Power Electronic Interface for Distributed System

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Abstract— **Now a days effectiveness of Distributed Energy (DE) systems is rising, integration with Distributed Systems to electric power systems is very significant. A grid-connected solar photovoltaic system is depicted in this paper. The Circuit contains DC-DC B₀₀st converter and inverter to convert DC-AC since the grid voltage is AC. To adjust output voltage of Boost converter, DC-AC inverter (Voltage Source Converter) is used and this connects PV Array to Grid. This project would mainly concern on the PV array modeling and connection with grid and with the DC-DC Boost converter. Simulation results are shown in graphical waveforms and are performed in MATLAB using SIMULINK. MPPT algorithm can be implemented with the existing Photovoltaic and DC-DC converter and also with the inverter.**

Index Terms—**DC-DC, Boost converter, Inverter, MPPT, Inverter.**

I. INTRODUCTION

Distributed Energy(DE) systems are energy systems that are to be found at near the point of use. Distributed energy (DE) systems are well known as Distributed Generation (DG), Distributed energy (DE) refers to storage technologies or small electricity generating systems that are positioned to close to load. To convert power generated from distributed energy systems to useful power all DE technologies requires power electronics, that can be directly allied to a grid. Power electronic interface receive power from the distributed energy source and converts power at necessary voltage and frequency. In this paper, type of distributed energy system used is the photovoltaic system. Due to improved computerization, now we are all deeply depending on electrical energy. At times conventional energy sources are not competent to meet the peak load requirement and since the fossil fuels are deteriorating at the instance. So certainly we have to seem to be for the alternate sources of energy. It is compulsory to pay concentration towards non-conventional energy sources because of limitations of environmental issues and fossil fuels. Solar energy is the one of the Renewable energy source that is essential sustainable energy source as it is the unlimited source of energy. One of the most important renewable energy sources to produce electrical power is solar electric or photovoltaic technology and solar power is the fastest power generation in the world.

II. SYSTEM DESCRIPTION

The Grid-connected photovoltaic system with two-stage conversion is shown in below figure. This scheme mainly consists of dc-dc boost converter, PV array, dc-ac inverter. PV array converts sunlight into dc power and output of PV array is given to Boost converter, dc-dc Boost converter is used to boost up the PV array voltage to higher level dc voltage and inverter is used to convert dc-ac power. The generated ac power is inserted into grid
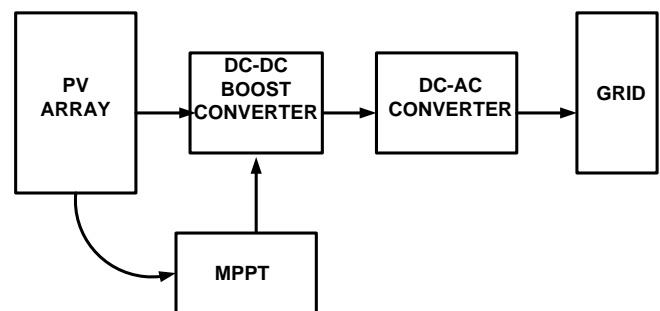

Fig.1. Basic structure of grid-connected PV system.

III. TYPES OF DISTRIBUTED ENERGY SYSTEMS

Distributed Energy systems can be motorized either by renewable or fossil fuels. Most familiar types of distributed energy systems are briefly described in this section[1].

1. Photovoltaic systems
2. Fuel cells
3. Microturbines
4. Wind systems
5. Energy storage systems
6. Gas turbines

In this paper the type of distributed system used is PHOTOVOLTAIC SYSTEM

1. PhotoVoltaic systems

Function of PV systems is to transfer solar energy into electrical energy. PV modules generate dc power. similar to fuel cells, the dc power is then transformed into ac using inverter since ac power is well-matched with the grid.

IV. INTERCONNECTION REQUIREMENTS FOR DIFFERENT GENERATOR TYPES

The output of Distributed Energy systems can be connected to the grid by means of three basic interconnection interfaces.

 1. Induction Generator
 2. Synchronous Generator
 3. Inverter-based systems (Power Electronics)

1. INDUCTION GENERATOR

Induction generators are used for some wind turbines. Before interconnecting to a grid induction generator need not be synchronized with the grid. A soft starter is used to tie induction generator to the grid and this soft starter will limit high inrush currents. To induce currents and generate a magnetic field in the generator's rotor. Induction generators require reactive power from the grid or from capacitors. Thus induction generators cannot produce electricity without a peripheral source of current. Capacitors located near induction generator reduce the reactive load on the grid.

2. SYNCHRONOUS GENERATOR

To connect Synchronous generator to a grid, the Synchronous generator output voltage must be synchronized with the grid voltage before relating to grid. The waveforms of grid frequency and generator frequency must be in phase and their frequency must be same. If they are not matched large currents will run and the generator will be rigorously damaged. Synchronization is needed for the protective relays and the equipment essential for interconnection of a synchronous generator are to some extent more difficult than for an induction generator.

3. INVERTER

Inverters are power electronic devices that change DC power to AC power. Since solar PV modules produce DC, inverters are an important module of these systems. There are two basic types of inverters:

 i.   Grid-interactive(grid-tie)
 ii.   Standalone(or off-grid)

In grid interactive inverters, the grid controls equally frequency and voltage. These inverters are designed to export power to the grid, grid interactive inverter requires exporting power to the utility grid. Though, most grid-tie inverters cannot function without a grid connection.

A stand-alone inverter regulates its own frequency and voltage and can function without a grid connection. some standalone inverters let the grid to be used as a backup for the renewable generation.
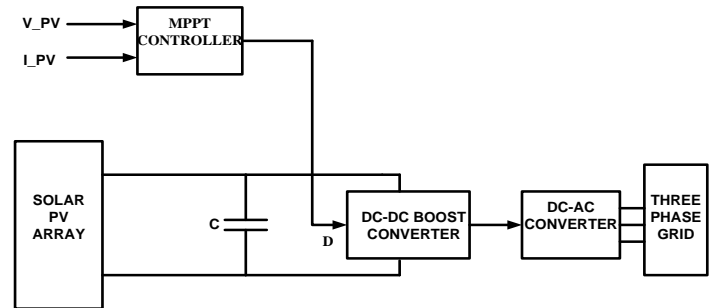
V. SCHEMATIC REPRESENTATION

Fig.2. Schematic representation.

SYSTEM DESCRIPTION

a) PV ARRAY

A photovoltaic device is a non-linear device. To study the photovoltaic system in distributed generation system, a modelling and circuit model of the PV array is important. PV cell parameters mostly depend on temperature and sunlight. The photovoltaic cell transfers the solar power into electrical energy[2]. Based on photovoltaic cells and based on how the cells are connected either parallel or series, the model of the photovoltaic array is obtained. A PV cell is semiconductor diode with a p-n junction. The material used in PV module is monocrystalline and polycrystalline silicon cells. The equivalent circuit of a photovoltaic cell with internal resistance and diode is shown in figure below. The effects of parallel and series resistance of the PV have to include in a real photovoltaic device.
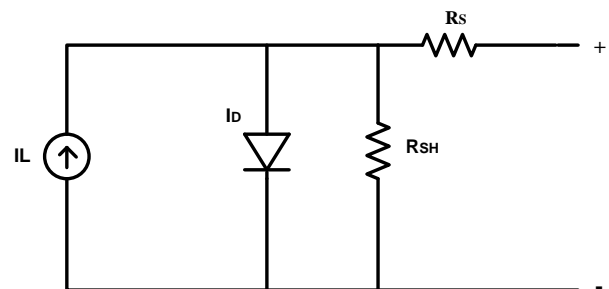

Fig.3. Equivalent circuit diagram of solar PV cell

Below equation describes the I-V characteristics of PV module,

$$I = IL - Io\left(e^{\dfrac{q(V + IRs)}{KT}} - 1\right) - \dfrac{V + IRs}{Rsh}$$

Above specified equation is bounded only to a single diode model. where the ideality factor (n) is equivalent to unity. If a two-diode model is used. This factor ranges from 1-2. In given equation Io is the diode saturation, the current formed where there is no light. It is thermally generated. Diode saturation current is too called as temperature dependent. Therefore by

changing the temperature in Kelvin(T), the overall current(I) would vary. If temperature increases the current reduces.

b. BOOST CONVERTER

By means of diode and MOSFET/IGBT, B00st converter is used in the projected system. In boost converter the average inductor current is more than the average output current. When the switch i.e MOSFET/IGBT is ON, the current starts increasing through the inductor and the inductor starts to store energy. When MOSFET/IGBT is OFF, the energy which is stored in the inductor will starts to dissipate. The current will starts flowing from the voltage source and the inductor and through the diode D to the load. As a result the average voltage across the load is superior than the input voltage and is determined with help of the duty cycle of the gate pulse of switch. Boost converter used in this work is shown in the following figure. Boost converter is used to boost up the PV cell output voltage to a higher level. Figure below shows the boost converter circuit. The boost converter can function in two modes i.e continuous conduction mode and discontinuous conduction mode. The output voltage is dependent on the duty cycle D. Following equation represents the relation between output voltage and input voltage as a function of duty cycle is given by,

$$\frac{Vo}{Vt} = \frac{Ts}{Toff} = \frac{1}{1-D}$$

Where,

Vo= average output voltage
Vi = input voltage
Ts= switching period
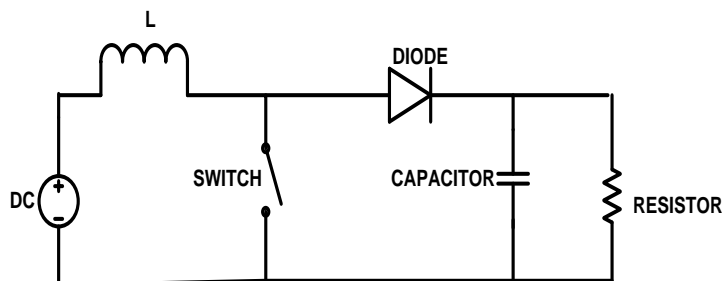D= Duty cycle
Toff= switching off of the IGBT

Fig.4. Boost converter for PV

Always input voltage is less than the output voltage in Boost converter. Figure 4 shows the schematic diagram of Boost converter. In this model, dc-dc B0ost converter is used to increase the dc voltage which is carried by the PV array. MPPT controller is merged in the boost converter, the MPPT controller will mechanically varies the duty cycle to produce the voltage that is required to extract the maximum power.

b)   P & O MPPT TECHNIQUE

At any given time, the solar PV system has to be merged with a Maximum Power Point Tracker(MPPT) to pull out maximum power generated by the solar cell. To operate Photovoltaic system at maximum output power MPPT is used. Thereby maximizing the array efficiency[4][5]. The MPPT techn0l0gy is usually applied in the DC-DC converter, but in modern times MPPT method also be used in DC-AC inverters because of technological advancements. Even though a number of MPPT techniques are accessible, perturb and observe technology is the most frequently practiced technique. So P&O technique is used in our present study. To track maximum power there are many number of algorithms that are available. Some are simple, for example, those which are based on current and voltage feedback, and some are complex such as perturbation and observation (P&O) or the incremental conductance method. At a given temperature and irradiance PV array delivers maximum power, P&O method is used.
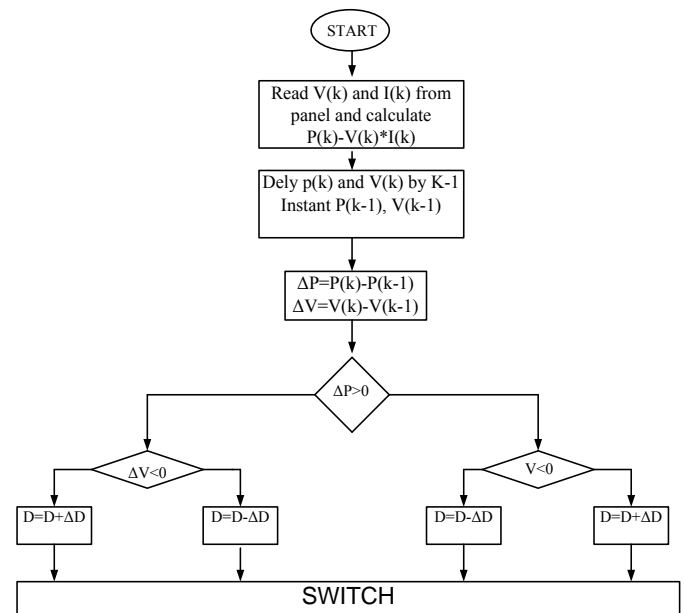

Fig.5. Flowchart of Perturb and observe algorithm

In P&O method, the MPPT algorithm depends on the calculation of the PV output power and the power change by both the PV array current and PV array voltage. The maximum power point tracker operates by at regular intervals increasing or decreasing the solar array voltage. If a perturbation leads to an increase in the output power of the PV, is then generated in the same direction. If perturbation decreases the output power then generated is in opposite direction. This process is repeated by altering duty cycle of boost converter until maximum power is reached. The PV array would exhibit different characteristic curves. For different values of irradiance and cell temperature. Each curve has its maximum power point, this is the point, where the consequent maximum voltage is delivered to the converter
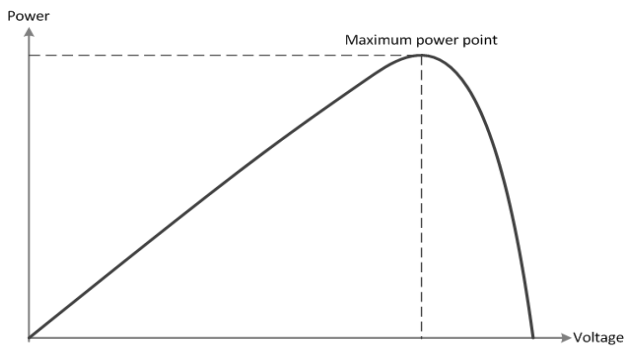
Fig.6. maximum power of PV array

Name of PV model	Sun power SPR-305E-WHT-D
Number of series modules connected per string	5
Open circuit voltage	64.2
Short circuit Current	5.96
Maximum power voltage(Vmp)	54.7
Maximum power current(Imp)	5.58

Table-1.Specifications of Solar PV array

d) VOLTAGE SOURCE CONVERTER

The output of PV modules is direct current(DC) and DC voltage. Alternating currents AC and AC voltage are needed to provide electricity to the grid. To convert dc into ac Inverters are used. The Voltage Source Converter transfers the DC link voltages to AC and keeps power factor at unity.

Sinusoidal Pulse Width Modulation procedure is used to control the voltage source inverter by generating the gating signals for semiconductor switches. This procedure is used to acquire 3-φ output voltages that can be controlled in magnitude and frequency.

VI. SIMULATION RESULTS AND DISCUSSION

PV array of 100KW is connected to 25KV grid by using Boost converter and 3-φ Voltage Source Converter. Using Perturb and Observer technique MPPT is merged in boost converter by Simulink. The proposed model contains PV array[2][7]. PV array produces maximum of 100KW at sun irradiance of 1000W/m2. Boost converter is used to boost up the voltage output to 500V DC. 3-φ Voltage source converter is used to convert the DC voltage delivered by the array i.e 500V to an AC voltage. Capacitor banks of 20KVAR used to filter the harmonics generated by voltage source converter.

The efficiency of solar PV cell is calculated by using following formula, knowing the efficiency of panel is important in order to choose correct panels of photovoltaic system.

$$ɳ_{max} = \frac{P_{max}}{incident\ radiation*area}$$

$$= \frac{305.226}{1000*2.79}$$

$$= 0.1094*100 = 11\%$$

Therefore efficiency of Solar cell obtained is 11%.

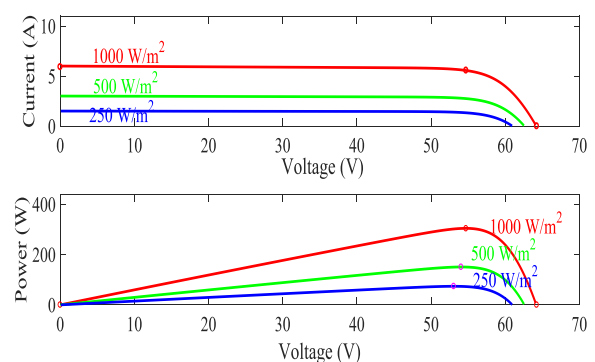Simulation starts with conditions at temperature 25ºC and irradiance of 1000W/m2

Fig.7. MPPT at different irradiation levels

From time(t) = 0 seconds to t = 0.05seconds, boost converter pulses and VSC inverter are choked-up.

Thus PV array voltage is given as,

Number of panels connected in series*open circuit voltage = 5*64.2=321 V

At this instant VSC inverter operates as a diode rectifier and DC capacitors charges nearly 500V as shown in figure 8,

At time t=0.05sec, b00st c0nverter and V0ltage S0urce Converter inverter are unblocked. DC voltage is set to 5OOV(Figure-8)

Dutycycle of PV array at irradiance=1000W/m2 and temperature=25 ºC is 0.5,as given in Figure 9.

Voltage generated by PV array at this instant is,

Vpv=(1-D)*Vd

=(1-0.5)*500

=250V, as shown in figure 8

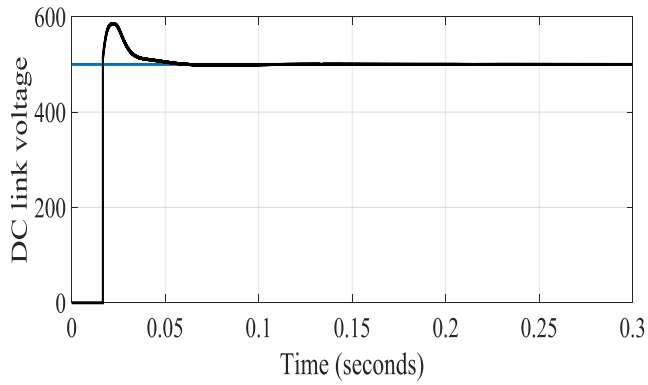Power generated by PV array is of order 97kilowatts as shown in figure 11.

Fig.8. DC link voltage

Fig.9. Duty ratio
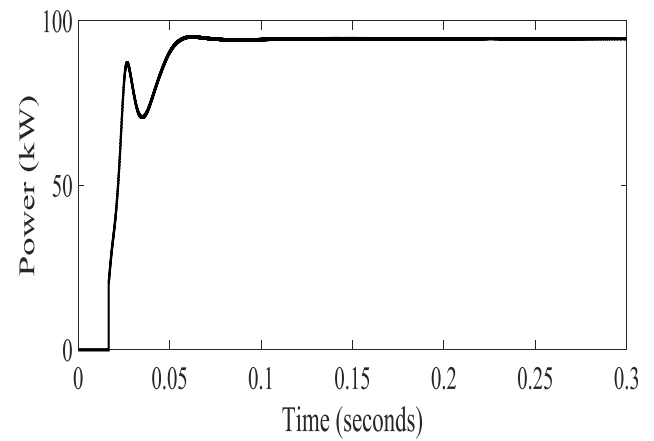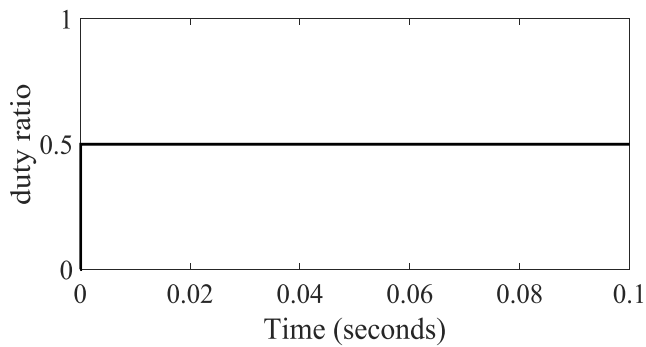
Fig.10. Voltage produced by PV array

Fig.11. Power produced by PV array
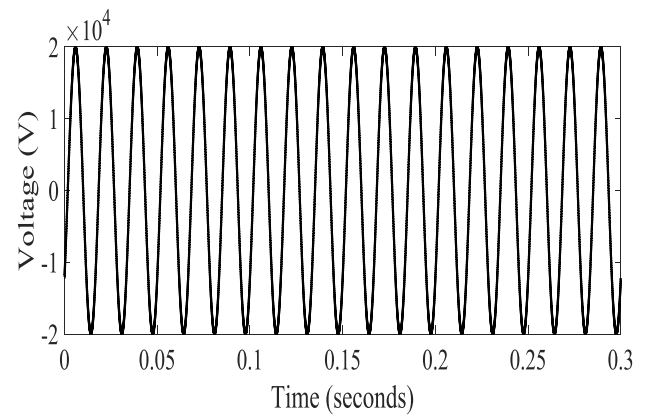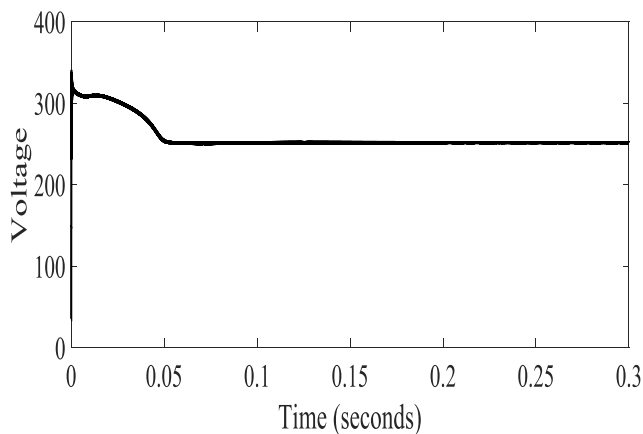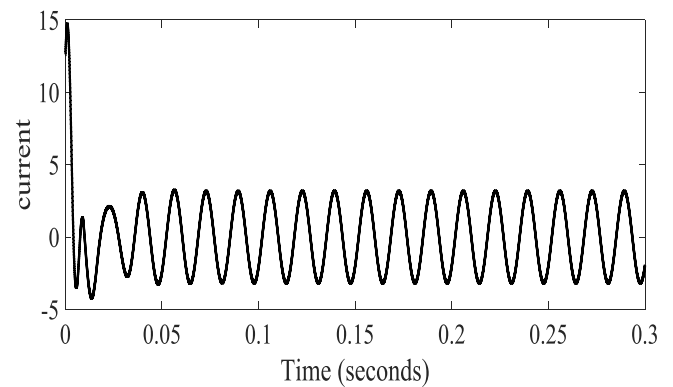
Fig.12. Voltage injected into grid

Fig.13. Current injected into grid

Harmonics in expressions of Total Harmonic Distortion (THD) in a given signal can be considered by following formula,

$$\text{THD} = \frac{\sqrt{\sum_{n=2}^{N/2} V_h}}{V_1}$$

Where,

h =Harmonic order,

N =quantity of samples per period

N/2 = Maximum harmonic order
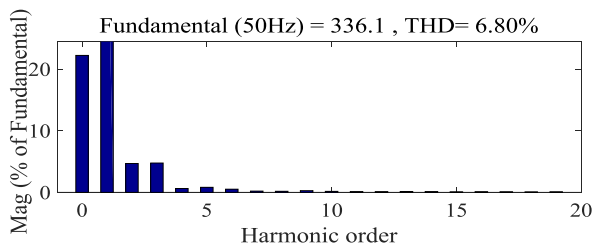
For calculating THD, FFT analysis tool of matlab is used.
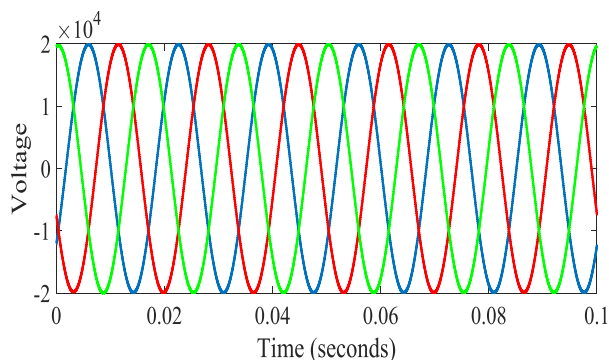

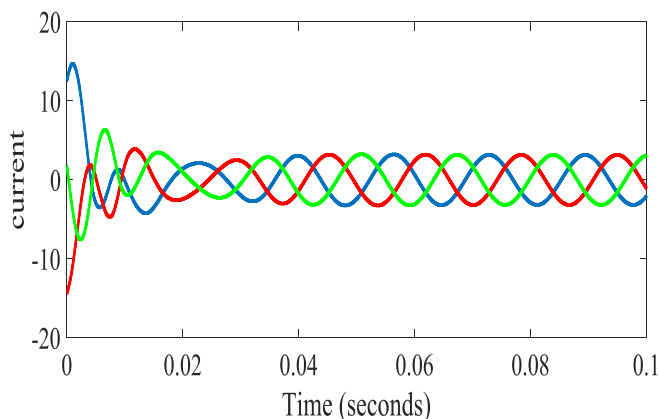Fig.14. Harmonic spectrum of Grid Voltage

Fig.15. Three phase voltages

Fig.16. Three phase currents

CONCLUSION

The design of 3Ø grid-connected photovoltaic array has been discussed in this paper. The common power electronics used in this process are DC-DC Boost converter, MPPT, three phase VSC. Boost converter controls the solar PV array to obtain maximum power with the help of MPPT. The grid required AC supply, but boost converter obtains the maximum DC output power. To achieve DC-AC power an inverter is used. In the proposed design, an MPPT algorithm using a boost converter is designed to operate using P&O method to control the boost converter, which is adapted to the maximum power tracking in PV system. DC–DC boost converter is used to b00st up the voltage from natural voltage to DC, which is then transformed three phase AC voltage by the inverter.
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