DESIGN AND SIMULATION OF GRID CONNECTED PV SYSTEM USING MPPT

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Abstract: As Conventional sources of energy are rapidly depleting and the cost of energy is rising, photovoltaic energy becomes a promising alternative source. Among its advantages are that it is abundant; pollution free; distributed throughout the earth; and clean and noise-free source of electricity. The main drawbacks are that the initial installation cost is considerably high and the energy conversion efficiency is relatively low. To overcome these problems, the following two essential ways can be used, increase the efficiency of conversion for the solar array and maximize the output power from the solar array Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. MPPT is not a mechanical tracking system that "physically moves" the modules to make them point more directly at the sun. MPPT is a fully electronic system that varies the electrical operating point of the modules so that the modules are able to deliver maximum available power. Even though there are many methods of MPPT techniques, here we use perturb and observe (P&O) type of MPPT. In extension to this the proposed system with MPPT is connected to grid system.

Index Terms—Modeling, Photovoltaic Cell, MPPT, DC-DC Converters, Simulation, MATLAB/ Simulink.

1. INTRODUCTION

PV energy is the most important energy resource since it is clean, pollution free, and inexhaustible. Due to rapid growth in the semiconductor and power electronics techniques, PV energy is of increasing interest in electrical power applications. The most important aspect of a solar cell is that it generates solar energy directly to electrical energy through the solar PV module, made up of silicon cells. Although each cell outputs a relatively low voltage (≈ 0.7V under open circuit condition), if many cells are connected in series, a solar PV module is formed. Although the price for such cells is decreasing, making use of a solar cell module still requires substantial financial investment. Thus, to make a PV module useful, it is necessary to extract as much energy as possible from such a system. Photovoltaic (PV) solar panels exhibit non-linear current–voltage characteristics. But It is important to operate PV energy conversion systems near the maximum power point to increase the output efficiency of PV arrays. Also we know that according to maximum power transfer theory it can transfer maximum power only at particular point namely when source impedance matches the load impedance and this match cannot be granted spontaneously ,further more maximum power point changes with temperature and light intensity variation . Therefore many algorithms have been developed to provide maximum power. Evaluating the performance of these algorithms for various PV systems operating under highly dynamic environment conditions are essential to ensure a reliable, efficient, cost effective and high performance system. In this paper MPPT based P&O algorithm is used.

A DC/DC Boost Converter is used which will boost the output voltage of PV system. This DC/DC boost converter is responsible for transferring maximum power from solar PV module to load .This it important to operate a PV array under constant voltage and power ,As we know that in order to get maximum power generally according to maximum power transform theory , when the source impedance matches with load impedance then only the maximum power can be able to transfer from source to load and hence under varying environment conditions this match of source and load impedance is to be done with the help of DC/DC converter by changing the Duty cycle of DC/DC boost converter with the help of P&O algorithm. In this our aim is to address the use of simulation in order to evaluate the performance of MPPT based PV system and synchronization of PV system to grid in case of access power is available with PV system . During night time the battery tank will feed the power to the load. or we can say that when grid is under loaded condition then if the PV system is having more power than the demanded power at that time in order to reduce the stresses on grid the excess power will be feeded to grid so that collapse of frequency is to be prevented.

This paper is divided into six sections this section presents the main theme of this paper. Section II Modeling and characteristics of PV system. Section III Control algorithm for MPPT .Section IV presents the DC/DC Boost converter. Section-V presents Proposed block system . Section VI present the simulation results of grid connected system.

2. MODELLING AND CHARACTERISTICS OF PV SYSTEM

A. PHYSICAL STRUCTURE OF PV CELL

A photovoltaic cell is basically a semiconductor diode whose p–n junction is exposed to light. Photovoltaic cells are made of several types of semiconductors using different manufacturing processes. The monocrystalline and polycrystalline silicon cells are the only found at commercial scale at the present time. Silicon PV cells are composed of a thin layer of bulk Si or a thin Si film connected to electric terminals. One of the sides of the Si layer is doped to form the p–n junction. A thin metallic grid is placed on the Sun-facing surface of the semiconductor. Fig. 1 roughly illustrates the physical structure of a PV cell. The incidence of light on the cell generates charge carriers that originate an electric current if the cell is short circuited. Charges are generated when the energy of the incident photon is sufficient to detach the covalent electrons of the semiconductor—this phenomenon depends on the Semiconductor material and on the wavelength of the incident light. Basically, the PV phenomenon may be described as the absorption of solar radiation, the generation and transport of free carriers at the p–n junction, and the collection of these electric charges at the terminals of the PV device.

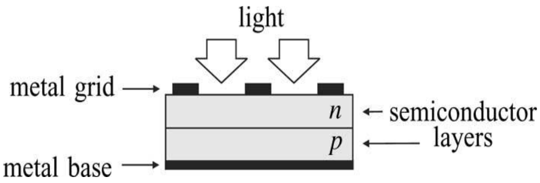

Fig. 1. Physical structure of a PV cell

B. MODELLING OF PV SYSTEM:

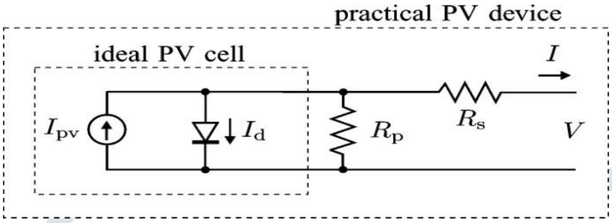

Fig. 2. Single-diode model of the theoretical PV cell and equivalent circuit of a practical PV device including the series and parallel resistances.

$$I = I_{PV\ CELL} - I_{DIODE} \ldots\ldots\ldots\ldots\ldots(1$$

$$= I_{PV\ CELL} - I_{OCELL}\left[EXP((Q*V)/\alpha*K*T)-1 \ldots 2\right.$$

Where:

- PV,cell is the current generated by the incident light .
- Idiode is the Shockley diode equation.
- I0,cell [A] is the reverse saturation or leakage current of the diode [A].
- q is the electron charge [1.60217646 · 10-19C].
- k is the Boltzmann constant [1.3806503 · 10-23J/K].
- T [K] is the temperature of the p-n junction.
- α is the diode ideality constant which lies between 1 and 2 for monocrystalline silicon.

C. CHARACTERISTICS OF THE PV CELL

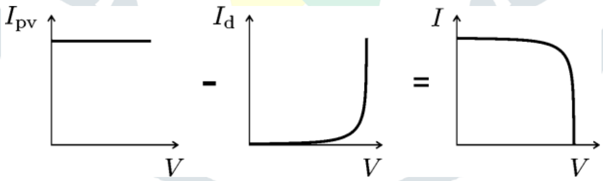

Fig 3. Characteristic I–V curve of the PV cell. The net cell current I is composed of the light-generated current Ipv and the diode current Id .

$$I = I_{pv} - I_d \ldots\ldots(3$$

For ideal pv cell Rs and Rp =0

D. SIMULINK MODEL OF SOLAR PV MODULE:

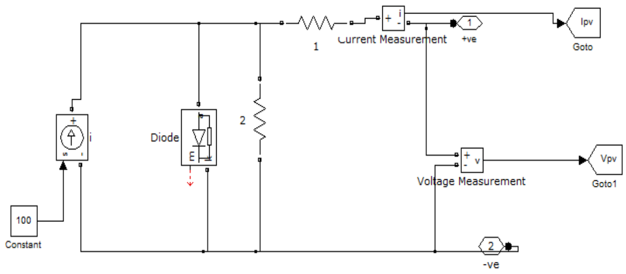

Fig.4: Simulink model of solar pv module

TABLE-I: SPECIFICATION OF PV SYSTEM

Input voltage	100v
Input current	2 A
Input power	200w
Iscr	4.75
Np	4
Ns	72
Vg	1.12
Diode ideality factor	1.62

E. SIMULATION OUTPUT VOLTAGE OF PV SYSTEM:

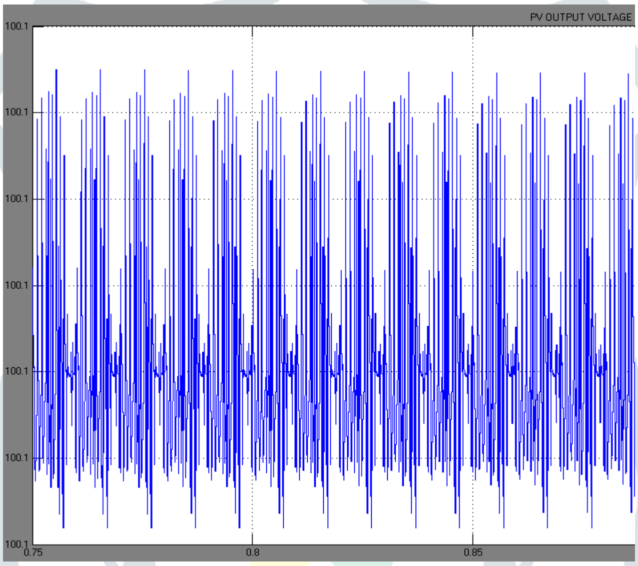

Fig 5. Shows output voltage waveform of pv system

3. CONTROL ALGORITHM FOR MPPT:

A. PERTURBE AND OBSERVE (P&O):

P&O algorithm is widely used in MPPT because of their simple structure and high reliability. They operate by periodically perturbing & incrementing & decrementing the array terminal voltage and comparing the PV output power with that of the previous perturbation cycle. If the power is increasing, the perturbation will continue in the same direction in the next cycle, otherwise the perturbation direction will be reversed. This means the array terminal voltage is perturbed for every MPPT cycle.

Therefore, when the optimum power is reached, the P&O algorithm will oscillate around it, resulting in a loss of PV power, especially in cases of constant or slowly varying atmospheric conditions. The flow chart of the implemented algorithm is shown in Figure. The algorithm reads the value of current and voltage from the solar PV module. Power is calculated from the measured voltage and current. The value of voltage and power at k_{th} instant are stored. Then next values at (k+1)th instant are measured again and power is calculated from the measured values. The power and voltage at (k+1)th instant are subtracted with the values from kth instant. In the power voltage curve of the solar pv module, it is inferred that in the right hand side curve where the voltage is almost constant and the slope of power voltage is negative (dP/dV<0) where as in the left hand side, the slope is positive.(dP/dV>0).Therefore the right side of the curve is for the lower duty cycle(nearer to zero) where as the left side curve is for the higher duty cycle(nearer to unity).Depending on the sign of dP(P(k+1) - P(k)) and dV(V(k+1) -V(k)) after subtraction the algorithm decides whether to increase the duty cycle or to reduce the duty cycle.

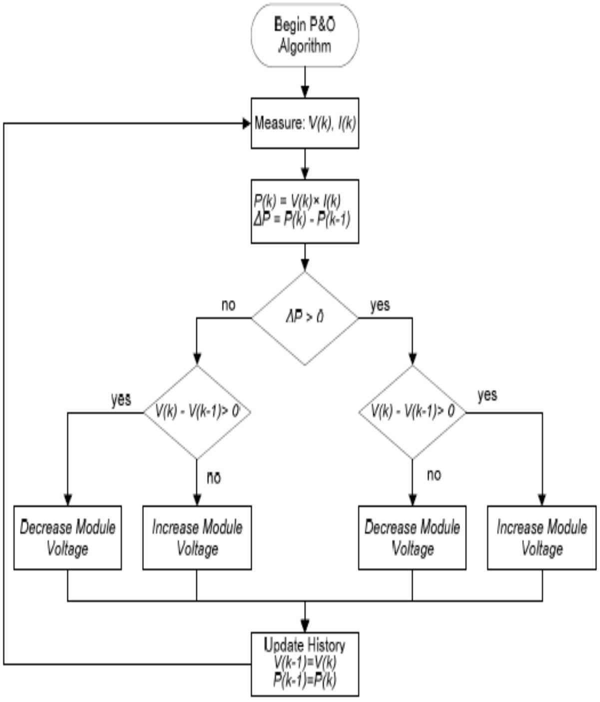

Fig 6. Perturb and Observe Algorithm

B. PV CHARACTERSTICS OF MPPT BASED PV SYSTEM USING P&O ALGORITHM

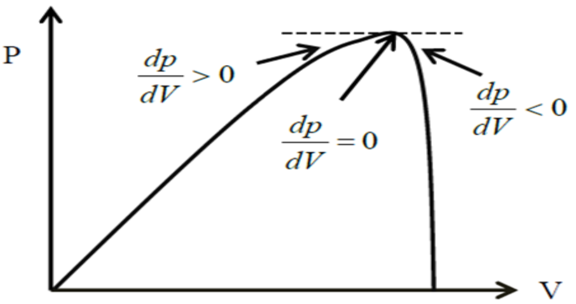

Fig 7: shows PV characterstics using MPPT

a . I and V curve without MPPT:

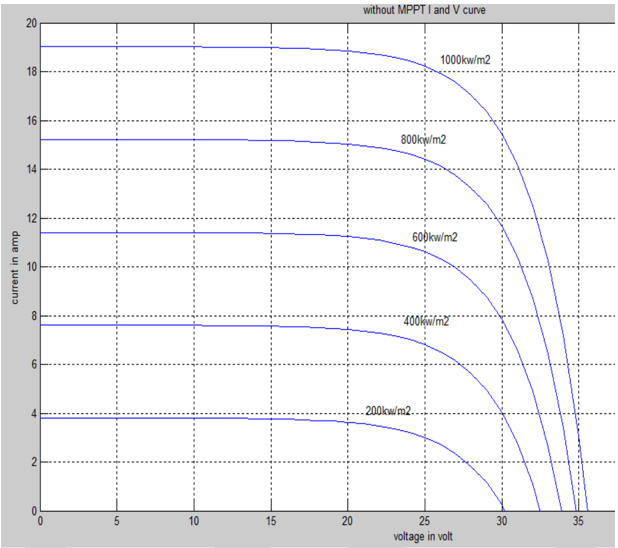

Fig8: shows V-I curve with different solar insolation and constant temperature 25deg cel.

b. P-V curve with MPPT:

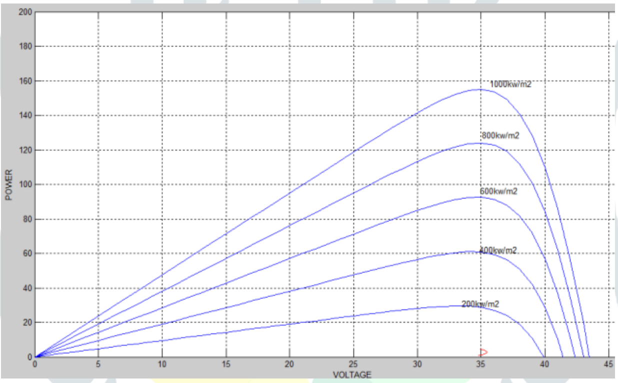

Fig9: shows p-v curve with different solar insolation and constant temperature 25deg cel

c. I-V curve with constant insolation and different temperature:

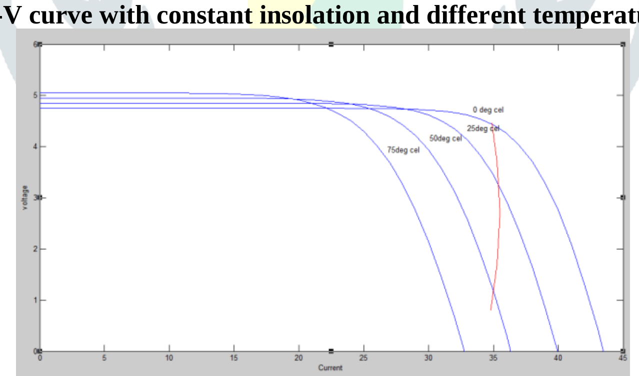

Fig. 10: I-V curve for different temperature and constant insolation .

d . I and V curve with MPPT

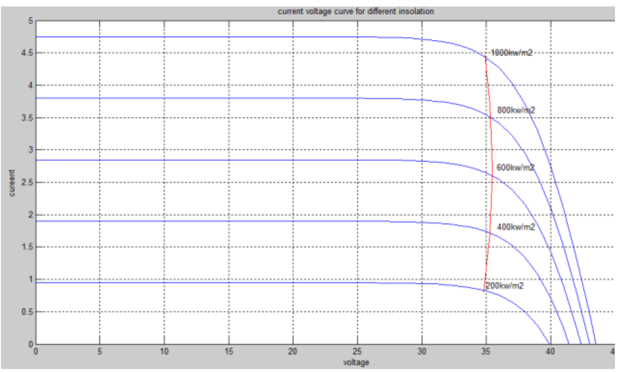

Fig11: shows V-I curve with different solar insolation and constant temperature 25deg cel

4. DC TO DC BOOST CONVERER:

A .Boost Converter Design

A simple boost converter consists of an inductor, a switch, a diode, and a capacitor as shown in Fig. 12. Boost converter circuit can be divided into two modes . Mode 1 begins when the switch SW is turned on at t = Ton as shown in Fig. 13. The input current which rises flows through inductor L and switch SW. During this mode, energy is stored in the inductor. Mode 2 begins when the switch is turned off at t = Toff. The current that was flowing through the switch would now flow through inductor L, diode D, capacitor C, and load R as shown in Fig.12. The inductor current falls until the switch is turned on again in the next cycle. Energy stored in the inductor is then transferred to the load. Therefore, the output voltage is greater than the input voltage and is expressed as in equation 4

$$V_{out} = \frac{1}{(1-D)} * V_{in} \quad (4)$$

Where V_{out} is the output voltage, *D* is duty cycle, and Vin is input voltage which in this case will be the solar panel voltage.

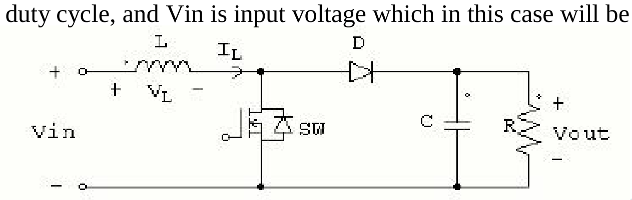

Fig 12 : boost converter

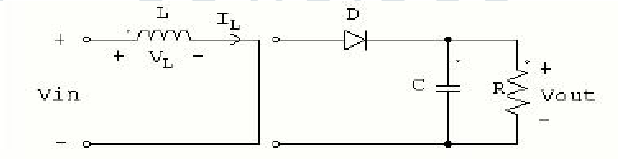

Fig 13: mode 1 operation

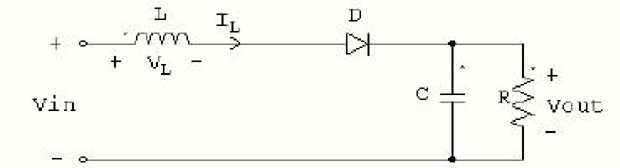

Fig 14 :model- 2 operation

In order to operate the converter in continuous conduction mode (CCM), the inductance is calculated such that the inductor current IL flows continuously and never falls to zero as shown in Fig. 15. Thus, L is given by equation 5

$$L_{min} = \frac{(1-D)^2 * D * R}{2 * f} \quad (5)$$

Where Lmin is the minimum inductance, D is duty cycle, R is output resistance, and f is the switching frequency of switch SW. The output capacitance to give the desired output voltage ripple is given by equation 6:

$$C_{min} = \frac{D}{R * f * V_r} \quad (6)$$

Where Cmin is the minimum capacitance, D is duty cycle, R is output resistance, f is switching frequency of switch SW, and Vr is output output voltage ripple factor. Vr can be expressed as equation 7:

$$V_r = \frac{\Delta V_{out}}{V_{out}} \quad (7)$$

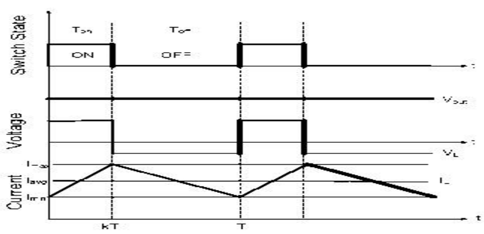

Fig. 15. Switch State, Vout, VL and IL.

5. PROPOSED SYSTEM:

A. PROPOSED SYSTEM CONFIGURATION:

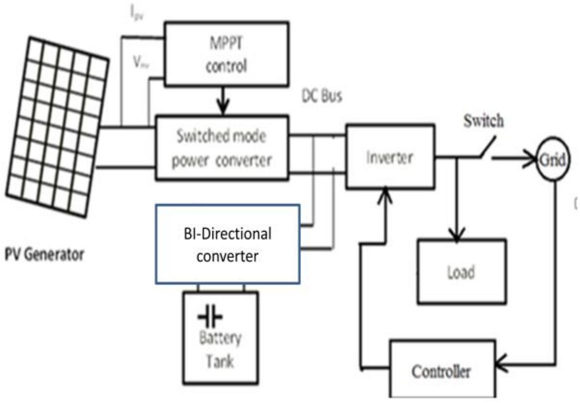

Fig 16 : grid connected pv system

In this paper we are using bi-directional DC to DC converter which will perform the operation of buck and and boost converter i.e it will perform buck operation when power supply is supplied by pv system into battery. And vice-versa that is when the power flow from battery bank to load .

B. SYNCHRONIZATION OF PV GENERATED POWER WITH GRID POWER:

Whenever there is excess power generated in PV system that is when the local demand is less then with the help of MPPT the maximum available power with PV system can be extracted and supplied to grid in order to reduce the stress on grid during overloaded condition. But before supplying the power to the grid the PV system power is to be synchronized with the grid power , i.e parameters like frequency ,phase sequences should be same in other words voltage and current both should be in phase teach other. Thus the phase sequence of PV systems inverter output should be same as that of grid phase sequence.If there is any disturbance in grid during overloaded condition then the frequency ,current and voltage of both grid and pv system inverter output does not match with each other and thus the PV system is to be made isolated from grid via three phase breaker hence the system this system is know as islanded mode .so, by that time the system will only supply the power to local load and battery bank via DC-DC bi-directional converter. Thus the phase sequence and frequency of both grid system and pv system is to made same of current wave form. hence the three phase beaker is to be switched on and the power is supplied to grid therefore now the pv system is in grid connected mode .

6. SIMULATION RESULTS OF PROPOSED SYSTEM:

1. INVERTER BOOST OUTPUT WAVEFORM:

The boost inverter output voltage is 376.5 volts and is shown below

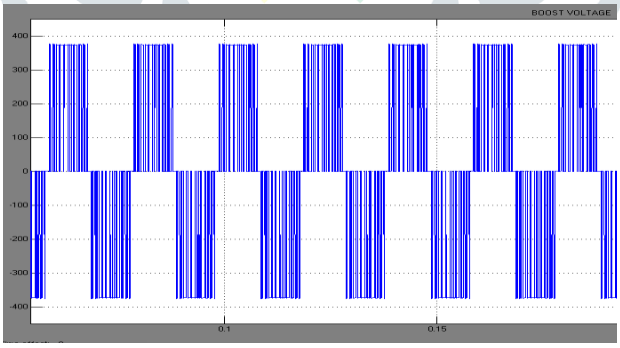

Fig. 17: shows boost output voltage.

2. SIMULATION RESULTS OF THREE PHASE GRID VOLTAGES DURING SYNCHRONIZATION:

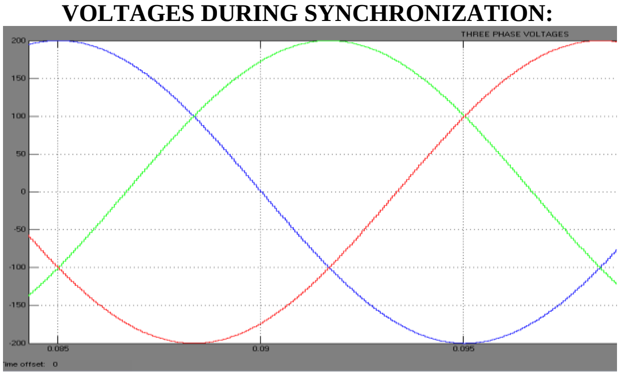

Fig.18 : shows three phase voltages of grid connected system

3. SIMULATION RESULTS OF THREE PHASE CURRENTS OF GRID:

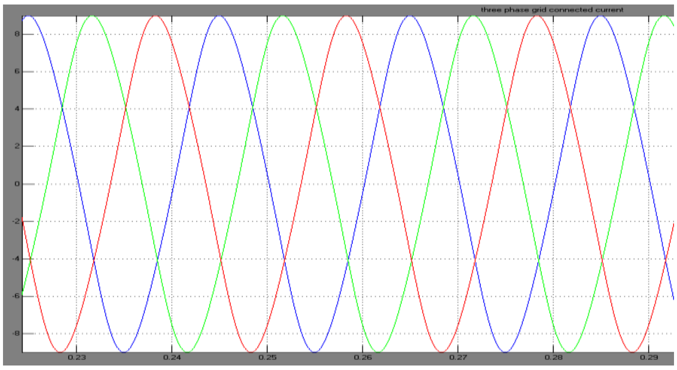

Fig.19: shows three phase grid currents during synchronization

4. SIMULATION OF SINGLE PHASE VOLTAGE AND CURRENT RESULTS DURING GRID CONNECTED MODE

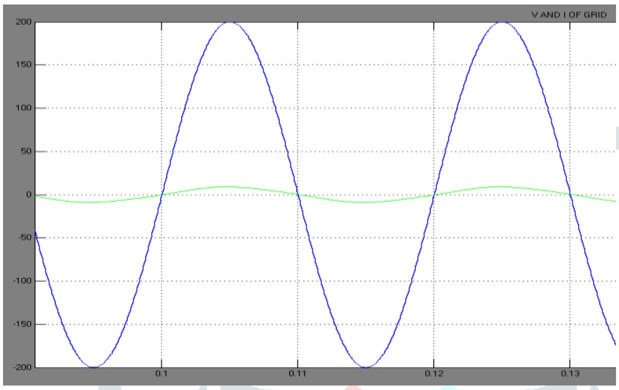

Fig. 20: shows 1-phase voltage and current phase during grid connected mode.

7. CONCLUSION:

The Grid connected pv system is modeled with MPPT under various climatic conditions that is variation in temperature, solar irradiance, isolation levels with P&O Algorithm . Thus with the help of MPPT Algorithm the maximum available power with pv system can be fed to grid. and also by using this system the dependence on non- renewable energy resource can reduced and clean and pollution free environment can be maintained Many other parameters can be modeled and investigated using the same model which all left for future research. This system is also applied to various other resources of energy.

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