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**Research Article**

# Non Linear Analysis of MPPT for Power Quality Improvement

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**Abstract:** In this study the conventional inverter interfacing renewable energy sources with the grid, without any additional hardware cost. Here, the main idea is the maximum utilization of inverter rating which is most of the time underutilized due to intermittent nature of RES. Based on the non-linear characteristics of PV, these thesis designs a VSS controller to realize the maximum power output of PV arrays. The output power from renewable energy sources fluctuates because of weather variations. This study proposes an effective power quality control strategy of renewable energy sources connected to power system using Photovoltaic (PV) array. If the main controller used is a PR controller, any dc offset in a control loop will propagate through the system and the inverter terminal voltage will have a nonzero average value. In this strategy both load and inverter current sensing is required to compensate the load current harmonics. The non-linear load current harmonics may result in voltage harmonics and can create a serious PQ problem in the power system network.

**Keywords:** Power quality, PV array, RES, voltage control

## INTRODUCTION

In Electrical Power distribution networks, it is essential to balance the supply and demand of active and reactive power in an electric power system. If the balance is lost, the system frequency and voltage excursion may occur resulting, in the worst case, in the collapse of the power system. Appropriate voltage and reactive power control is one of the most important factors for stable power system. The distribution system losses and various power quality problems are increasing due to reactive power (Guerrero *et al*., 2004). The voltage regulation is also poor in the distribution system due to the unplanned expansion and the installation of different types of loads in the existing distribution system (Enslin and Heskes, 2004; Borup *et al*., 2001).

Several large industrial users are reported to have experienced large financial losses as a result of even minor lapses in the quality of electricity supply. As the number of power electronics equipment increase in power systems, the quality of electric power supply is spoiled (Pinto *et al*., 2012). Both high power industrial loads and domestic loads are the source of unbalanced currents and current harmonics distortions in electric power supplies (Kimball *et al*., 2009).

A voltage dip is caused by a fault in the utility system, a fault within the customer's facility or a large increase of the load current, like starting a motor or transformer energizing (Paatero and Lund, 2007). Typical faults are single-phase or multiple-phase short circuits, which leads to high currents. The high current results in a voltage drop over the network impedance. At the fault location the voltage in the faulted phases drops close to zero, whereas in the non-faulted phases it remains more or less unchanged (Kim *et al*., 1996). In this study analysis of an effective power quality control strategy of renewable energy sources connected to power system using Photovoltaic (PV) array. In this strategy both load and inverter current sensing is required to compensate the load current harmonics.

## PROPOSED SYSTEM DESCRIPTION

The proposed system consists of RES connected to the dc-link of a grid-interfacing inverter. The voltage source inverter is a key element of a DG system as it interfaces the renewable energy source to the grid and delivers the generated power. The RES may be a DC source or an AC source with rectifier coupled to dc-link. Usually, the fuel cell and photovoltaic energy sources generate power at variable low dc voltage, while the variable speed wind turbines generate power at variable ac voltage. Thus, the power generated from these renewable sources needs power conditioning (i.e., dc/dc or ac/dc) before connecting on dc-link. The dc-capacitor decouples the RES from grid and also allows independent control of converters on either side of dc-link is as shown in the Fig. 1.

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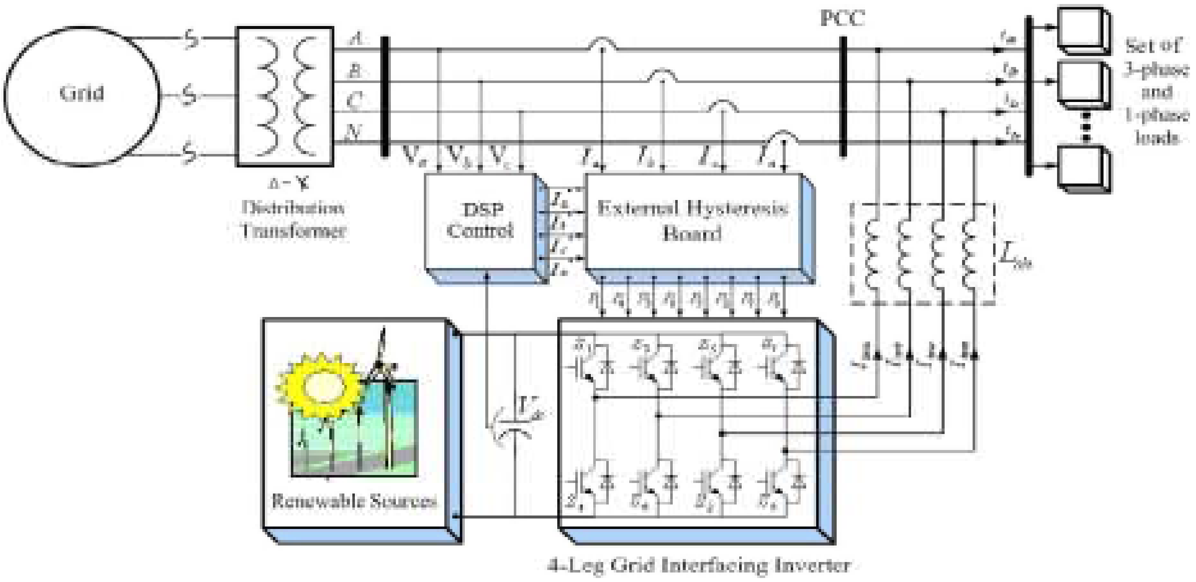


Fig. 1: Proposed renewable based distributed system

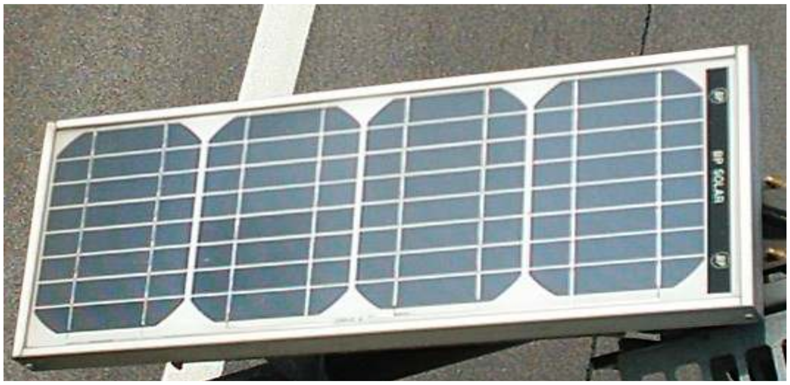


Fig. 2: Solar panel

**Solar panel:** The term solar panel is best applied to a flat solar thermal collector, such as a solar hot water or air panel used to heat water, air, or otherwise collect solar thermal energy. But 'solar panel' may also refer to a photovoltaic module which is an assembly of solar cells used to generate electricity. The schematic arrangement is as shown in the Fig. 2.

An array is an assembly of solar-thermal panels or Photovoltaic (PV) modules; the panels can be connected either in parallel or series depending upon the design objective. Solar panels typically find use in residential, commercial, institutional and light industrial applications.

Recently there has been a surge toward large scale production of PV modules. In parts of the world with significantly high insulation levels, PV output and their economics are enhanced. PV modules are the primary component of most small-scale solar-electric power generating facilities. Larger facilities, such as solar power plants typically contain an array of reflectors (concentrators), a receiver and a thermodynamic power cycle and thus use solar-thermal rather than PV. The PV cells are made of semiconductor materials, such as silicon. For solar cells, a thin semiconductor wafer is specially treated to form an electric field, positive on one side and negative on the other. When light energy strikes the solar cell, electrons are knocked loose from the atoms in the semiconductor material. If electrical conductors are attached to the positive and negative sides, forming an electrical circuit, the electrons can be captured in the form of an electric current-that is, electricity. This electricity can then be used to power a load. A PV cell can either be circular or square in construction.

The efficiency of a PV cell is defined as the ratio of peak power to input solar power:

$$\eta = \frac{Vmp.Imp}{I\left(\frac{KW}{m^2}\right).A(m^2)} \tag{1}$$

where,

Vmp = The voltage at peak power
Imp = The current at peak power
I = The solar intensity per square meter
A = The area on which solar radiation fall

The efficiency will be maximum if we track the maximum power from the PV system at different environmental condition such as solar irradiance and temperature by using different methods for maximum power point tracking.

**Dc-link voltage and power control operation:** Due to the intermittent nature of RES, the generated power is of variable nature. The dc-link plays an important role in transferring this variable power from renewable energy source to the grid. RES are represented as current sources connected to the dc-link of a grid-interfacing inverter. Figure 3 shows the systematic representation of power transfer from the renewable energy resources to the grid via the dc-link. The current injected by renewable into dc-link at voltage level Vdc can be given as:

$$I_{dc} = PRES/V_{dc} \tag{2}$$

where, PRES is the power generated from RES.

The current flow on the other side of dc-link can be represented as:

$$I_{dc} = P_{inv}/V_{dc} = (P_G + P_{Loss})/V_{dc} \tag{3}$$

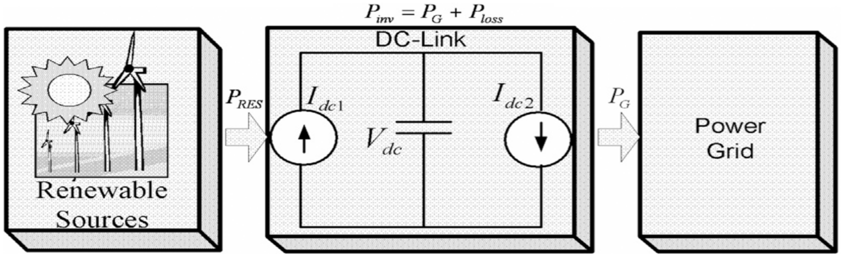


Fig. 3: DC-link equivalent diagram

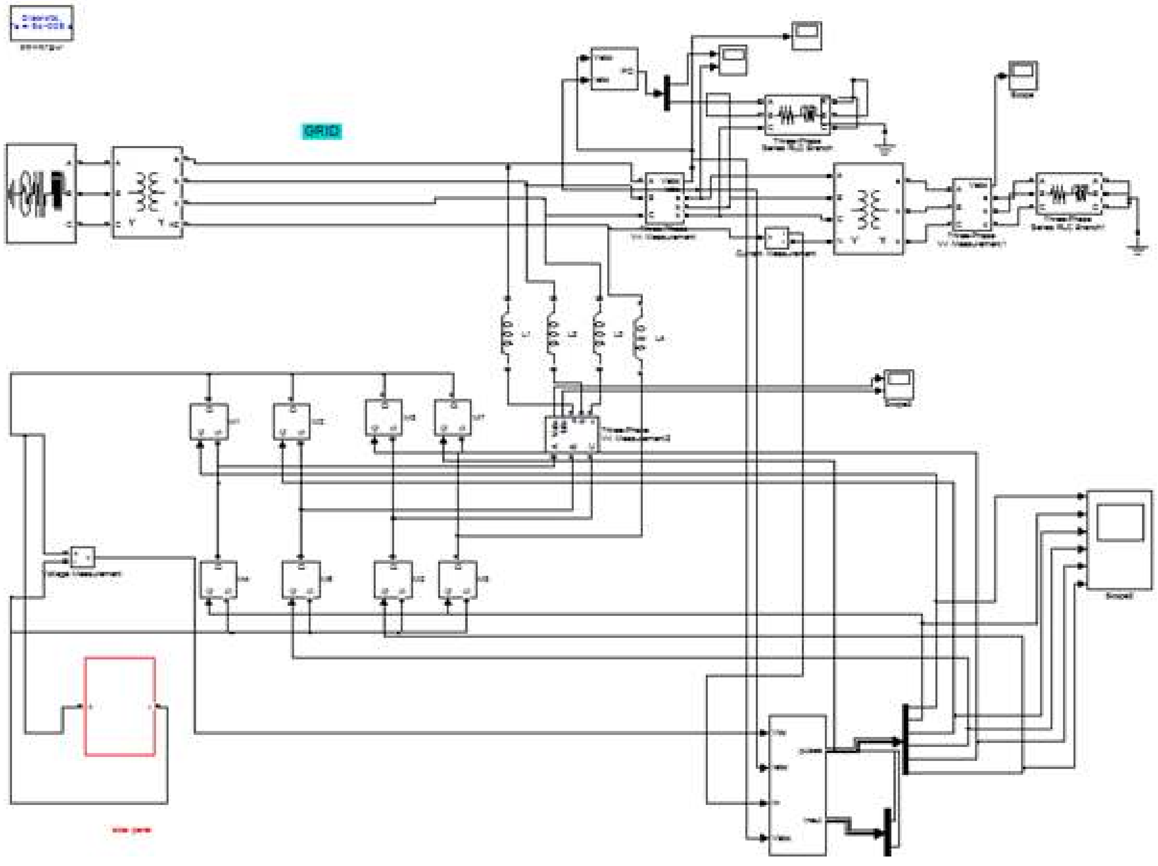


Fig. 4: SIMULINK model for three phase closed loop control system

The fourth leg of inverter is used to compensate the neutral current of load. The main aim of proposed approach is to regulate the power at PCC during 1. $P_{RES} = 0$, 2. $P_L$<total load Power ($P_L$), 3.$P>P_L$ While performing the power management operation, the inverter is actively controlled in such a way that it always draws/supplies fundamental active power from/to the grid. If the load connected to the PCC is non-linear or unbalanced or the combination of both, the given control approach also compensates the harmonics, unbalance and neutral current.

## SIMULINK FOR THREE PHASE CLOSED LOOP CONTROL

We can visualize the simulation behavior by viewing signals with the displays and scopes provided in SIMULINK are as shown in the Fig. 4. We can also view simulation data within the Simulation Data Inspector, where we can compare multiple signals from different simulation runs. Scope is the block in SIMULINK by which we can measure and view the voltage, current and power in electrical domain.

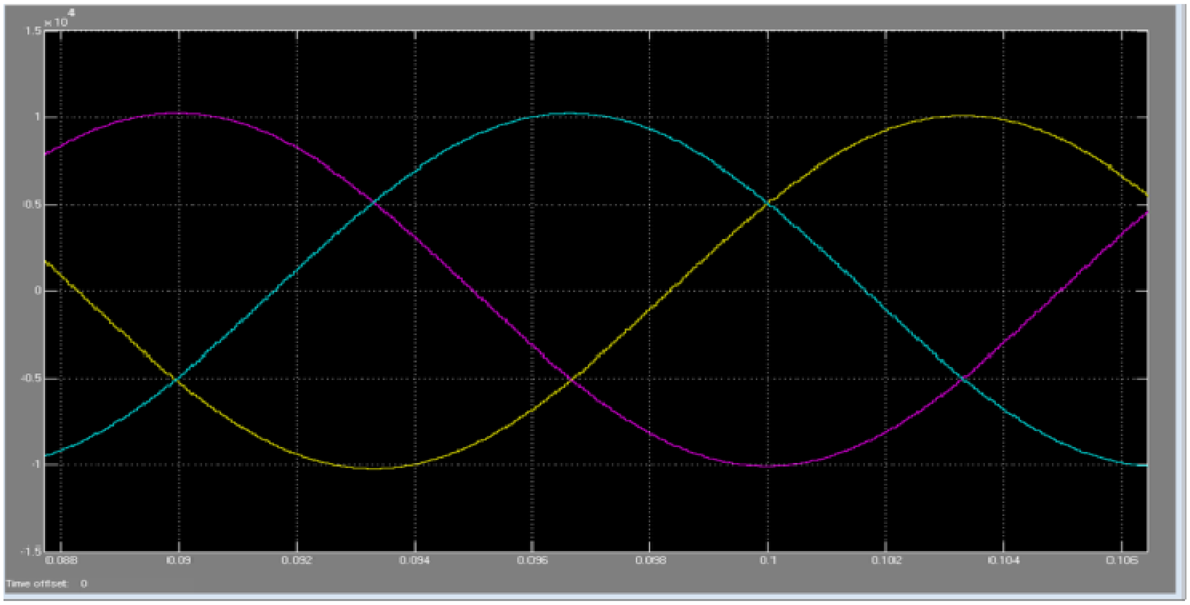


Fig. 5: Input source voltage waveform

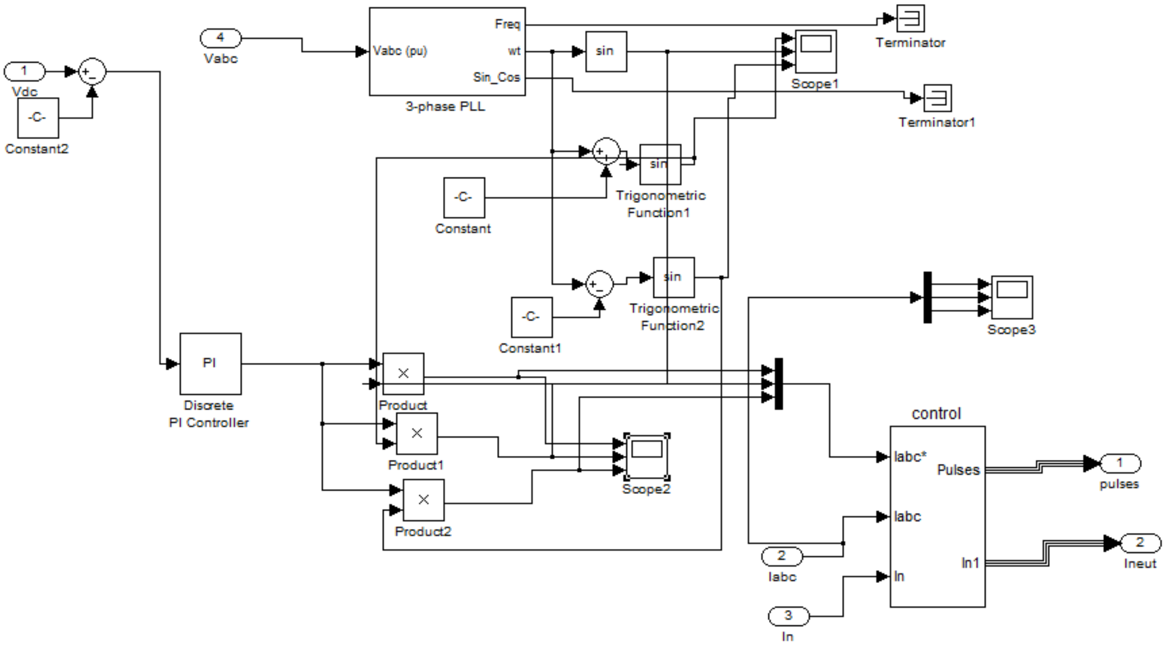


Fig. 6: Controller loop control system

In this model 3-ph 4-wire system is applied in which fourth wire is act as neutral. If there any fault occurs in any of the phases neutral will act as that phase for continuous power transmission. The given input is 440 V which is step up for 11 kV and it will step down at the load side.

Figure 5 represents the input voltage rating of 11 kV. By using step up Transformer input voltage 440 V is stepped up to 11 KV. Initially 440 V is stepped up in the transmission line using transformer and 11 KV to minimize the transmission losses.

This loop is designed for measuring the voltage and current rating and values are compared with reference value for pulse production. The loop controller and various power flows output is as shown in the Fig. 6 and 7 respectively.

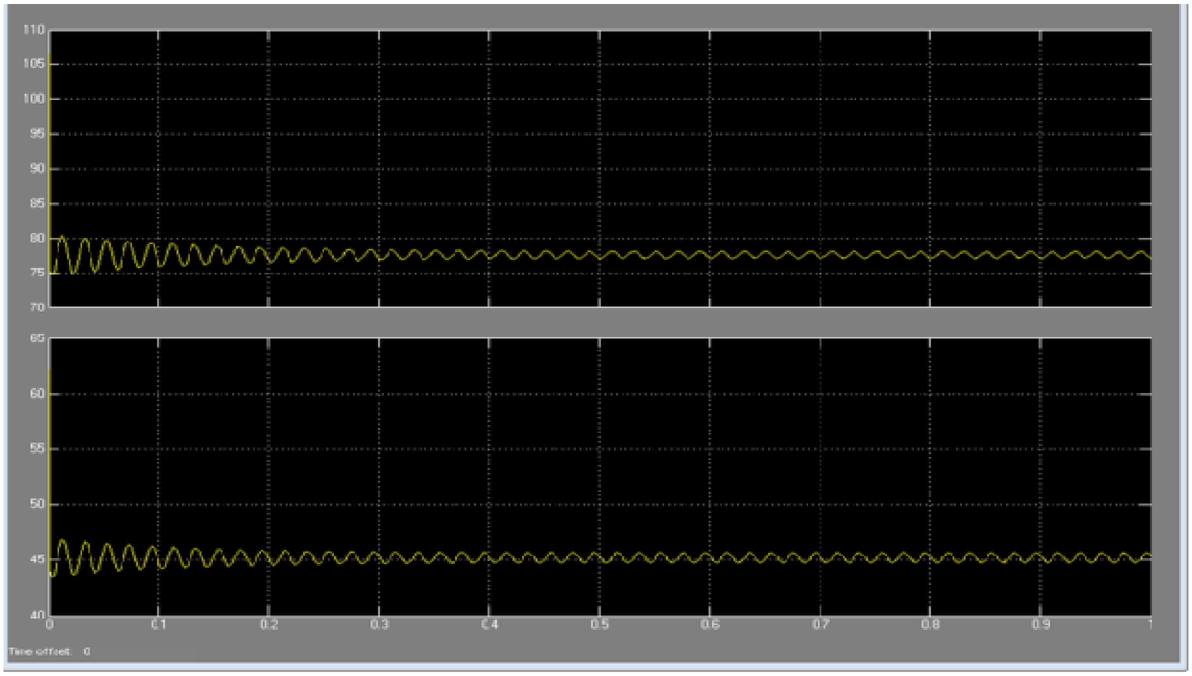


Fig. 7: Results of real and reactive power

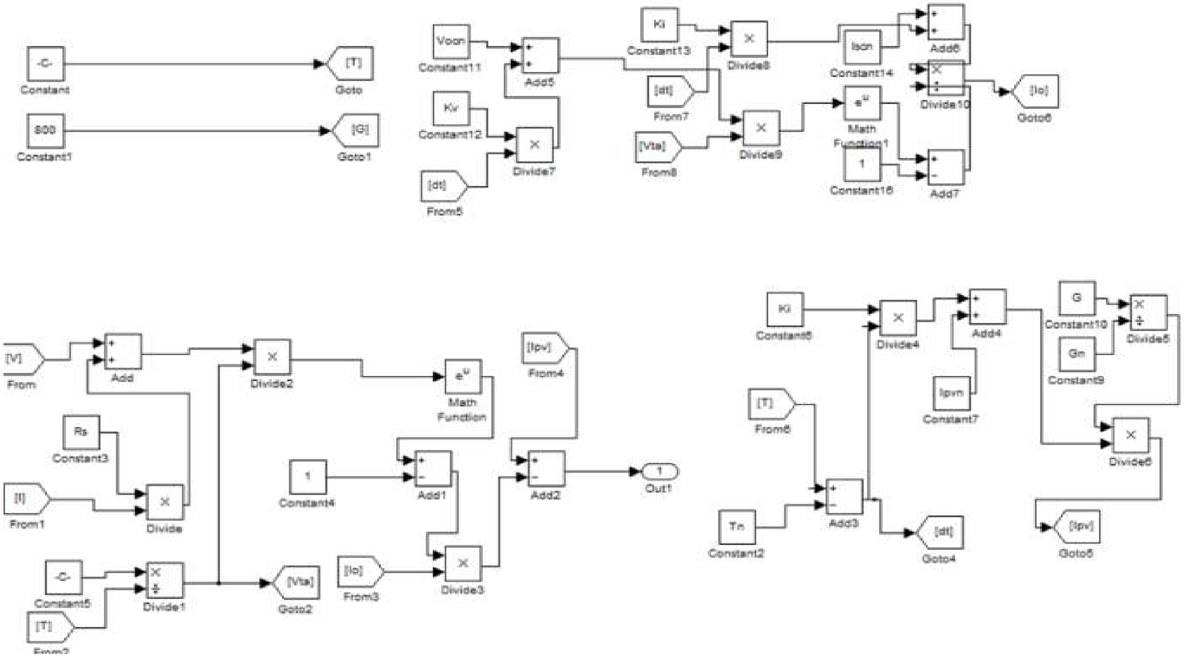


Fig. 8: Inner loop control system

This curve shows the variations in real and reactive power during the time period between 0 and 1.

This model is designed for pulse generation which is given to operate Switches ON and OFF during the time period produced by the crystal oscillator. The pulse was generated using reference value calculated. The inner loop control circuit is as shown in the Fig. 8.

This curve shows that the pulse is generated after some time delay and the pulses are in square wave form produced from the Inverter circuit is as shown in the Fig. 9.

This curve shows the voltage rating after stepping down is done. The solar input is given for boost up the voltage rating in transmission line if there any voltage drop or fault occurred.

Due to the presence of power electronic component the output waveform is not pure sinusoidal instead the output is in square waveform because of the harmonic content present in the system is as shown in the Fig. 10.

The reduction in the harmonic content will improve the performance. The total harmonic distortion of a system is determined by performing the FFT analysis which gives the THD value of the output waveforms in the system.

Figure 11 the FFT analysis is done for the ouput voltage waveform. The THD value is 0.07%. The main

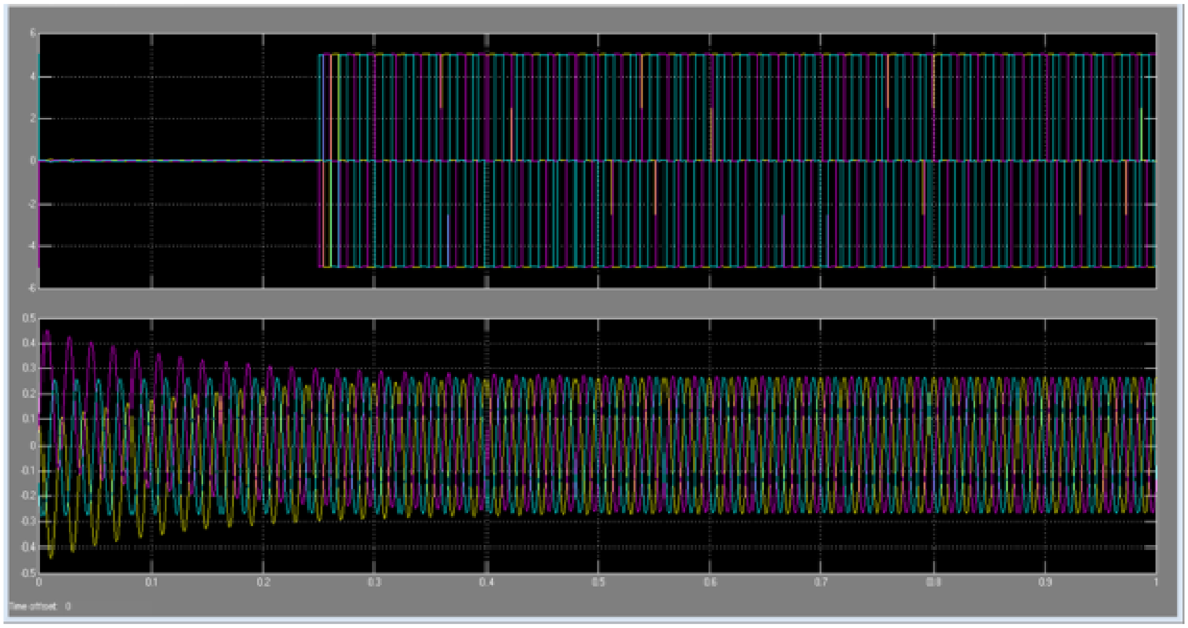


Fig. 9: Waveform for pulse generation

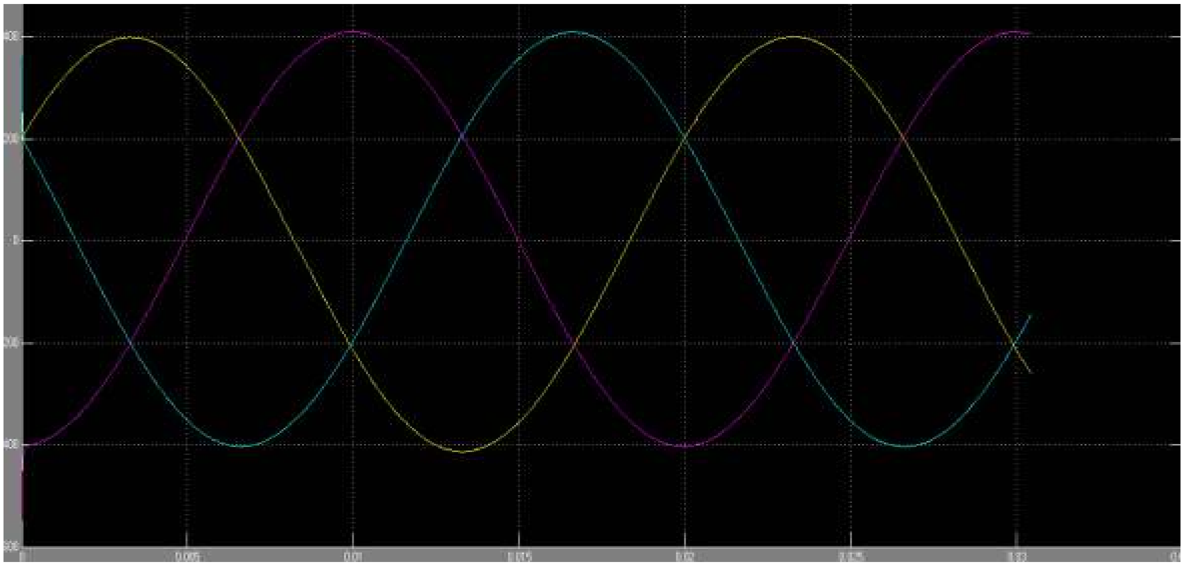
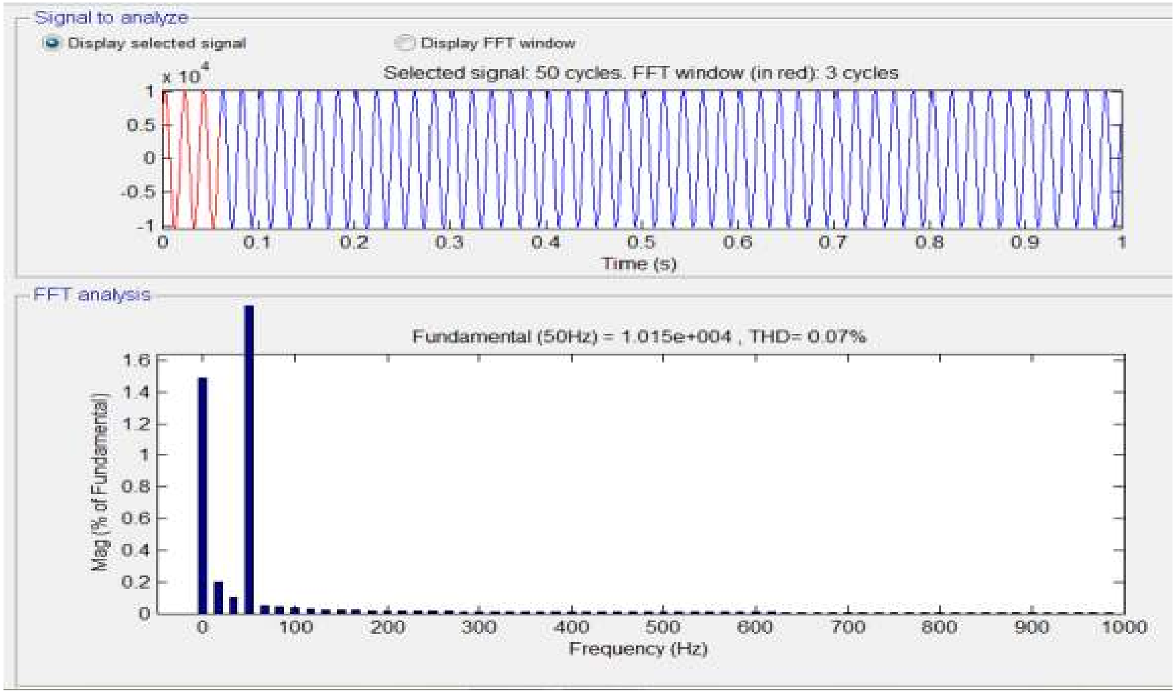


Fig. 10: Voltage waveform at distribution level



Selected signal: 50 cycles. FFT window (in red): 3 cycles

Fundamental (50Hz) = 1.015e+004 , THD= 0.07%

Fig. 11: FFT analysis of output voltage

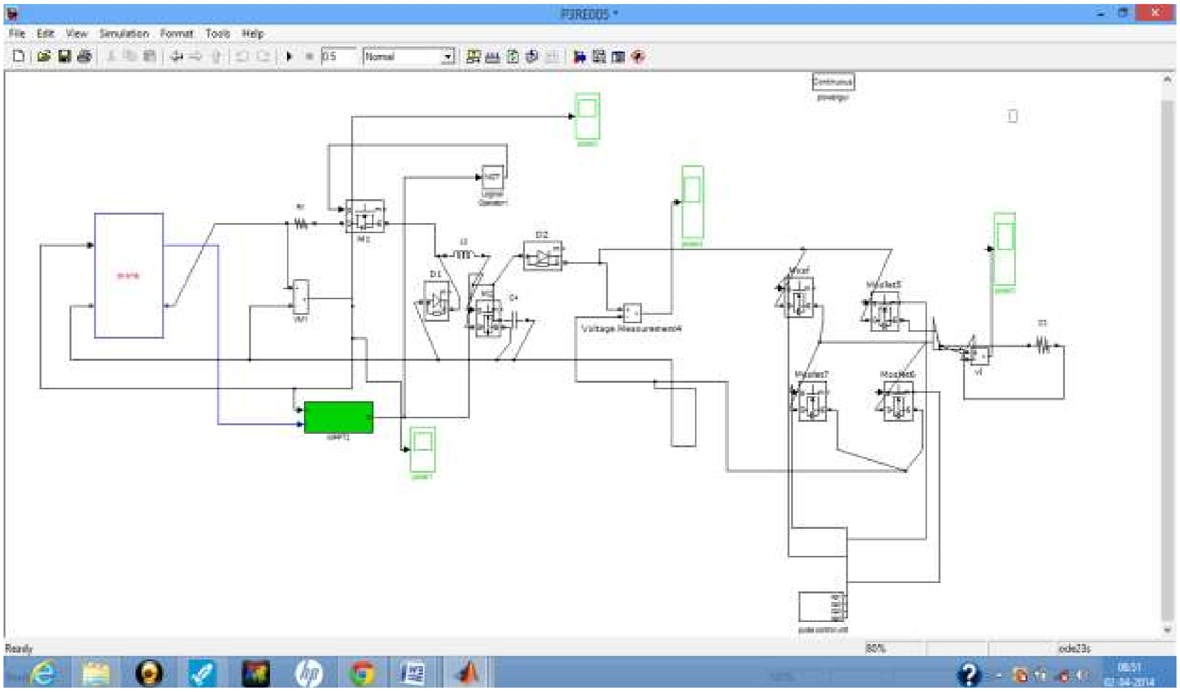


Fig. 12: Simulation diagram of the conventional circuit diagram

advantage of this method after compensation produces the result of lower THD rating. It will improves the system performances. If ther is any voltage drop during transmission the solar energy we are injecting will compensate the voltage drop at the distribution level. Reduction of lower order harmonics by using below simulation Fig. 12.

The voltage which is supplied from the source is measured from the voltage measurement block. From the Fig. 12 it is clear that the magnitude of voltage is approximately 35 V. The line voltage of the source is shown in the following Fig. 13. The waveform of the source voltage is as shown in the Fig. 14. The waveform of the output voltage and current with

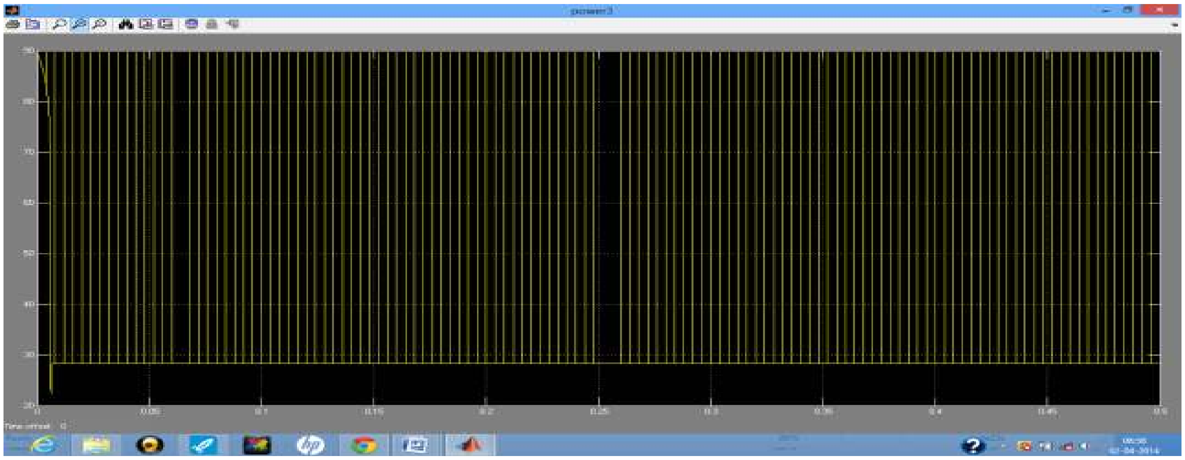
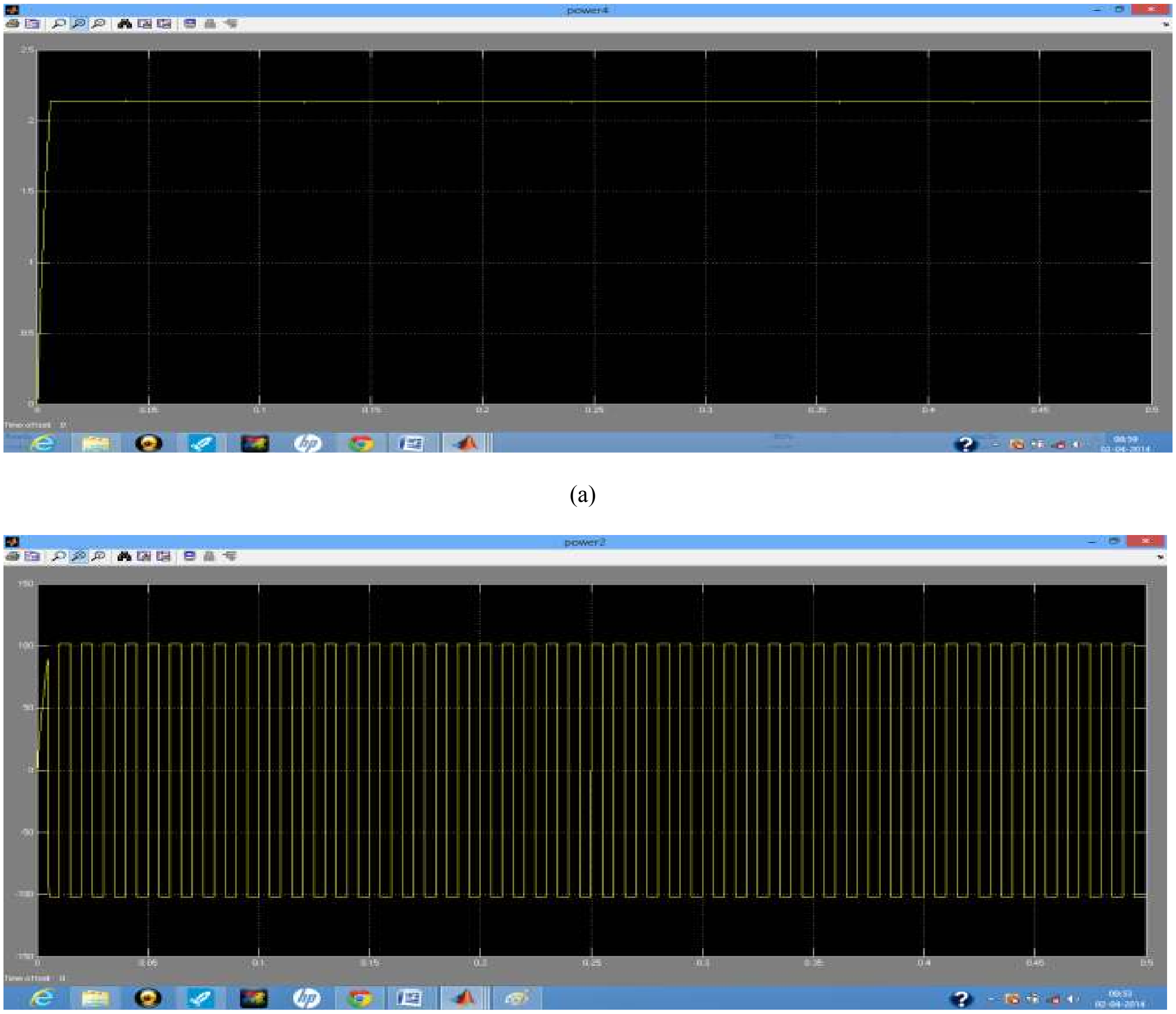


Fig. 13: Waveform of the source voltage



(a)

(b)

Fig. 14: Waveform of the output voltage and current with harmonics

harmonics is as shown in the Fig. 14a and b respectively.

The Proposed project takes into account the loss of the power and voltage in due to more number of the

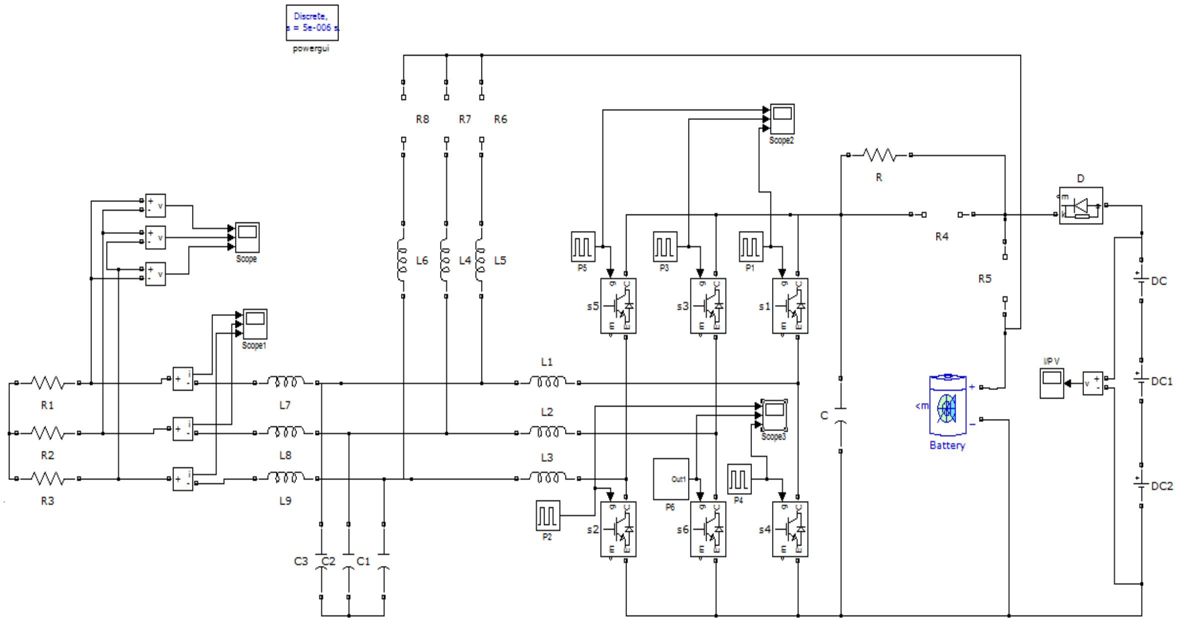


Fig. 15: Simulated diagram for the proposed circuit

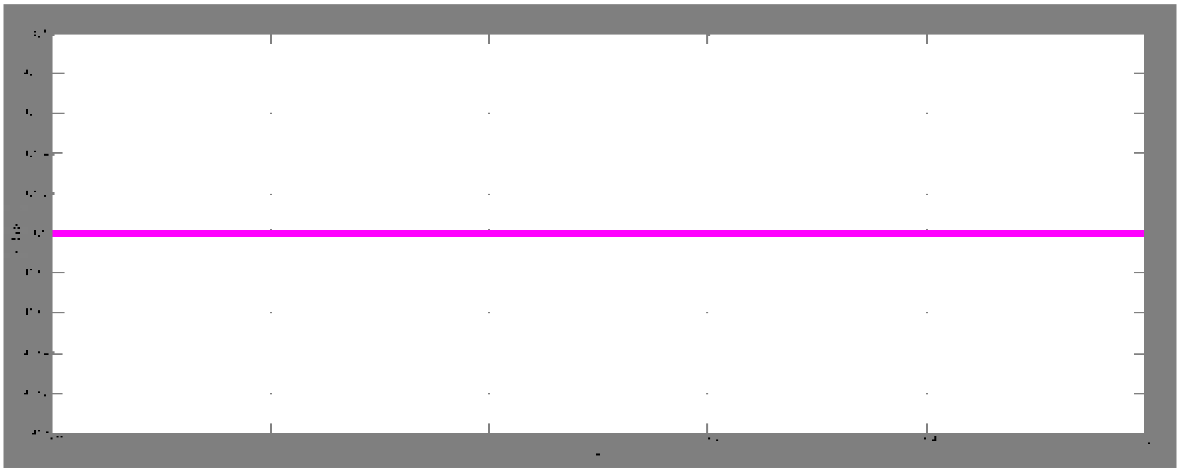


Fig. 16: The simulated input voltage for the proposed circuit

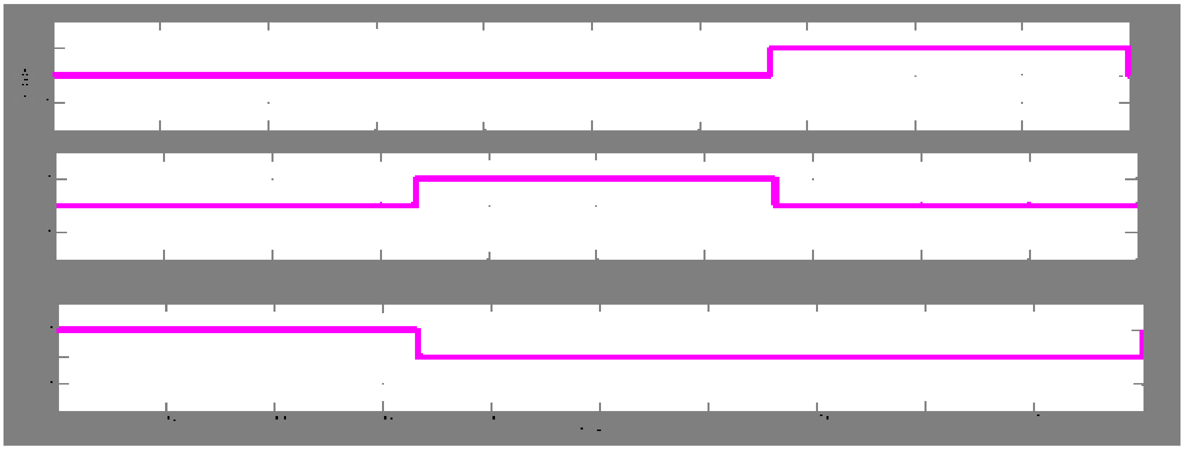


Fig. 17: The simulated triggering pulse (S1, S3, S5)

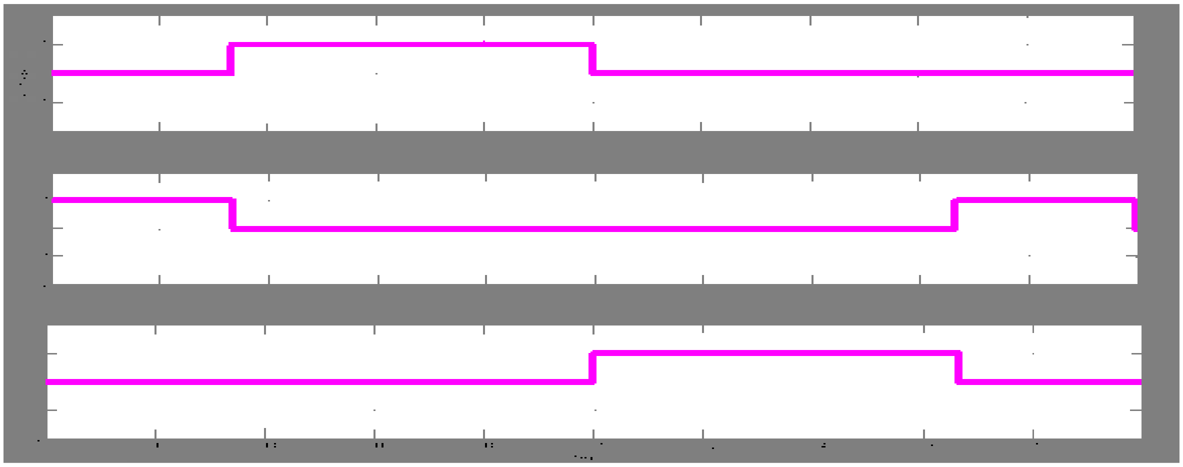


Fig. 18: The simulated triggering pulse (S2, S4, S6)

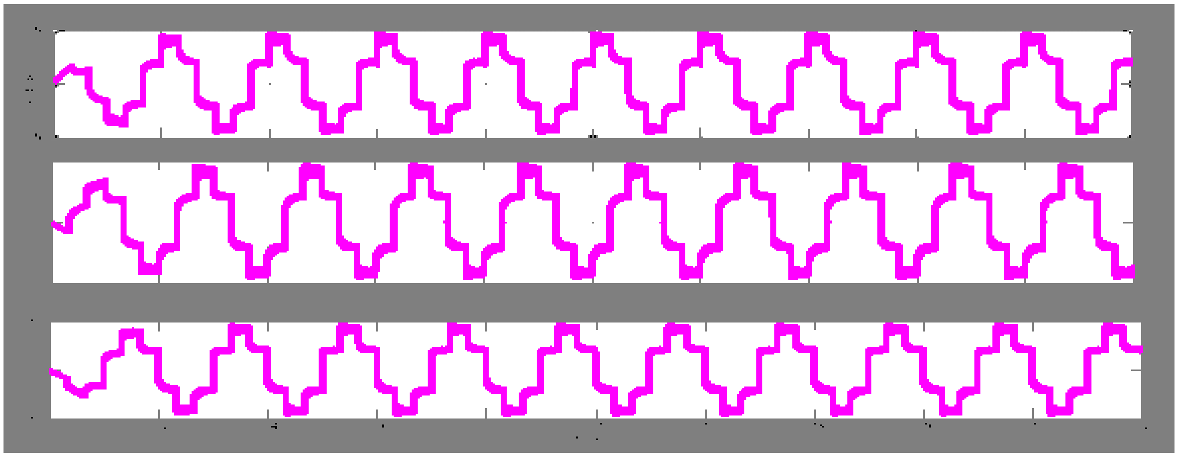


Fig. 19: The simulated three phase output voltage for the proposed circuit

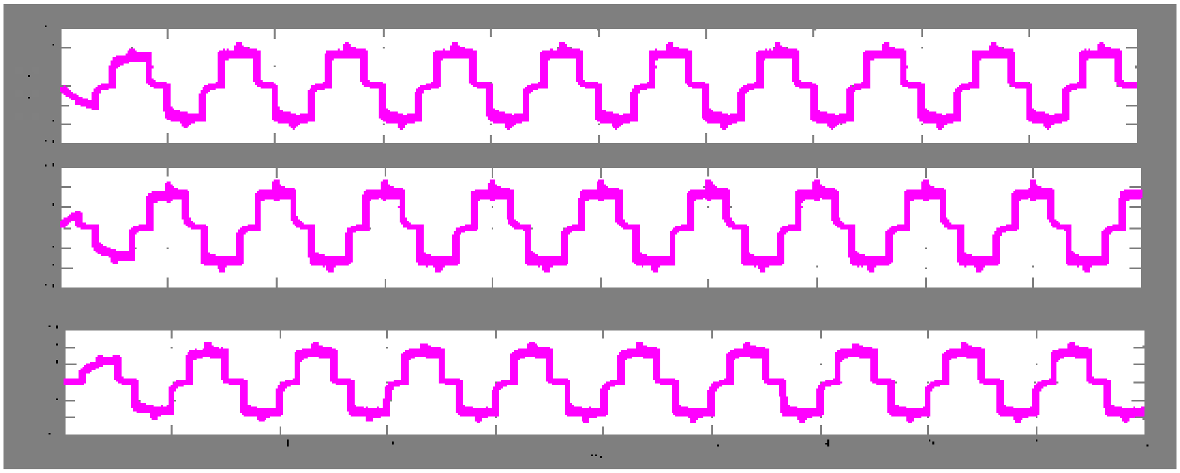


Fig. 20: The simulated three phase output current for the proposed circuit

switches utilized for more efficient conversion and hence uses core materials like inductor and capacitor to boost up the voltage and thereby reducing switching loses and improving the efficiency of the converter. The circuit simulation and waveform output is as shown in the Fig. 15 to 21 respectively.

In this curve of I-V, it is very clear that the short circuit current increases with increase in irradiance at a

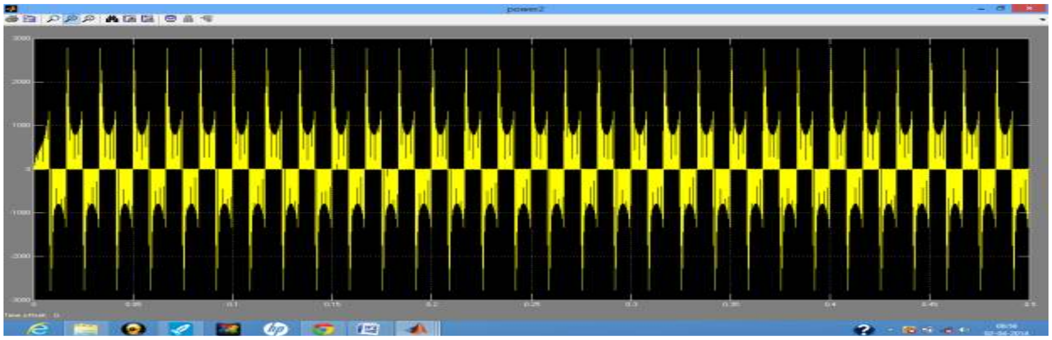


Fig. 21: Waveform of the output voltage and current without harmonics

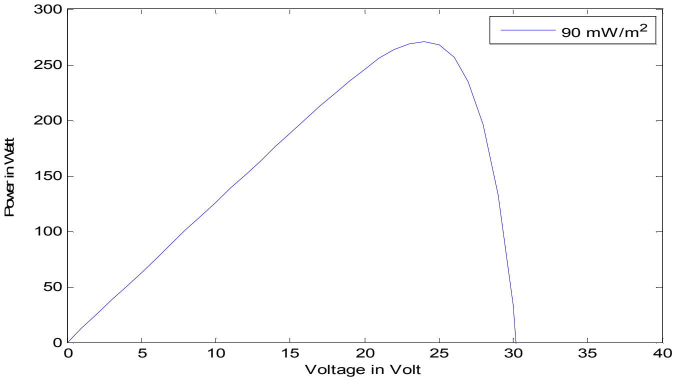


Fig. 22: I-V curve with PV array system (case-1)

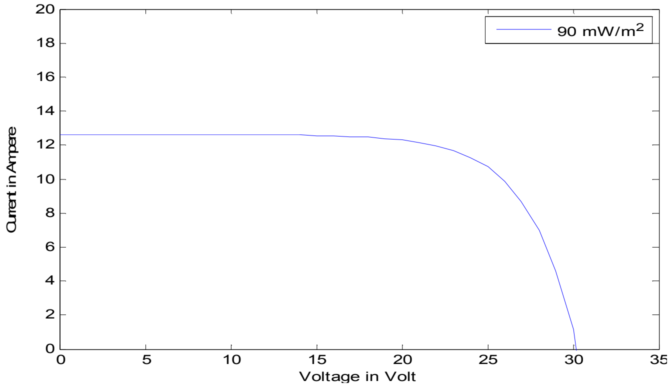


Fig. 23: I-V curve with PV array system (case-2)

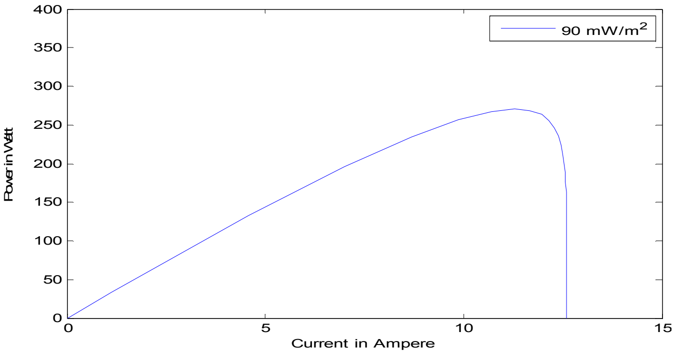


Fig. 24: I-V curve with PV array system (case-3)

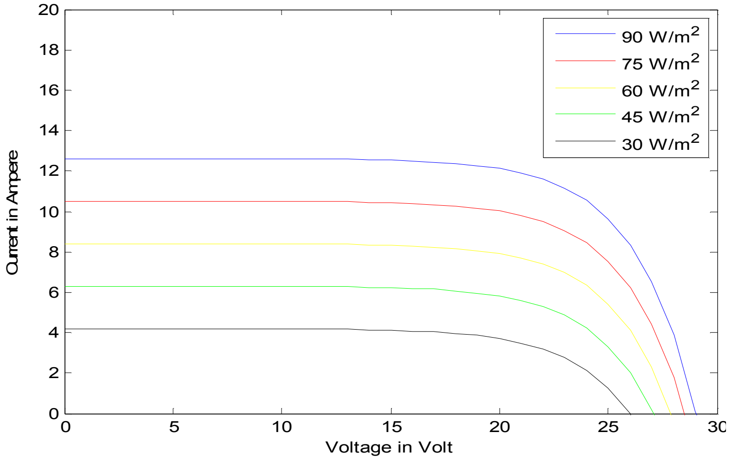


Fig. 25: I-V characteristic of a solar array for a fixed temperature

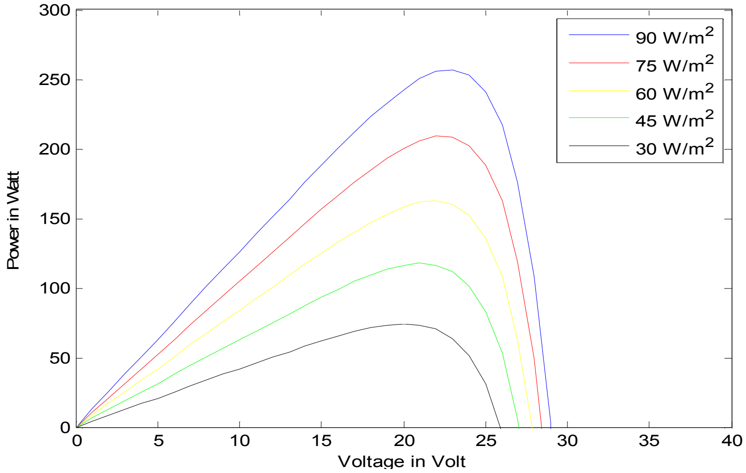


Fig. 26: P-V characteristic of a solar array for a fixed temperature

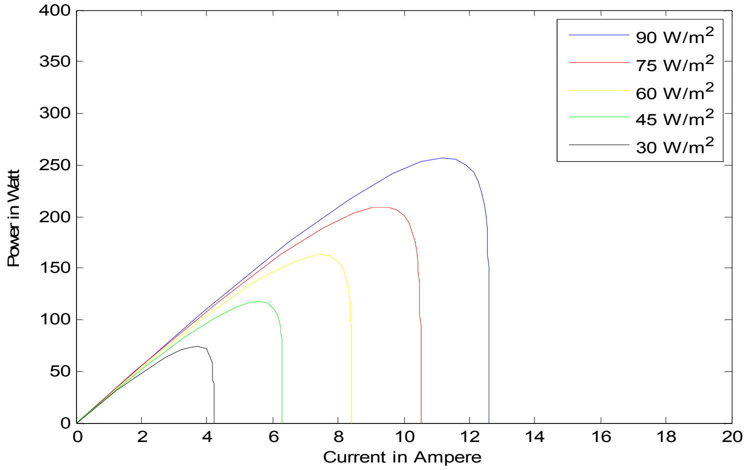


Fig. 27: P-I characteristic of a solar array for a fixed temperature

fixed temperature. Moreover, from the I-V and P-V curves at a fixed irradiance, it is observed that the open circuit voltage decreases with increase in temperature. The different waveforms are shown in the Fig. 22 to 24. The characteristic I-V curve tells that there are two regions in the curve: one is the current source region and another is the voltage source region. The operating model of the system is done and simulation results are obtained. PV system has to be studied to understand its source response; hence its I-V characteristics can be studied. The respective waveforms are as shown in the Fig. 25 to 27.

The MPPT method is applied and results are obtained. In the voltage source region (in the right side of the curve), the internal impedance is low and in the current source region (in the left side of the curve), the impedance is high. An important part is played by irradiance temperature for predicting I-V characteristics and for designing PV system effects of both factors have to be considered. Whereas the irradiance affects the output, temperature mainly affects the terminal voltage.

## CONCLUSION

This study has presented a novel control of an existing grid interfacing inverter to improve the quality of power at PCC for a 3-phase 4-wire DG system. It has been shown that the grid- interfacing inverter can be effectively utilized for power conditioning without affecting its normal operation of real power transfer. The grid-interfacing inverter with the proposed approach can be utilized to inject real power generated from RES to the grid and operate as a shunt Active Power Filter (APF). This approach thus eliminates the need for additional power conditioning equipment to improve the quality of power at PCC. This study has provided a brief summary of solar PV systems and power quality issues in grid connected power system. This study has also presents a summary of converts and inverters in solar power system and its power quality issues.

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