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PERFORMANCE EVALUATION AND POWER QUALITY ANALYSISOF SOLAR PV-UPQC CONNECTED WITH MICRO GRID

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Abstract- Non-renewable technologies have traditionally been used to satisfy the world's electricity need, however that contributes to increased prices, environmental degradation and global climate change. The power industries now focus and use sustainable forms of electricity, including wind, hydro, tidal and solar and help them to solve the boundaries of conventional energy sources. Solar Photovoltaic (SPV) is apparently increasingly important among renewable energy sources due to its features such as static, noise-free, non-fuel requirements, easy to maintain and ecologically friendly functionalities. The power-conditioning circuitry connects the SPV system to the utility grid. This power-conditioning circuitry has an integrated filtering and grid interconnection functionality. In existing distribution systems, reactive loads like motor drives, fans, pumps and electronic power converter have produced a significant volume of energy usage. Usually such loads drain the lagging power factor sources and thus increase reactive power burden in an electric power distribution network.

Static Synchronous Compensator (STATCOM), Dynamic Voltage Restorer (DVR) and Unified Power Quality Conditioner (UPQC) are in the Custom Power Devices (CPD) family and are used to mitigate for current and/or voltage waveform power quality issues. The UPQC consists of Active Power Filters (APFs) both in shunt and series. Shunt and series connected APFs are among the best design control devices, which counteract the impact of current and voltage disturbance. The conventional UPQC is not supported by the Distributed Generation (DG). The DC- link of the UPQC is therefore supported by a storage capacitor. The UPQC with a DC-link storage condenser cannot provide long-term compensatory steps against current and voltage-based fluctuations and reactive strain as its storage capacity are insufficient. In this work we are about to eliminate the PQ issues generated due to non-linear loading and grid connected PV-system with a versatile UPQC controller, Which is preferred in the distribution system. Photo Voltaic (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 and voltage related PQ issues. The UPQC has its own supply system which is energized through PV system.

1 INTRODUCTION

Power Quality (PQ) has been described as a significant consideration for optimizing device performance, reducing errors and guaranteeing the quality of production. Quality of electric power may usually be defined as a metric of the energy supply for consumers. If waveforms deviate from the desired sinusoidal, voltage magnitude does not correspond to the value defined, and the power transmission efficiency is under risk, power output is diminished from its desired value. In the last 20 years, the introduction and broader use of high-frequency power electronic switches have brought a new dimension to the problem of power efficiency. As these switches can be controlled with high speed, high control stability, and performance, they have established an utterly critical role in the production and usage of power beginning at a very limited level of transmission, distribution by the operation. Because their non-linear switches result in the use of extensive Volt Ampere Reactive (VAR) and current harmonics, non- sinusoidal current in usage has alarmingly risen, polluting power supply and voltage at the typical point of interconnection. Even with a healthy environment, the requirement for modern technical activities is often safe because of a variety of electrical network hazards and infrastructure dangers such as overheating, increased losses, designed capacities being under-utilized, transition exhaustion, breakdown of control signal interacts with service, etc The twin constraints of fossil fuel scarcity and the need to reduce pollution are threatening modern central power generation systems.

One of the key sources of losses of electric power is long transmission lines. Therefore, a growing focus has been on Distributed Power Generation (DPG) networks connected with the utility power grid with a renewable power generating system contributing to energy savings and carbon mitigation. The enhanced renewable energy integration into the power grid is a significant field of concern for the electricity efficiency of the medium to low voltage power transmission network. The incorporation of renewable power generation systems in the power grid with the aid of power electronic converters takes place. One more foremost issue in the power distribution system is the smooth interconnection renewable energy-based power generating system into the utility grid [1]. Renewable sources, for example, solar, wind and biomass are the best alternative energy largely available from our environment. The interconnection renewable power generating system into the utility grid causes the power balancing and power quality issues. For interconnection of renewable power generating system requires source voltage quality to be maintained within the specified tolerance band, which is disrupted on the occurrence of faults on the utility grid. International bodies such as the International Electrotechnical Commission, Institute of Electrical and Electronics Engineers have established numerous harmonic standards guidelines for points of common connection and individual equipment to safeguard the functionality of the utility grid. Several custom power devices are available. The electronic power compensation systems are attached in shunt, in a series or both. Each individual or a mixture of two or more of these devices is used to accomplish each of the above purposes.

1.1 PV Energy Conversion Technology

The PV energy conversion process is shown in Fig.1. Each PV cell consists of two layers of silicon, one of which is positive and another negative. As a photon of light is absorbed by one of these N-type silicon atoms, an electron is dislodged and a free electron and a hole is formed. The free electron and hole have enough energy to jump from the field of depletion and flow into an external load. The PV cell acts as a current source. The higher the solar irradiation intensity, the greater the current generation in this PV cell. In general, a standard PV cell generates very small, so a number of PV cells are linked in series and parallel according to the output power requirement. If this panel is connected to a load, the electrons start flowing in a specific direction, resulting in current flow through the load. Certain standard technologies may be used to manufacture the PV cells using silicon wafer and thin film technology. The wafer cells are made of silicon crystalline, consisting of polycrystalline silicon and mono crystalline silicon. These are the most widely utilized PV cells in large-scale energy generating systems with grid connection.

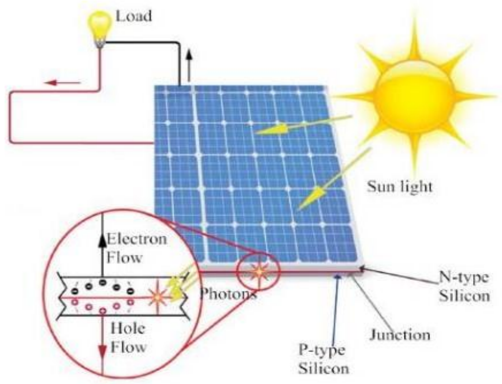

Fig. 1 Conversion mechanism of solar irradiation into electricity

1.2 Power Quality Problem

Power distribution systems, ideally, have to be compelled to provide their customers with associate uninterrupted flow of energy at smooth sinusoidal voltage at the narrowed magnitude level and frequency however, in follow, power systems, notably the distribution system, have varied nonlinear loads, that significantly have a bearing on the standard of power provides. As a results of the nonlinear loads, the purity of the waveform of provides is lost. These finally end up producing many power quality problems. While power disturbances occur on all electrical systems, the sensitivity of today's refined electronic devices makes them lots of at risk of the quality of power provide. for some sensitive devices, a brief disturbance can cause disorganized knowledge, interrupted communications, a frozen mouse, system crashes and failure etc. an influence voltage spike can damage valuable components.

1.3 Objectives of the Research Work

The objectives of the research work are:

1. To establish the SPV array integrated UPQC (SPV-UPQC) to alleviate the current and voltage harmonics and offer the reactive power compensation in the electric power distribution system.
2. To optimize the ratings of the shunt and series APFs for acquiring the highest utilization rates of the power converters in the UPQC.
3. To improve PQ by reducing the THD and maintaining the voltage stability at PCC.
4. To integrate the PV with grid and it mitigates the PQ issues caused by different loading condition.

2. LITERATURE SURVEY

1. Patjoshi et. al. [1] implemented the UPQC with Non-Linear Sliding Mode Control (NLSMC) and modern technologies to enhance the power quality problem on the network electricity distribution network. The suggested non-linear slide surface illustrates regulating the operation of the DC-link condenser voltage with a damping factor variance and allows a low over-shooting and a low settling time of the DC-link voltage. This technique incorporates a new control method for the generation of a speedy and reliable reference signal for shunt as well as series converters with a new SRF unit. Thus, along with the latest switching technique in UPQC, NLSMC-SRF technology offers a powerful compensator for voltage-current harmonics, voltage sag /swell and disturbance. The suggested UPQC monitoring technique is tested by MATLAB/SIMULINK, then by real-time hardware in the loop-testing framework.

2. W. Li, Y et.al. [2] studied a comprehensive literature survey on the unified power quality conditioner (UPQC) to improve the electric force quality at conveyance level is introduced in this paper. A nitty gritty outline on accessible UPQC designs for single- stage (2-wire) just as 3-stage (3-wire and 4-wire) systems, distinctive remuneration methods, and late development in control geography is talked about point by point order dependent on the control, errand, application, or geography viable is introduced.

3.Sandipan Patra et.al., [3] This paper addresses the assessment of power quality (PQ) in 3-Phase grid connected photovoltaic (PV) system that consists of single and dual stage power extraction circuits. The effect on power quality in both type of grid connected system has been analysed and presented here.

3. METHODOLOGY

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.

- 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 arrangement converter must be sufficiently high to confine the symphonious flows created by the nonlinear burdens.
- 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 a 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. The

simulation model and output waveforms of all the three modes of operation are presented in the subsequent sections.

4. 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 confine to low in a way of absorbing 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 0.01 and 500.

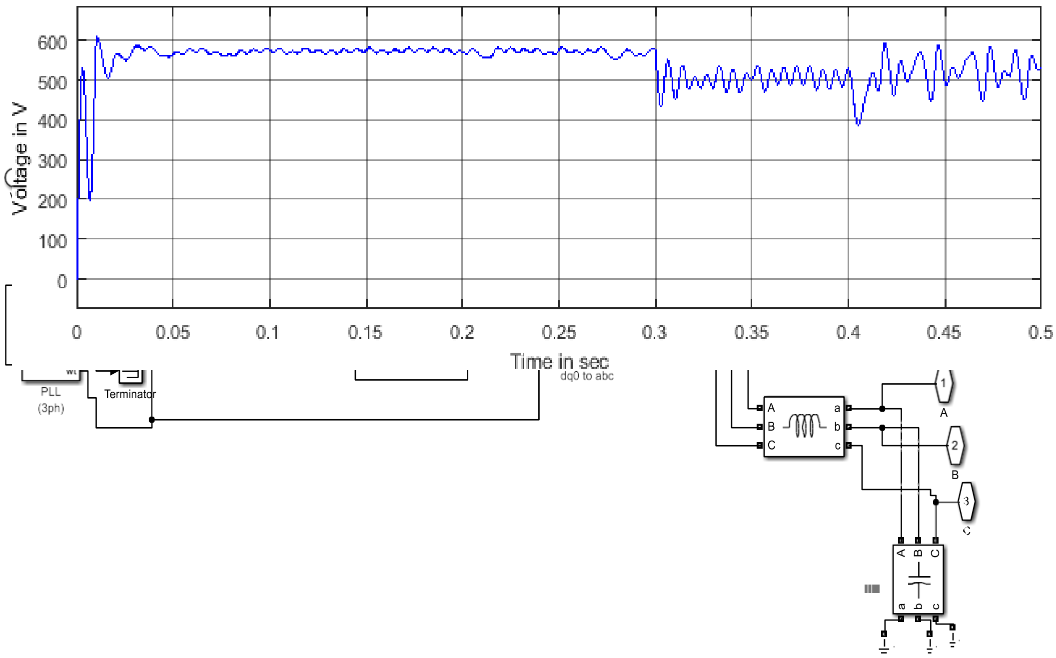

Figure 2 Proposed PLL-PI controller

5. RESULTS & ANALYSIS

The complete simulation model of the system designed is presented in figure 5.1. The parameter selection is presented in table-5.1. A 150 KW PV system with 600 V PV Dc output is considered to fed to the Dc-link capacitor of PV-UPQC system. Three phase voltage source is considered as an AC bus, replica of grid with short circuit capacity of 100MVA.

To design a UPQC two back to back DC/AC converter is connected through a dc-link capacitor with 1micro farad capacitance. One side of the converter is connected to the synchronized AC output of the PV system and other side to the grid. The system is synchronized with the grid using PI controller and Phase Lock Loop. The system is analysed for linear loading of 50 KW and non-linear loading of 40 ohms connected through three phase rectifier. The performance analysis of the designed PV-UPQC system under following three operating mode has been carried out;

1. Performance of PV-UPQC under Varying Irradiation.
2. Performance of PV-UPQC at Load Unbalancing Condition.
3. Performance of PV-UPQC at PCC Voltage Fluctuations

5.1 Performance of PV-UPQC Under Varying Irradiation

Under this condition non-linear loading of 40 ohms connected through three phase rectifier. The power output and voltage of PV-module under this condition is given in figure 3. Figure 4 presents the DC-bus voltage. Firstly to justify the operation of PV- UPQC system the system is analysed without connecting PV-UPQC controller. The output voltage and current waveforms source side without PV-UPQC are given in figure 5 and figure 6 presents the output voltage and current waveforms source side with PV-UPQC.

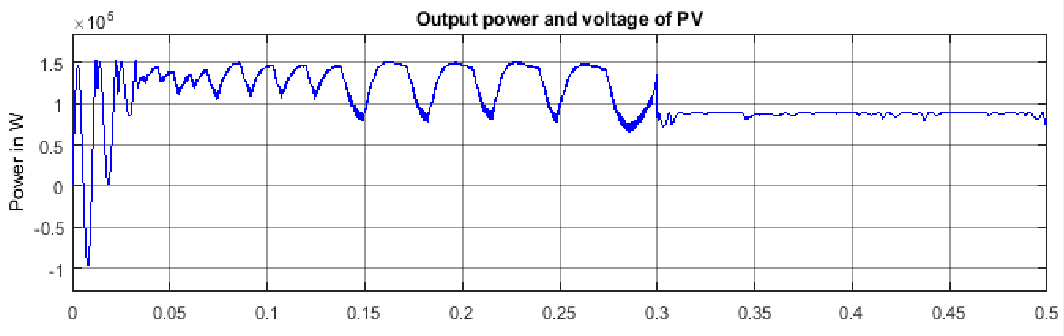

Figure 3 Output Power and Voltage of PV at variable irradiance

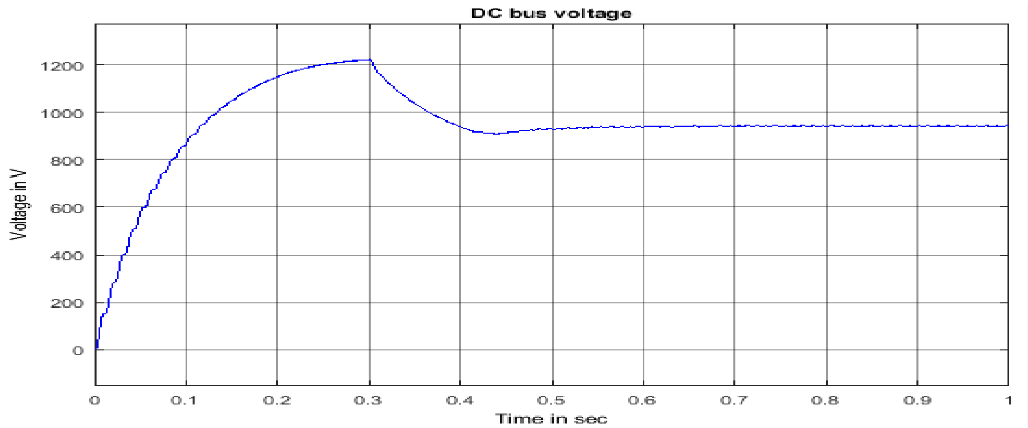

Figure 4 Output voltage of DC-bus at variable irradiance

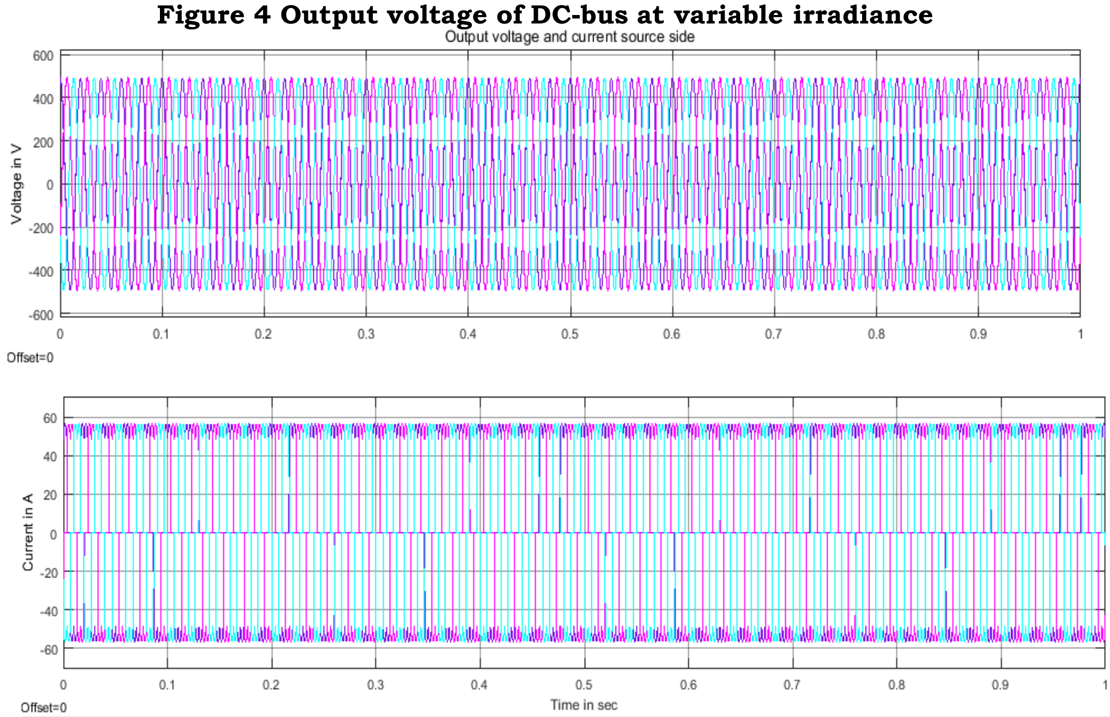

Figure 5 Output waveform Grid side for variable irradiance with non-linear loading without PV-UPQC

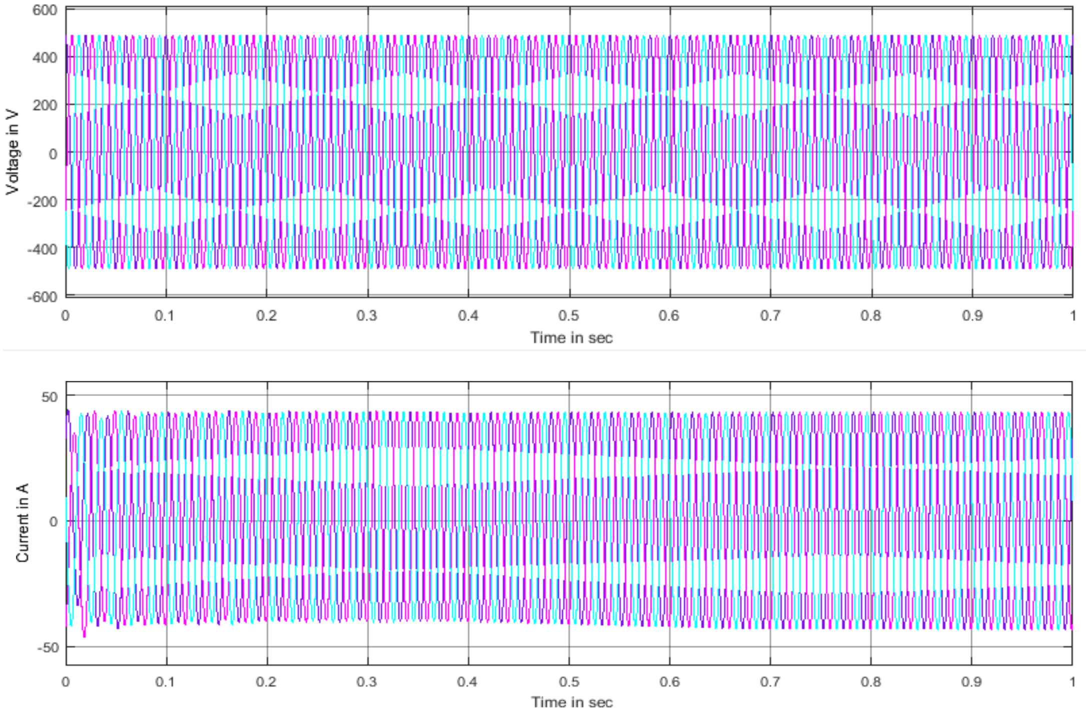

Figure 6 Output waveform load side for variable irradiance with non-linear loading with PV-UPQC

5.2 Performance of PV-UPQC Under UnbalanceLoading

Under this condition a linear load of 40 KW is connected and after time 0.3 sec load of phase b' is disconnected. Consequently load side has been unbalanced as shown in figure 7. Firstly system has been analysed without using PV-UPQC. The system has the same profile both at load side and source side.

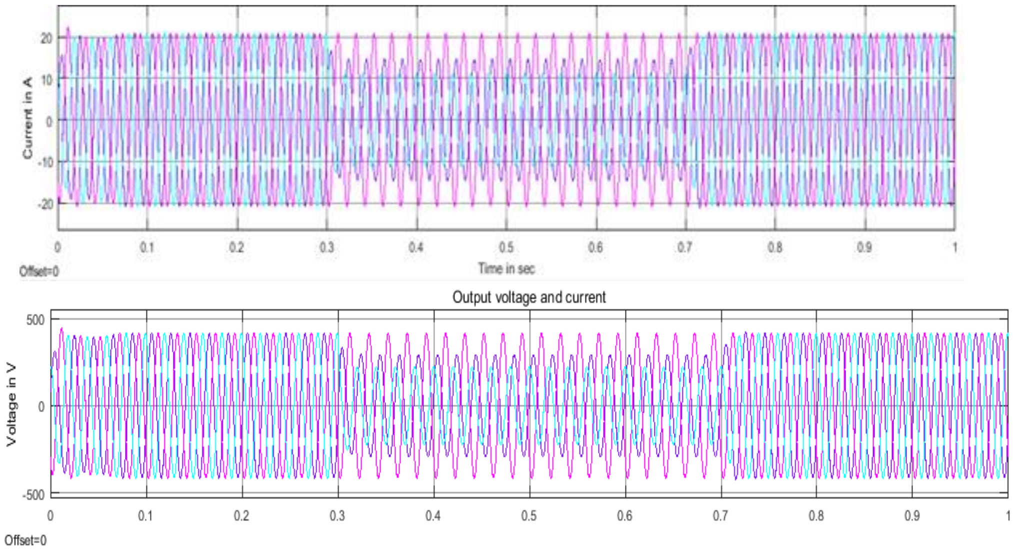

Fig-7 Output voltage at the condition of unbalanced loading both source side andload side without PV-UPQC controller

5.3 Performance of PV-UPQC at PCC voltageFluctuations

In this mode of operation balanced linear loading is applied to the system to study the behaviour of the proposed topology and a condition of voltage fluctuation is created at source side.

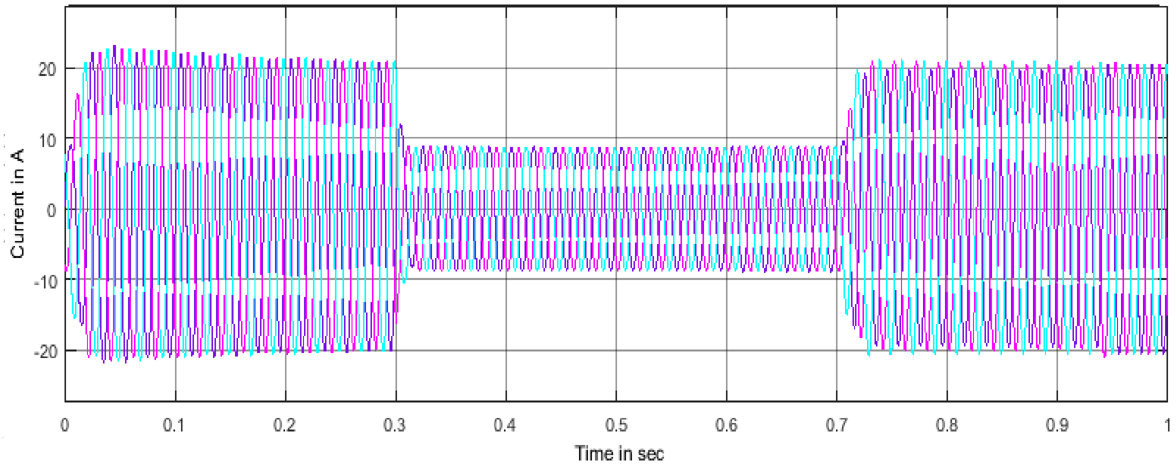

Figure 8 Output waveform for the condition of voltage sag source side

Table 1 Comparative analysis THD of with and without PV-UPQC for load andsource voltage.

THD% Load Voltage						
	Without UPQC			With UPQC		
	Ia	Ib	Ic	Ia	Ib	Ic
Case 1	0.05	0.05	0.05	0.05	0.05	0.05
Case 2	3.3	3.3	3.3	1.8	1.8	1.8
Case 3	1.12	1.12	1.12	0.05	0.05	0.05
THD% Source Voltage						
	Without UPQC			With UPQC		
Case 1	0.05	0.05	0.05	0.05	0.05	0.05
Case 2	0.05	0.05	0.05	0.05	0.05	0.05
Case 3	1.12	1.12	1.12	0.05	0.05	0.05

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.

6. CONCLUSION

This research work has aimed mainly to reduce the voltage sag/swell and source current harmonics in the distribution system by means of SPV or battery fed boost converter operated UPQC. The SPV operated UPQC configuration is employed to provide the necessary compensation during the day time. Similarly, the battery operated UPQC system is used to obtain the required compensation in the night time.

From the obtained simulation results, it is found that the proposed system has less THD in source current when compared with conventional system. The PV-UPQC is a good solution for obtaining green distribution system with power quality improvement.

- Static and dynamic performances of the system were evaluated under various modes of operation of grid voltage conditions, including sags, unbalances, andharmonics.
- Apart from series compensation, suppression of load harmonic currents, Carried out, such that an effective Unified power conditioning was achieved.

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