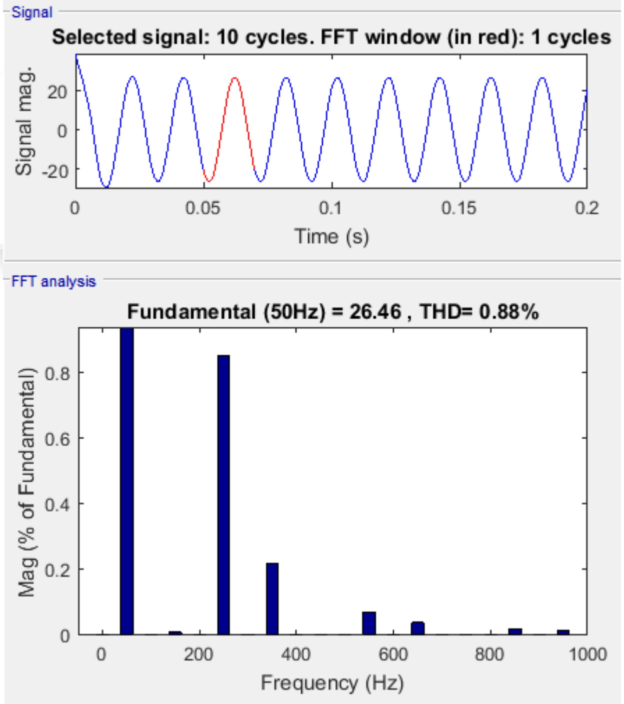
Fig. 8: Output waveform for the condition of voltage sag load side

V. RESULT ANALYSIS

The simulation results for the proposed PV-UPQC system under variable irradiance and unbalanced loading which may be the result of fault in the distribution network has been presented in the work done. Non-linear loading have very high harmonic content. If these harmonics in the load current and load voltages are not mitigated at the load side, they may pollute the source profile. Also can damage the equipment connected to the same source. The THD analysis of the work done is presented in figure 8. The load current harmonics when non-linear load is connected are 21.8% and source current harmonics are 0.88%. From the THD spectrum it can be seen that the proposed PV-UPQC system successfully mitigate the Power quality issues by eliminating source current harmonics and regulating load voltages



a) THD of load current



b) THD of source current

Fig. 8: THD analysis of PV-UPQC with proposed topology under non-linear loads

VI. CONCLUSION

The UPQC have its own source specifically DC to feed the power electronic devices connected and to maintain the power quality of the system where it is connected. In this paper UPQC is fed by PV source and it has been analyzed under conditions of variable irradiation and grid voltage sags. The simulation model and performance of the system has been studied in MATLAB-SIMULINK tool kit. It is observed that PVUPQC mitigates the harmonics caused by nonlinear load and voltage sag. The system successfully maintains the THD of grid current under limits of IEEE-519 standard. The stable system for voltage and current profile has been obtained for variations in irradiations, and also mitigation of voltage sags/swell and load unbalance. The PV-UPQC is a good solution for obtaining green distribution system with power quality improvement.

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