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Solar Power Flow Through Grid Using Vector Control Principle For Voltage Source Converter

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Abstract: This work is concerned with the generation of solar power using MPPT with the help of modelling and also simulation of photovoltaic (PV) array interfaced with boost converter then supply it to the three-phase grid connected Voltage Source Converter (VSC). In present scenario solar energy is a sustainable and reliable renewable energy resource that is integrated into the main electrical supply grid with the use of power electronics converters. The VSC is connected to the grid with the help of a filter and transformer. VSC needs a dc link voltage across the shunt capacitor which is provided by the solar PV which behaves as a voltage source. An Incremental and Conductance (ICE) mechanism is used to achieve maximum power point (MPP) from the solar PV array. The Power generated from the solar PV is varying in nature due to varying solar insolation and temperature. So the VSC balance the magnitude of the grid voltage at PCC. Also to reduce the harmonics active LCL filter is used. The modelling of the system is simulated by MATLAB/SIMULINK software.

Keywords: Photovoltaic (PV); Maximum power point tracking (MPPT); Incremental and conductance (ICE); Voltage source converter (VSC); Boost converter.

I. INTRODUCTION

Solar Photovoltaic is emerging strongly recommended and one of the non-conventional energy resources. As Solar Photovoltaic is capable of generating power during the day only, during the night hours the power electronics converters used in solar PV are idle. The solar PV electricity generation is renewable resources, pollution free and free of cost input power. The converter used is voltage source converter which can be constructed to effectively use renewable energy sources by injecting active power from these sources while simultaneously power quality improvement of the connected grid bus. Because the electrical energy provided by this solar PV source is DC, it must first be converted to fixed dc using a boost converter to maintain a constant DC bus voltage. Then, to integrate this electricity into the grid, a voltage source converter is attached [1].

As the use of switched mode power supply (SMPS) and power electronics given the non –linear loads has grown in recent years. The power being supplied is getting contaminated and needed to reduce the harmonics using filters. The compensation of reactive power is needed to non-linear loads. Filters are increasingly being used to reduce the harmonics and effect of reactive power. Shunt compensators are the most extensively used active power filter because voltage profile and harmonics current produce the bulk of power quality concerns. In the commercial and residential markets, the number and variety of nonlinear loads has increased dramatically. This current with harmonics are injected into the electric distribution system by battery chargers, computers, electronic ballasts and variable frequency drives. At the PCC (point of common coupling), these harmonic current cause distortions. So the voltage wave-form is disturbed and other electrical and electronics equipment can experience malfunctioning or failure which are connected to the distribution system. As a result, improving power quality (PQ) is a critical necessity of the present distribution system.

The control algorithm is also at the core of the power electronic system. Control algorithms define the output and working of converters. The DC-DC boost converter and the voltage source converter are two stages in the proposed system. For boost converter control, the MPPT (maximum power point tracking) control mechanism is used, here incremental conductance (INC) mechanism is used because of simplicity and easy to implement.

In this article, Operation and control of the shunt-connected VSC (voltage source converter) for mitigation of voltage fluctuation is discussed. The VSC is in charge of by injecting the reactive power at PCC to maintain the grid voltage and compensate voltage fluctuation and making the grid voltage constant. Also using LCL filter to reduce current harmonics. The development of rapid switching power semiconductor switches such as MOSFET and IGBT has benefited converter technology advancement. The simulation experiments are conducted using a photovoltaic array as a non-conventional energy source.

In the present electrical power system day by day demand is increasing so it exceeds production in the current power scenario. Since crucial practices such as residential, transportation, private, municipal, agricultural, and manufacturing activities in society are closely intertwined with electrical energy, demand has been gradually growing in recent

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decades. Alternative sources of energy such as solar energy, wind, tidal, and geothermal sources are considered ideal options in grid interconnected systems to satisfy the capital power load. Solar and wind energy sources use modern power converters, which have the capability to absorb or inject real power and reactive power into grid-connected networks to improve power efficiency.

II. Proposed System Design

When electricity is generated from the solar PV system and integrated through the grid, it will send any excess electricity to the grid until the local demand has been met. However, if the system generates less electricity than is required to meet local demand, additional energy is drawn from the grid. In this work, a 100KW PV system is planned with the aim of transferring electrical power to the grid from solar panels. To get the most power out of the PV module, the converter also offers full power point control. To monitoring MPP (maximum power point), a number of mechanisms are utilized, including the ICE (Incremental and Conductance) algorithm. The current and voltage of the solar PV module are also sensed in this system to monitor the peak power point. Then, a voltage source converter based on vector control principle is used to enforce a sinusoidal voltage waveform of phase and frequency matching with grid voltage. Since the output of converter has harmonics in current, a LC filter is attached to link the VSC to the grid. It's a low pass filter which reduces harmonics and current waveform to a pure sine waveform. Finally, a control mechanism is built into the converter to ensure that the solar PV panel supplies the required real & reactive electricity to the grid.

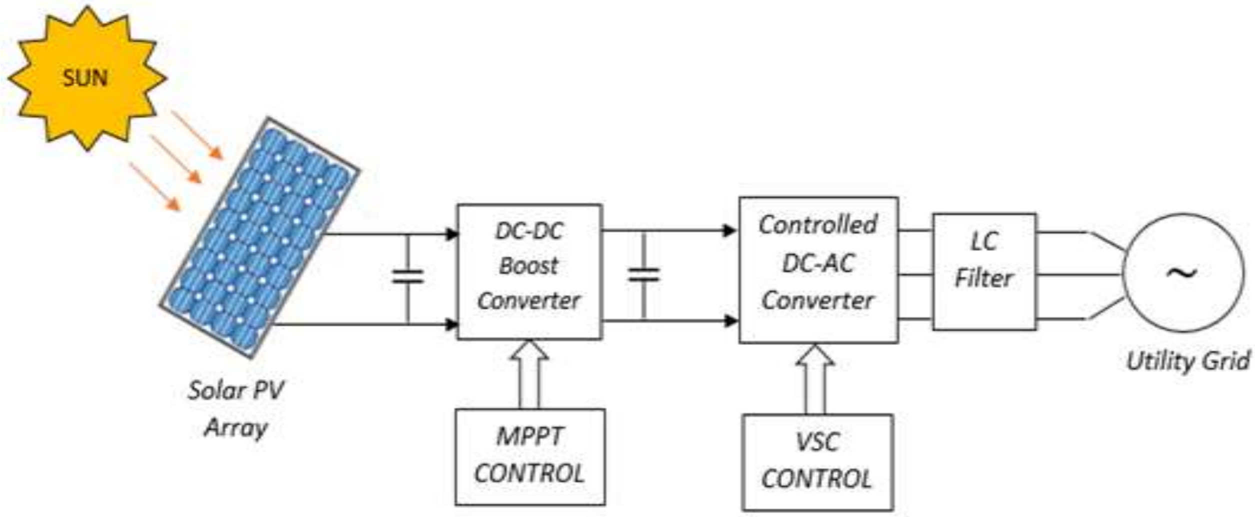

Fig. 1 Block diagram of proposed model

As shown in Fig. 1, grid-connected solar PV systems are comprised of PV arrays that are connected to electric utility grid through an active power control unit and are designed to run across parallel well to the grid. Control unit of the active power may incorporate the MPPT, converter, control system and grid interface, needed for optimal system functioning. The converter, which converts photovoltaic dc energy to ac energy, is crucial to the system's performance, but it's perhaps the most difficult operating system. The proposed system design consists, Photovoltaic array, boost converter, and a voltage source converter attached to 3-phase ac supply feeding 3-phase loads. DC–DC boost converter's input is connected to the solar PV array. The output of the boost converter is linked to the VSC through a DC link. The boost converter performs the MPPT function, and the resulting power is delivered to the VSC via a DC link. The extracted PV power is fed into the grid through a three-leg VSC. For smoothing VSC currents, interfacing inductors are used between the PCC and the AC terminals. A three phase load is also connected at the same PCC to compensate it and to simulate load unbalancing, mechanical switches are arranged to load lines in the series.

The shunt connected VSC has a capacitor on the DC side and AC side it has small reactor, which filters the high frequency segments connected to IGBT (Insulated Gate Bipolar Transistor) as shown in Figure 2. A PV-based compensator is a reactive power compensating device that can absorb and/or produce the necessary amount of real and reactive power for a power system's stable operation. The compensator is a VSC that transforms the input DC voltage from the PV Solar Farm to a series of AC output voltages and connects to the corresponding AC grid through a small reactance (leakage inductance of coupling transformer or an interfacing reactor).

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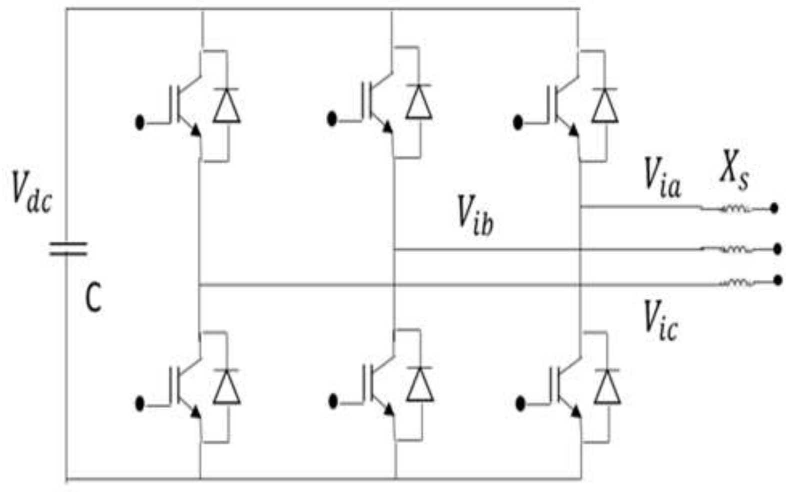

Figure 2: Voltage source converter

It is important to provide certain voltage magnitude difference for power exchange from the inverter to the planned grid system and from the grid system to the inverter. By implementing this VSC-based grid-connected solar PV system will completely eliminate power quality problems. The sufficient quantity of real power & reactive power managed by photovoltaic based shunt active power filters. The following steady state equations indicate about the real and reactive powers provided by shunt APF, for magnification of power quality in distribution network.

$$P_s = \frac{|V_s||V_i|}{X_s}\sin(\delta) \quad (1)$$

$$Q_s = \frac{|V_s||V_i|}{X_s}\cos(\delta) - \frac{|V_s^2|}{X_s} \quad (2)$$

Where P_s is real power, Q_s is reactive power, V_s is system voltage, V_i is inverter voltage, X_s is reactance and δ is the phase difference between both voltages.

To get the most power out of a given PV system, the duty ratio must be adjusted based on the load as well as climate change. Maximum Power Point Tracking is a strategy that allows you to monitor your maximum power points automatically. To obtain the maximum power point, many MPPT strategies have been investigated in industry, including increasing or decreasing duty cycle, reference voltage or reference current. The load to which a solar PV panel is attached determines its operating point. The working point of the solar PV module is bound to change as the solar irradiance on the solar photovoltaic module changes during the day. The algorithm and electronic circuitry are used in the full power monitoring mechanism. The system works on the theory of load-to-module impedance matching, which is required for optimum power transfer. A DC-DC converter is used to perform the impedance balancing.

A hill climbing method derived with the help of conductance $\left(I_{pv}/V_{pv}\right)$ is called as incremental conductance method (INC). The technique used here is in the form of resistance. At MPPT the slope is zero of the PV curve and it is simple to verify with the help of following derivation.

$$P = VI \rightarrow \frac{\partial P}{\partial V} = I + V\frac{\partial I}{\partial V} \xrightarrow{At\ MPP} \frac{-I}{V} = \frac{\partial I}{\partial V} \quad (3)$$

Above equation can be again written in the formula of incremental resistance as following

$$\xrightarrow{At\ MPP} \frac{\partial V}{\partial I} = \frac{-V}{I} \quad (4)$$

$$\xrightarrow{Left\ to\ MPP} \frac{\partial V}{\partial I} > \frac{-V}{I} \quad (5)$$

$$\xrightarrow{Right\ to\ MPP} \frac{\partial V}{\partial I} < \frac{-V}{I} \quad (6)$$

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To easily locate the maximum power point, compare the instantaneous conductance (I/V) to the incremental conductance ($\Delta I/\Delta V$) at every sampling time to determine the right path for altering the reference voltage (V_{ref}) of PV array. At Maximum power point, V_{ref} equals to V_{mpp}. Unless there is a change in ΔI, which implies a change in solar radiation or weather condition, the PV array functioning is maintained after the MPP is reached. To keep track of the new MPP, the mechanism decreases or increases V_{ref}. Once the MPP is reached, the operation of the PV array is maintained at this point unless there is change in ΔI, which indicates a change in solar radiation or weather condition. The algorithm decrease or increase V_{ref} to track the new MPP.

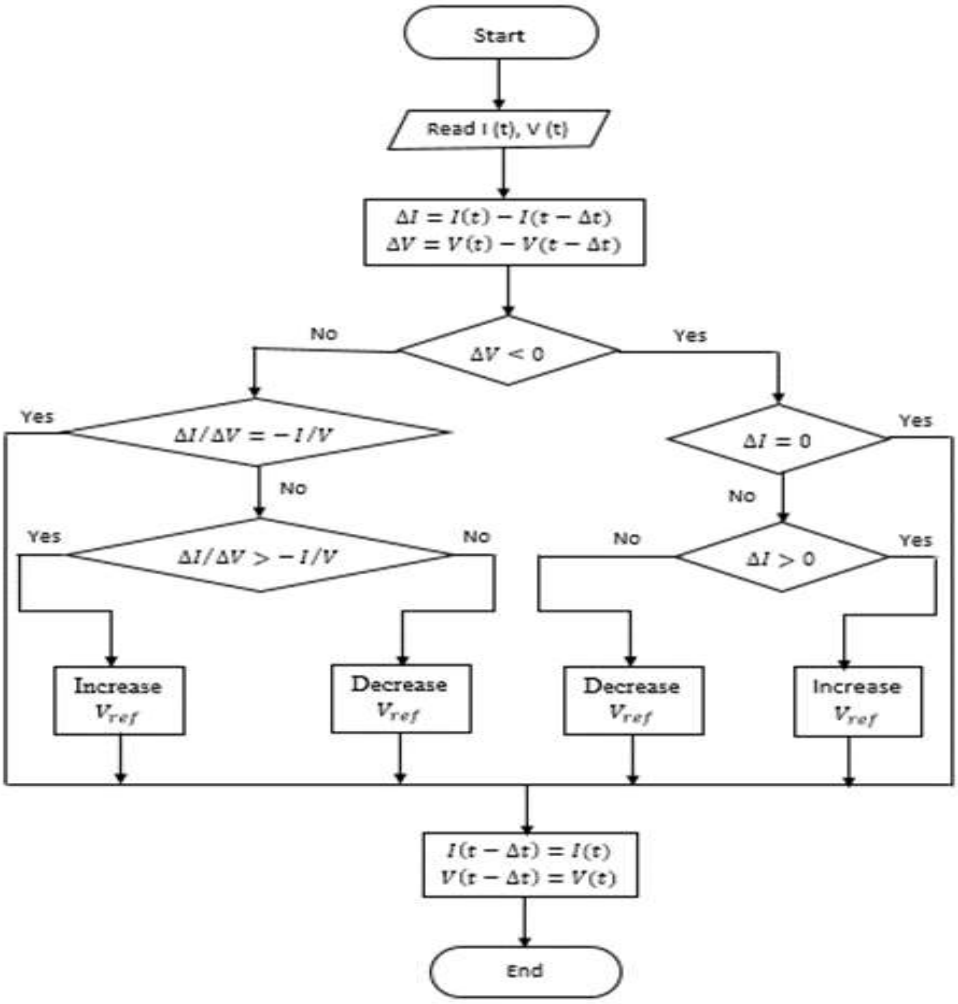

Figure 3: Flow chart of INC

The most common control approach for Voltage Source Converters is vector current control. Basic principle of the vector current control for VSC is to regulate instantaneous active and reactive grid currents independently of one another. Figure 4 shows the vector control scheme. It is feasible to adjust active and reactive power independently using a synchronously rotating d-q frame of reference. Currents and voltages in the system are first characterized as vectors in a stationary $\alpha\beta$ frame of reference, then translated to the rotating d-q coordinate system. The following is the procedure for converting to d-q coordinates.

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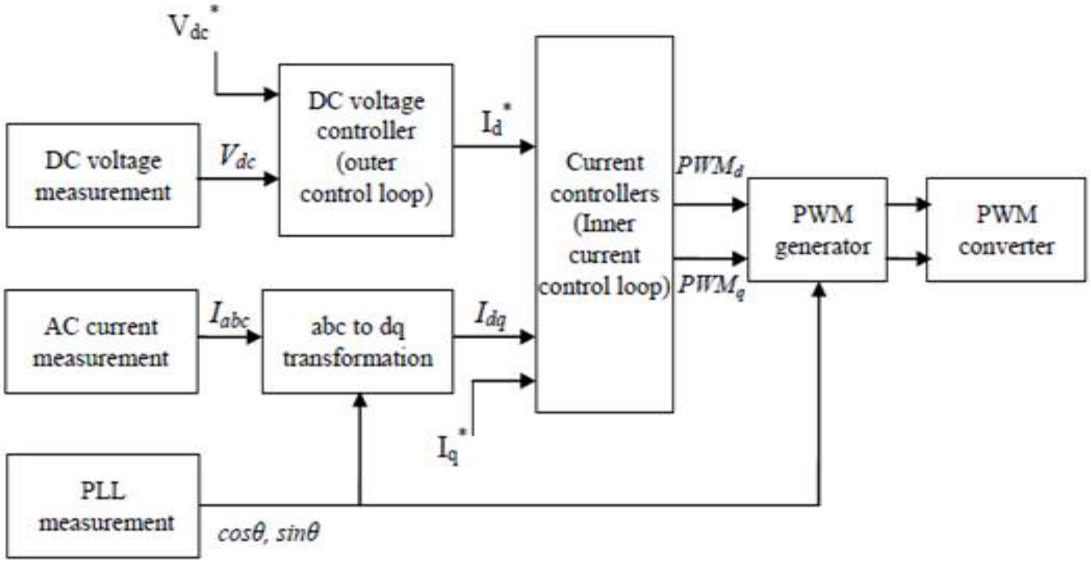

Figure 4. Block diagram of vector control principle

III. RESULTS

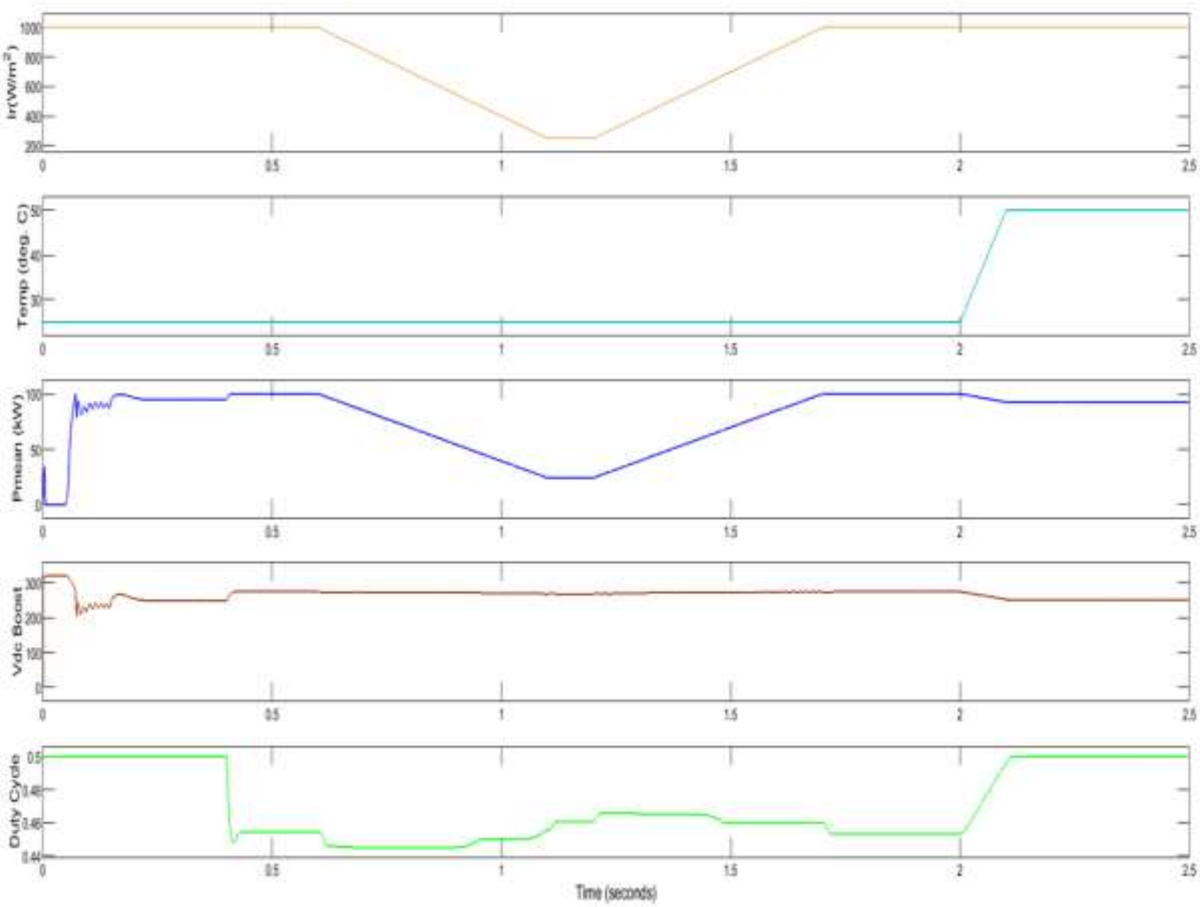

Figure 5. Output waveform of solar PV of power, voltage of boost converter and duty cycle

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As shown in fig. 5 the output waveform of mean power, voltage of boost converter and the duty cycle of the solar PV varies according to the solar irradiance and temperature changes which can be seen in the output waveform.

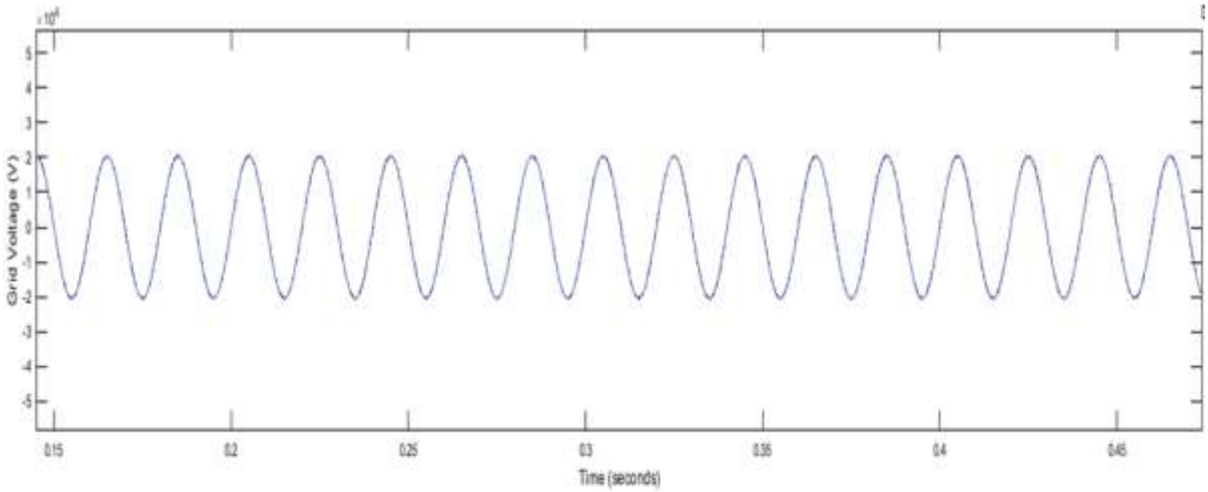


Fig. 6. Grid side voltage

Grid side voltage waveform is shown in figure 6. To integrate the solar power to grid the grid side voltage should be sinusoidal and power factor should be unity.

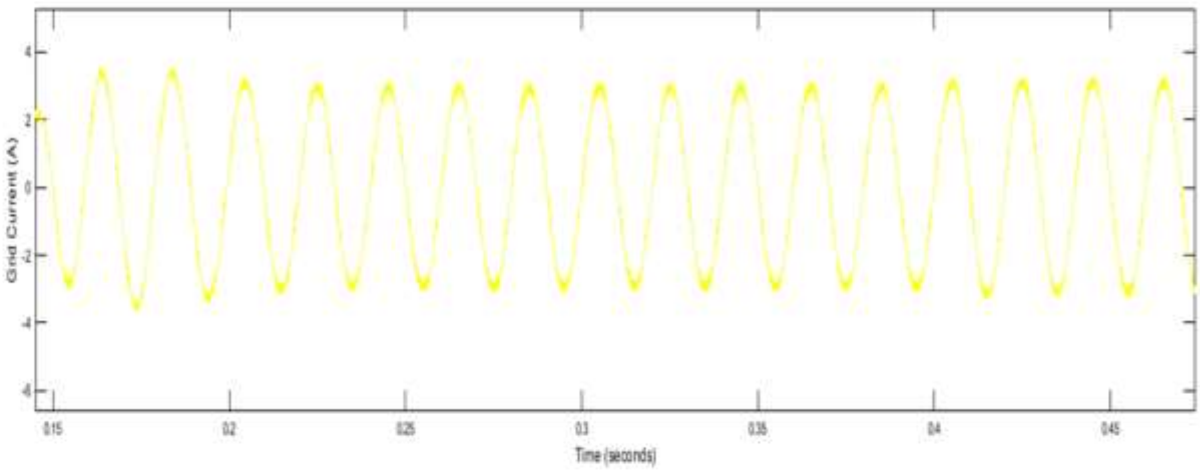
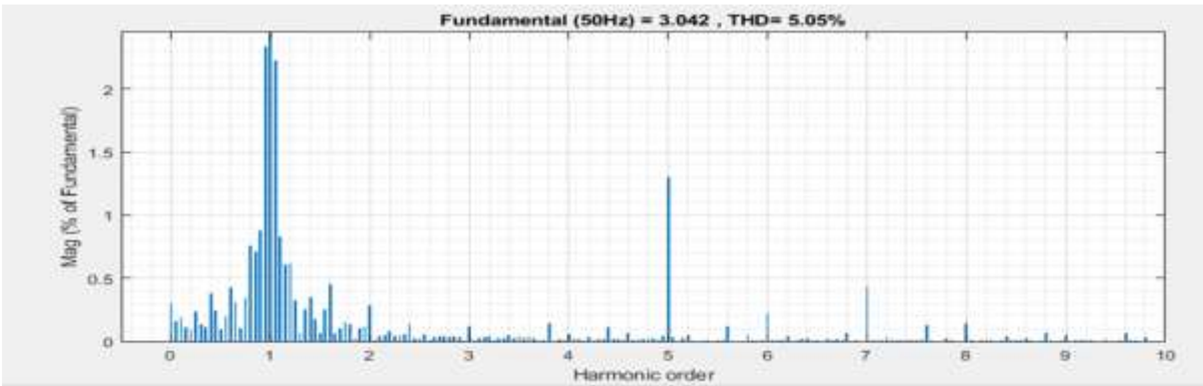


Fig. 7. Grid side current

The grid side current with changes in solar PV characteristics is shown in the simulation result above. The current will rise or fall in proportion to the solar irradiance and temperature.



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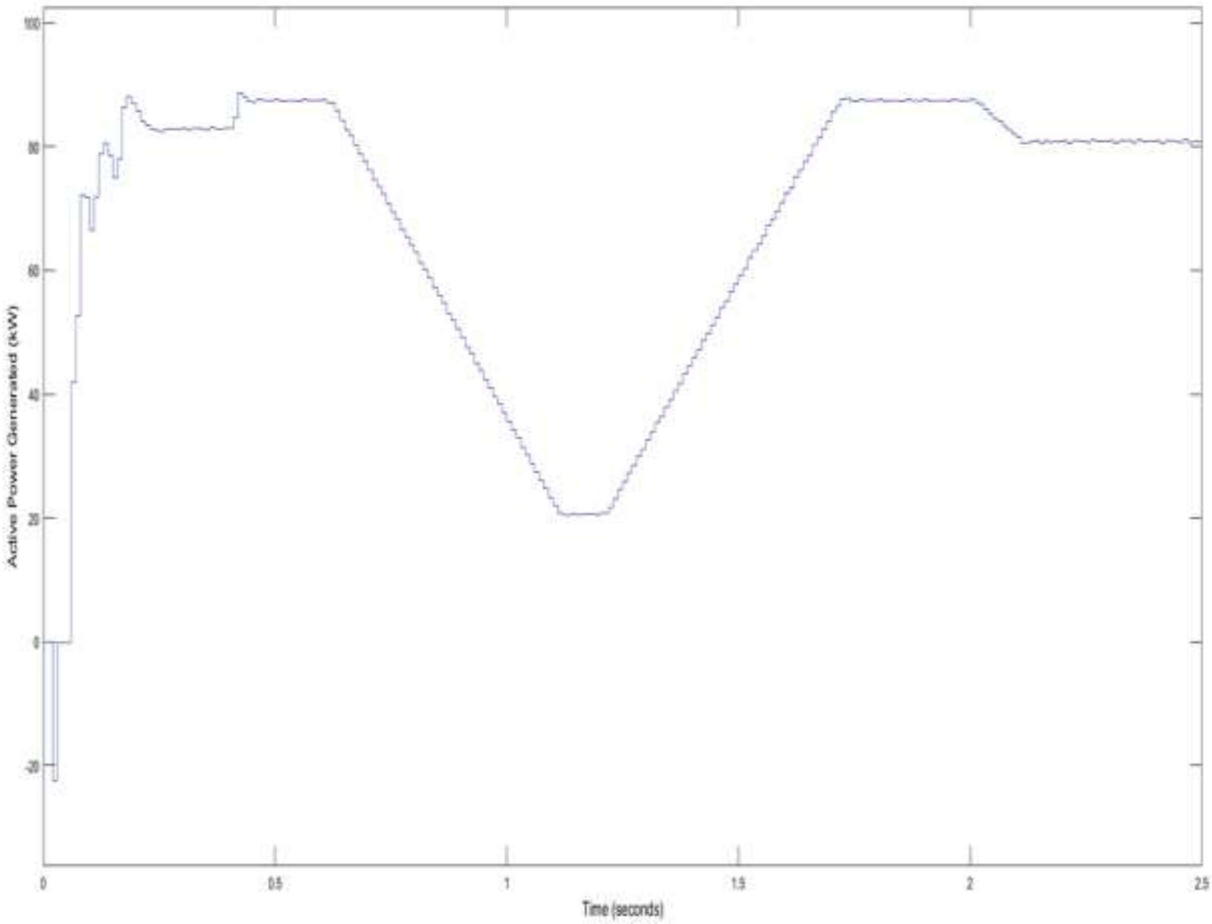

Fig. 8. Active power generated

The given simulation result clearly shows variations in active power generated. Active power fluctuated in response to variations in solar irradiation and temperature. MPPT is utilized to get the most power out of the solar PV system. As sun irradiance and temperature rise, power rises in response, and as temperature falls, power falls in response.

IV. CONCLUSION

In this paper, a shunt converter is used to incorporate a renewable energy resource. The shunt converter successfully accomplishes two goals: first, it solves power quality issues caused by nonlinear loads such as harmonics reduction and reactive power compensation, and second, it supply active power generated by the solar PV system. The results demonstrate that integrating solar PV power is simple when the source current is sinusoidal and the power factor is unity.
The MATLAB simulations are used to show how a shunt linked voltage source converter may be used for harmonic reduction, active and reactive power injection, and absorption when and where it is needed. The VSC for grid integrated solar PV systems is controlled using a revolutionary control methodology called vector control concept. The voltage at the PCC is controlled by maintaining a steady DC bus capacitor voltage. Total Harmonic Distortions have been reduced, and the power factor has improved to unity PF from lagging. The enhanced control strategy had the highest chance of increasing the projected grid integrated system's utilization factor.

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