SIMULATION OF GRID CONNECTED PHOTOVOLTAIC SYSTEM WITH MAXIMUM POWERPOINT TRACKING

A thesis submitted in partial fulfilment of the requirement for the degree of

Bachelor of Technology

in

Electrical Engineering

By

ABHISEK DASH (111EE0209)

DEPARTMENT OF ELECTRICAL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY

ROURKELA

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Under the guidance of

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CERTIFICATE

This is to for the certification that the work in this project report entitled "Simulation of grid connected photovoltaic system with maximum power point tracking" by ABHISEK DASH has been carried out under my supervision in partial fulfilment of the requirements for the degree of Bachelor of Technology in Electrical Engineering, National Institute of Technology, Rourkela and is a reliable and genuine work carried out by him under my supervision and guidance.

To the best of my knowledge, this work has not been submitted to any other university/institute for the award of any degree or diploma.

Place: Rourkela

Date: 10/05/2015

Prof. Sandip Ghosh

Department of Electrical Engineering

National Institute of Technology Rourkela, Orissa

769008

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Place: Rourkela

Date: 10/05/12015 **ABHISEK DASH**

(111EE0209)

ABSTRACT

Solar renewable energy harvesting is the demand of the century because of the huge energy requirement of the world today. India being a home to a huge population witnesses high Incident Solar radiations throughout the year. Planning has been made to produce at least 20 Gigawatts of high quality solar power by the year 2020. Energy harvested from the sun is a necessarily a valuable source but still most it part goes unutilised in Indian subcontinent although being a tropical region. The main obstacle for the wide usage of solar Photovoltaic systems is their efficiency which is very low (20-25% for single crystal 10-15% for polycrystalline and 3-5% for amorphous silicon solar cells [1]) and high cost of manufacturing. In main objective behind the work in this thesis lies in extracting maximum harvestable power from a Photovoltaic module and use the energy for a DC application as well as the grid connection of the generated power so that the surplus power unutilised in the load can be transferred to the grid. Maximum Power Point Tracking (MPPT), use of Boost converter and the importance of bridge inverter have been the main investigation in this project. Also the grid connection along with supply to a three phase load using bridge inverter and PWM has been shown. First SIMULINK software is used to model the photovoltaic cell. Then MPPT interfacing is done with a boost converter and resistive load and finally through an inverter connected to the 3 phase grid. All simulations have been done in SIMULINK software of MATLAB.

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Chapter 1

INTRODUCTION

1.1 The need for Renewable Energy

The various sources of renewable energy are tides, sunlight, rain, geothermal energy and wind. These resources can be naturally replenished and never go out of stock. Generally the prime source of energy these days come directly or indirectly from fossil fuels which are slowly getting exhausted from the earth storage unlike these renewable resources which are inexhaustible in nature. With time and development people around the world have been searching for nonconventional sources for long term fulfilment of their basic energy demand. With rapidly increasing population and growing consumption of fossil fuel the pollution caused to the environment also increases , hence there is a urgent need of Clean and Green Mechanisms which are now popularly adopted by nations throughout the world. The clean and no pollution consumption of these renewable energy is what attracted the current globe and hence a huge capital is investment is being done for harvesting these resources.

1.2 Solar power

The rising power demand of day to day life cannot only be maintained by using conventional energy recourses due to its unavailability. Along with conventional systems the demand for renewable sources has increased to meet the energy demand. Renewable sources like solar energy and wind energy are the prime energy sources which are being utilized in this regard. The continuous use of fossil fuels has drastically affected the environment depleting the biosphere and causing global warming.

Harvesting Solar energy is possible because of it's abundantly availability. Solar energy can be a standalone generating unit or can be a grid connected generating unit depending on the availability of a grid nearby. Since the availability of grid is very low at rural areas the use of renewable sources is maximum over there. Another importance of using solar energy is the portable operation, can be used everywhere as per the necessity.

The present energy crisis can be tackled by developing power efficiently and can be extracted from the incoming solar radiation. The power conversion techniques have been greatly reduced in the past few years. To withstand the high power demand the development in power electronics and material science has helped technicians to come up very brief but powerful systems. The increased power density is the major disadvantage of these systems. Trend has set in for the use of multi-input converter units that can effectively handle the voltage fluctuations. But due to high production cost and the low efficiency of these systems they can hardly compete in the competitive markets as a prime power generation source.

The constant increase in the development of the solar cells manufacturing technology would definitely make the use of these technologies possible on a wider basis than what the scenario is presently. The use of the newest power control mechanisms called the Maximum Power Point Tracking (MPPT) algorithms has led to the increase in the efficiency of operation of the solar modules and thus is effective in the field of utilization of renewable sources of energy.

The conversion of solar energy was originated by the British astronomer John Herschel who famously used a solar thermal collector box to cook food during an expedition to Africa. Solar energy has two major applications. Firstly, the captured heat can be used as solar thermal energy, with applications in space heating. Another alternative is the conversion of incident solar radiation to electrical energy, which is the most usable form of energy. This can be achieved with the help of solar PV cells or with concentrating solar power plants.

1.3 MOTIVATION

Photovoltaic power control is one of the modern research fields in these days. Researchers have given their best to develop better solar cell materials and efficient control mechanisms. The modern day challenge of the project and the latest technology study were the motivations behind the project.

1.4 OBJECTIVE

The primary focus will remain on the effect of Maximum Power Point Tracking and load matching and its successfully implement using the Simulink models.For obtaining the maximum power point operation, the modelling the PV module, boost converter, design of the discrete PWM generator and bridge inverter circuitry in Simulink and interfacing of these with the MPPT algorithm would be of prime importance of the work.

Chapter 2

LITERATURE REVIEW

While a solar panel has the capacity to convert only 30-40% of incident energy on it to useful electrical energy experiment show that the efficiencies of various types and makes of solar panel varies from 3%(amorphous grade silicon solar cells) to 25 % (single crystal silicon solar cells) [1][2]. Therefore in order to increase the power output of the PV system there is a need of various algorithms and tracking systems. There are different techniques for MPPT such as Hill climbing method (P&O), Fractional Short Circuit Current, Incremental conductance, Neural Network Control, Fractional Open Circuit Voltage, etc. The simplicity of implementation and short duration of operation makes Perturb and observe (P&O) and Incremental conductance algorithms popular .Economic factors also play a major role for using P&O because they are cheaper. Incremental Conductance has an advantage over P&O algorithm that is when there is an unusual change in weather or Insolation level ie when the Maximum power point changes in continuous basis P&O calculates the wrong value of MPP because it detects it as a perturbation change which is avoided to a large extent in IC method because two samples of voltage are taken. But, counterbalancing the higher efficiency factor of IC & its high complexity as compared to P&O boost the implementation cost by a visible margin. Complexity and efficiency has to be settled for a compromising balance. Another notable thing is that the type of converter used also affects the efficiency to a large extent. buck type topology staying at the top of the list, followed by buck-boost converter and boost topology residing at the lower end. While making the grid connection one has to also take care of the inverter and load requirement and the type of source connected to avoid losses and harmonics which may damage the PV system itself. Solar energy capture and harvest has been the topic of research since Einstein discovered the Photoelectric effect and won noble prize in physics 1905. The material he used in his experiment was primarily selenium coated with thin gold layer. But after that a lot of researchers have been putting together their nights and days for further technological improvement in the field solar energy worldwide. From silicon solar cells to gallium arsenide, Cadmium sulphide- Cadmium telluride have been used for manufacturing purpose. Apart from the hardware improvement researchers have also come up with advance electronics and logical operations for increasing the overall efficiency. Hence MPPT algorithms were developed which not only enhanced the efficiency but also gave a very effective control mechanism to the whole system.

Chapter 3

Modelling of PV system

3.1 Photovoltaic System Components:-

Photovoltaic cell

A photovoltaic cell or photoelectric cell is a semiconductor device basically a P-N junction diode that converts light to electrical energy by photovoltaic effect [1]. When photon particles of light having energy greater than the band gap of the valence electron is bombarded to the junction electron hole pairs are generated which when acted upon by internal electric field result in a photocurrent. PV cell is basically a current source [2] where current is produced by the variation of photons not the voltage.

PV module

It consists of a large number of P cells arranged in series or parallel or a mixture of both to meet the consumption demand. PV modules of various materials and enhanced efficiencies and of desired size are available in the market.

PV modelling

Typically a solar cell can be modelled by a current source and an inverted diode connected in parallel to it. The PV cell has its own series and shunt resistance. Series resistance is due to the diode resistance(of the bulk material) & resistance of metal contacts whereas parallel resistance represents the electron hole recombination before t reaches the load.

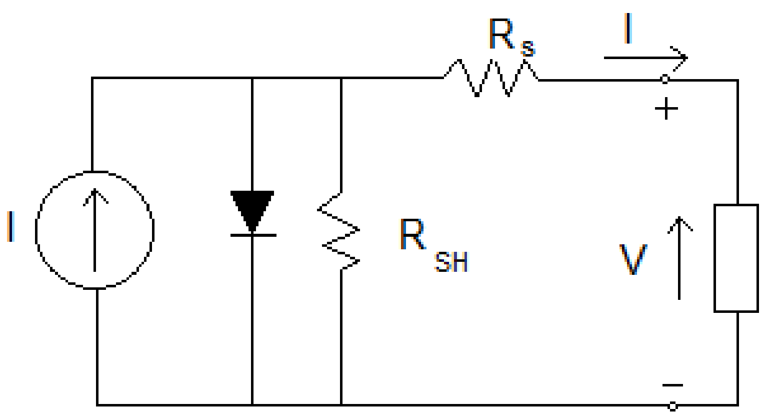


Fig 1:-**Single diode model of a PV cell**

A current source (I) along with a diode and series resistance (Rs) is considered. The shunt resistance (R_{sh}) in parallel is very high, has a negligible effect and can be neglected. The output current from the photovoltaic array can be given by

$$I=I_{SC}-I_d \qquad \text{----eqn 1}$$

$$I_d=I_0(e^{qVd/kT}-1) \qquad \text{----eqn 2}$$

Where Io is the reverse saturation current of the diode, q is the electron charge, Vd is the voltage across the diode, k is Boltzmann constant (1.38 * 10-19 J/K) and T is the junction temperature in Kelvin (K)

$$I=I_{sc}-I_0(e^{qVd/kT}-1) \qquad \text{----eqn3}$$

Using suitable approximations,

$$I=I_{sc}-I_0(e^{q((V+IRs/nkT}-1) \qquad \text{----eqn4}$$

Where, I is the photovoltaic cell current, V is the PV cell voltage, T is the temperature (in Kelvin)

and n is the diode ideality factor [3] In order to model the solar panel accurately we can use two diode model but in this project our scope of study is limited to the single diode model [3][4]. Also, the shunt resistance is very high and can be neglected during the course of our study.

3.2 SIMULINK MODEL of PV panel (Masked and Unmasked):-

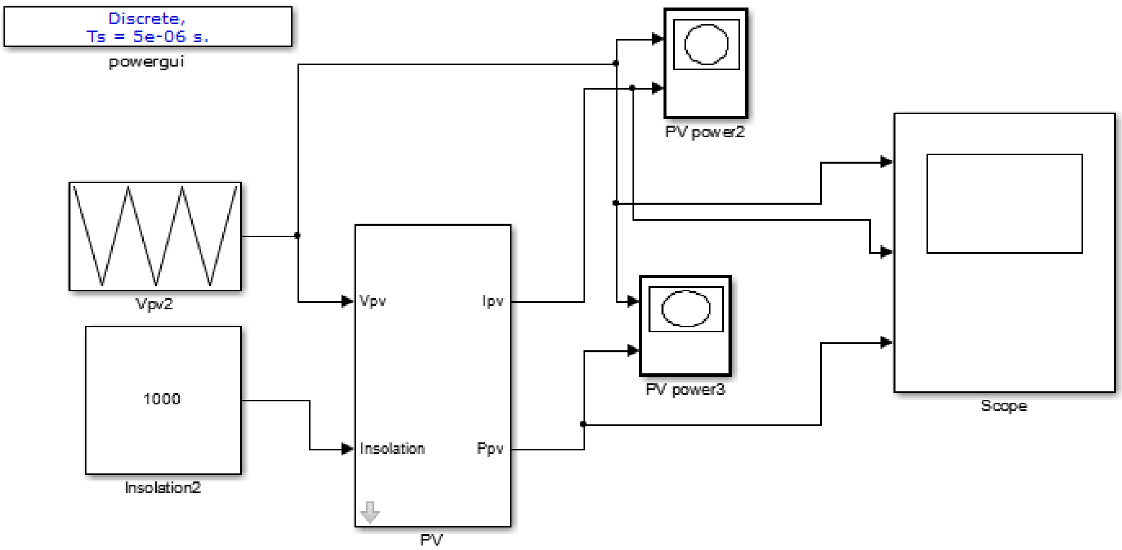


Fig 2:- Masked simulink model of a pv panel

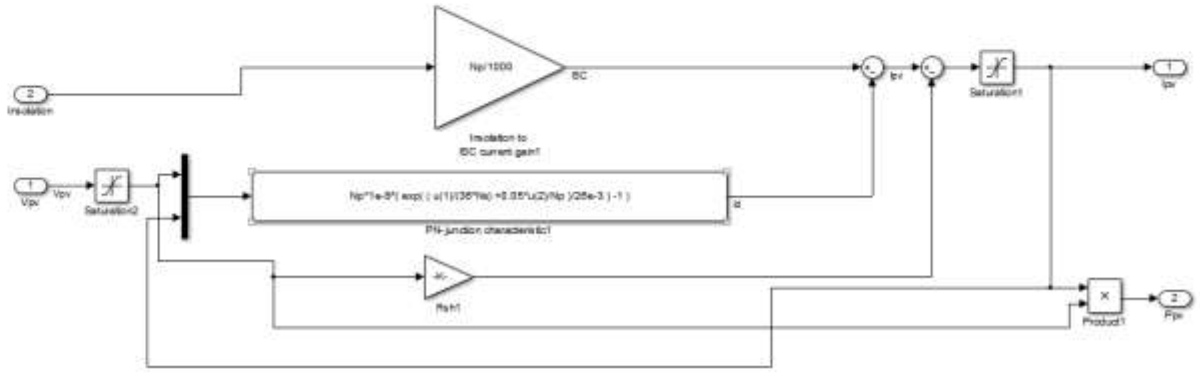


Fig 3:- Unmasked simulink model of a pv panel

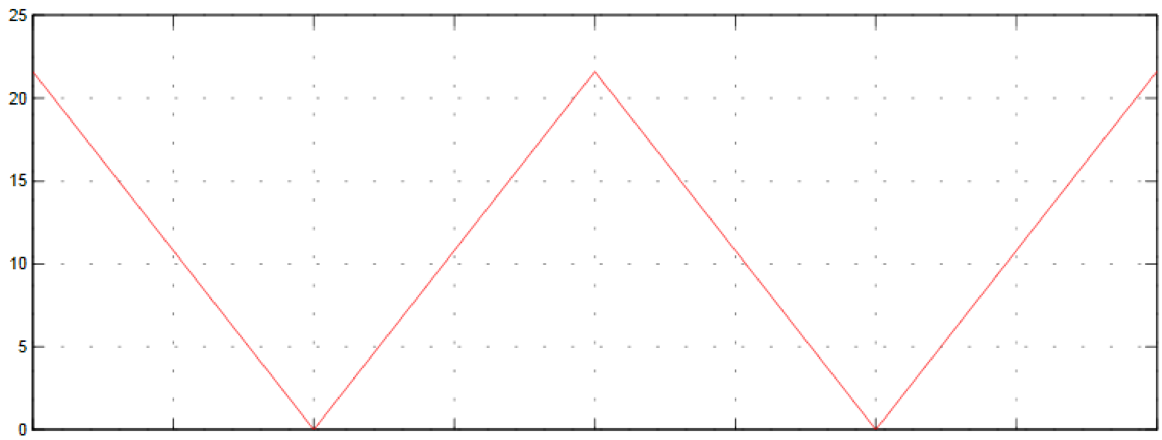


Figure 4: Voltage vs time plot of the solar panel

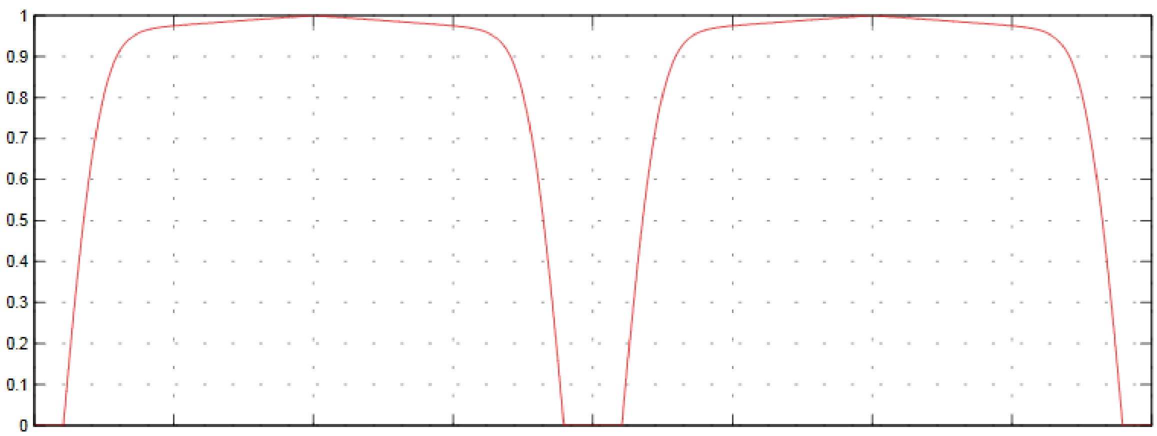


Figure 5: Current vs Voltage plot of the solar panel

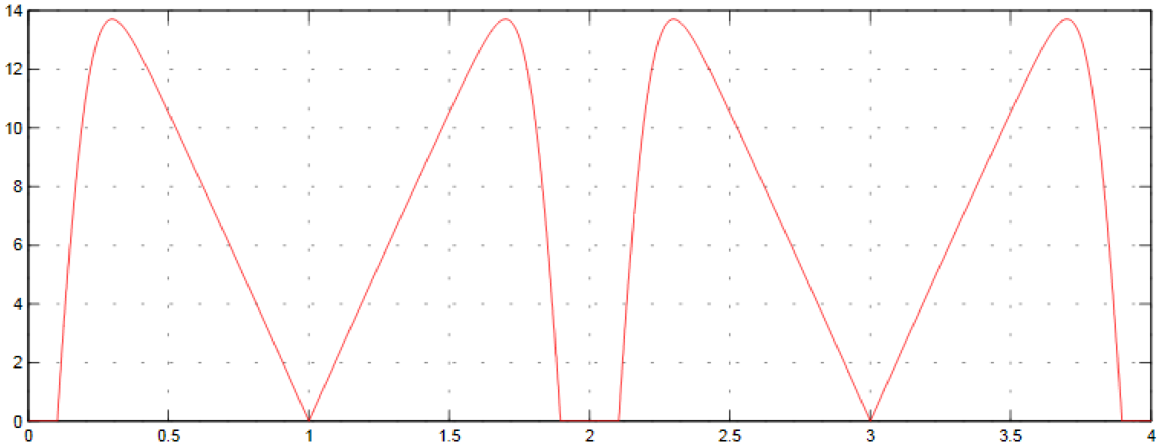


Figure 6 : Powervs Voltage plot of the solar panel

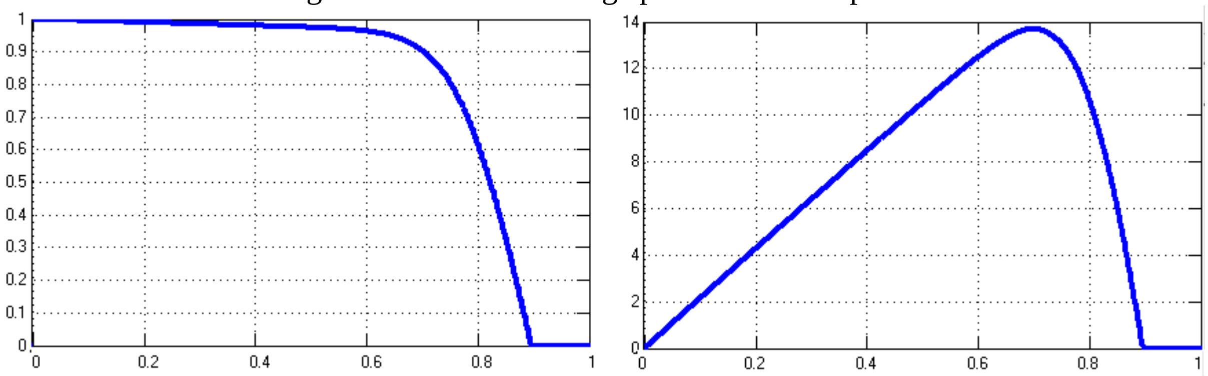


Figure 7(a):- Current (Y axis) vsVoltage(X axis) characteristic plot of the solar panel;
Figure 7(b):- Power(Y axis) vs Voltage(X axis) characteristic plot of the solar panel.

3.3 Boost Converter

The major disadvantage of a Buck type converter is the switch is at the output of PV panel so when it's ON it transfers power but when Off no output to the PV panel occurs which implies the operating point remains near the open circuit voltage which is a loss [5] . This issue is not there in boost converter mechanism. In a boost converter the Load matching is done by varying the resistance of the input side by altering the Duty ratio for which a DC-DC converter [6] is required. Basically this is called Tracking. Another purpose of using a Boost regulator in spite of the fact that it has a lower efficiency than its counterparts is that this DC-DC converter can be used to feed a load or a system with higher voltage demand thus justifying its name.

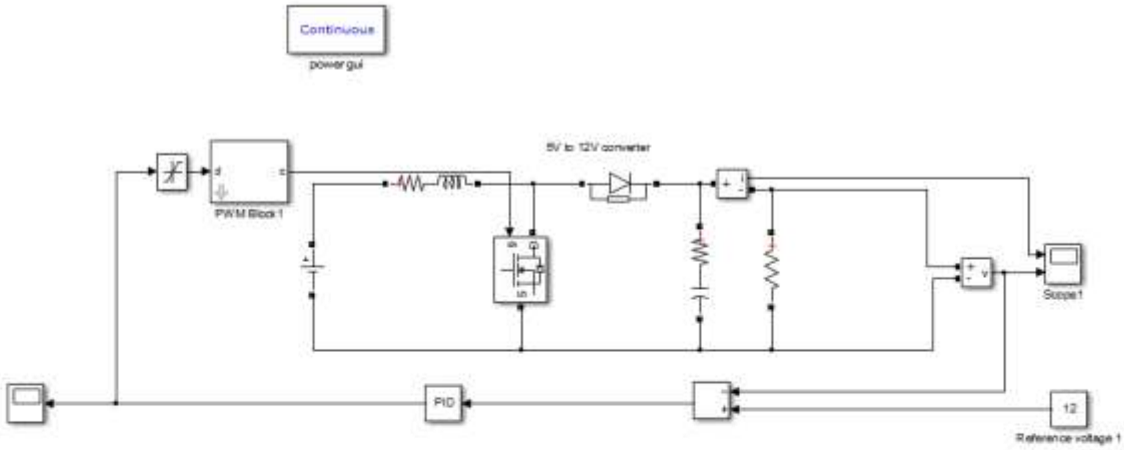


Fig 8:-Simulink model of a Boost Converter 5v to 12v DC:-

Converter Parameters: L = 80 µH, RL = 80 m-ohm ,C = 1.68 µF, Rc = 5 m-ohm,fs = 100 KHz, Vg = 5 ,D = 0.61, Load R = 120 ohm,Vout = 12V

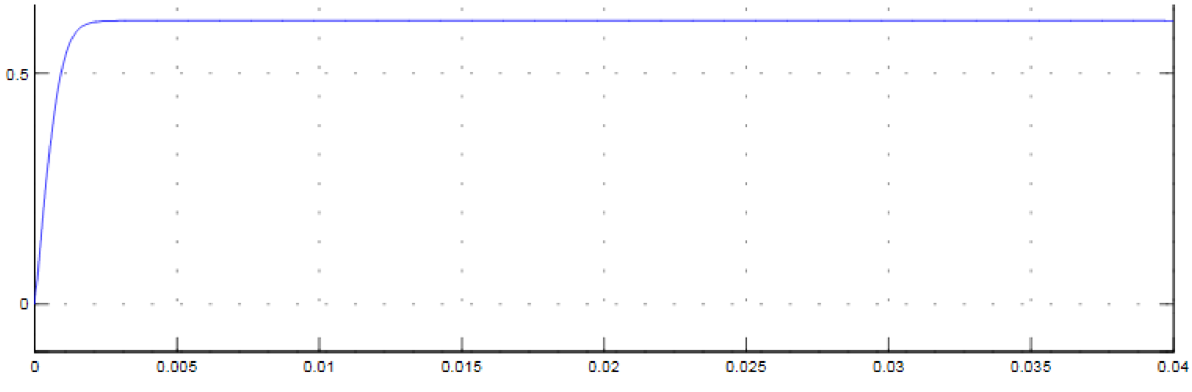


Figure 9 :Duty Ratio vs Time plot of the boost converter

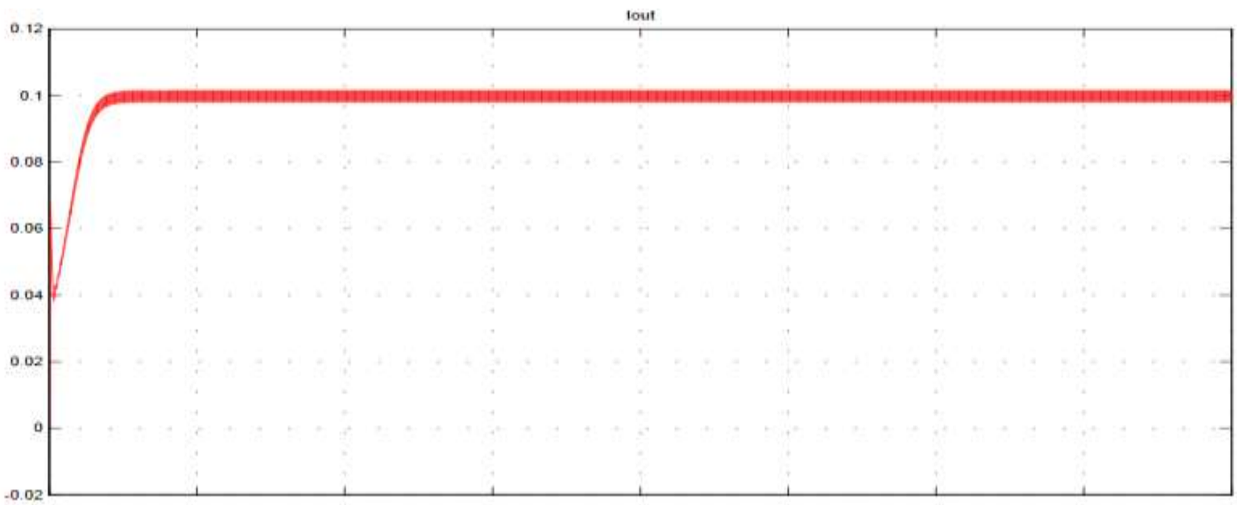


Figure 10: Current output Vs Time plot of the boost converter

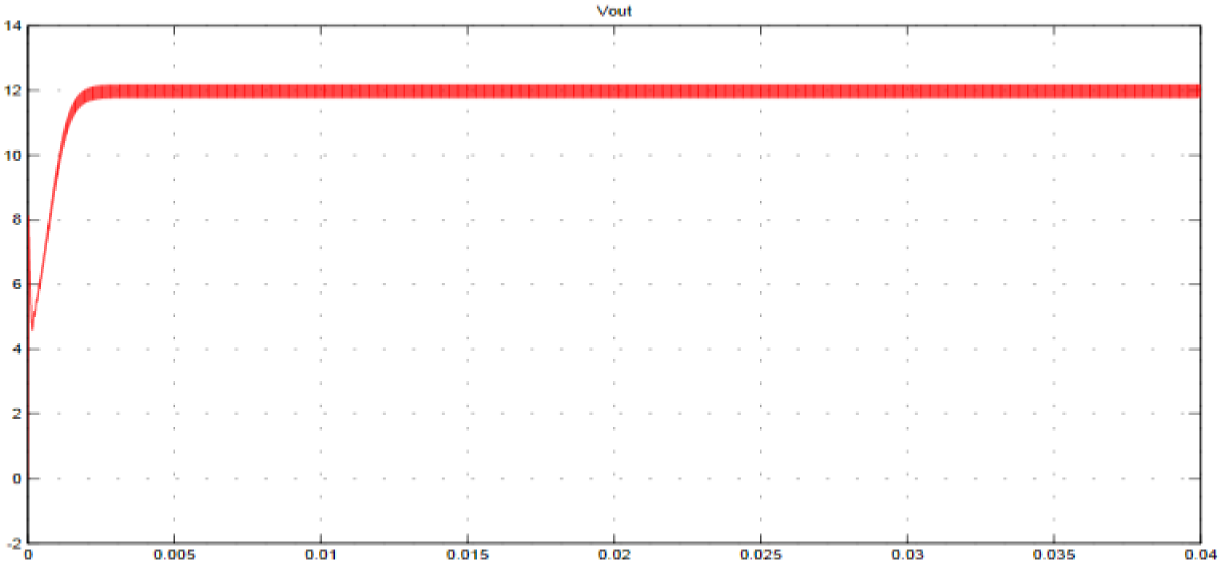


Figure 11: Voltage output vs Time plot of the boost converter

3.4 Maximum Power Point Tracking Algorithms

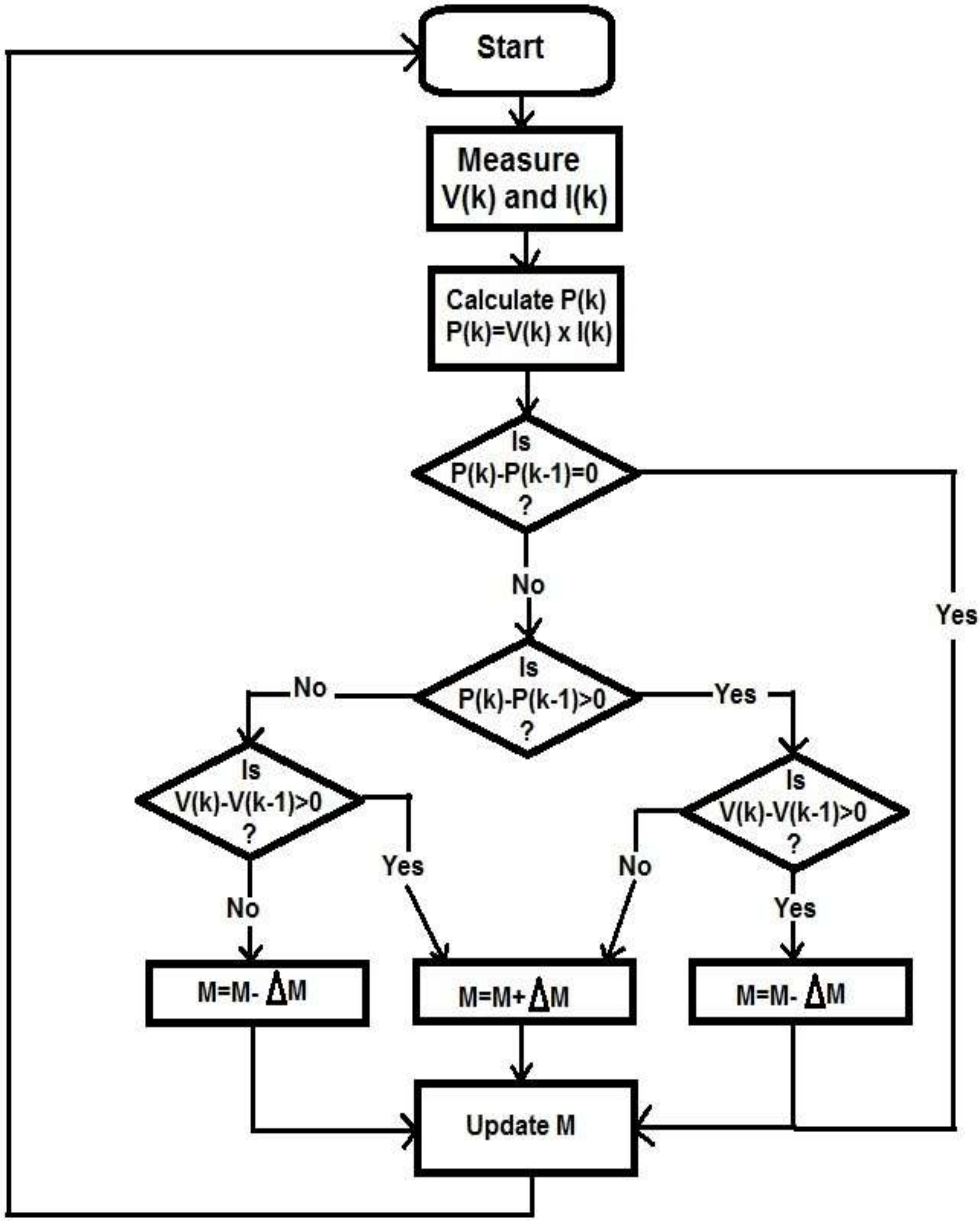
An overview of MPPT

The efficiency of a Solar PV module is measured to be not more than 30%. As seen from the Power vs Voltage curve the module has to operate at a specific range of voltage values in order to extract maximum power thus improving the efficiency. The Max Power Transfer Theory says that maximum power can be extracted from a source when the load impedance matches the source impedance (the Thevenin equivalent impedance). There are basically 3 methods to derive peak power operation electrically. The first method [7] is by measuring dV/dI ie the dynamic impedance by injecting a periodic signal current (small magnitude) and increasing the operating voltage until it equals the static impedance V/I. The second method is by increasing the operating voltage until dP/dV ie (slope of the P vs V curve) is positive [7][8]. In most of the cells a ratio between the maximum power voltage and open circuit voltage is maintained and experimentally found to be near 0.72.in the third method this idea is the key for MPPT [6]. From the above method what we can infer is that our basic motive can be achieved by matching the impedances by duty cycle alteration of the boost converter switch and obtain higher value of output voltage.

3.5 Perturb & Observe

Perturb & Observe (P&O) is one of the simple technique that uses a voltage sensor [8][9], to sense the voltage of Photovoltaic array voltage which reduces the implementation cost and hence easy to operate. The of this algorithm has a very less time complexity but when it reaches close to the maximum power point it perturbs on both the directions without stopping [9]. An appropriate error limit is to be set or a wait function can be added when MPP is reached thus increasing the time complexity of the algorithm.

<u>Fig 12:- Flow chart for Perturb & Observe (P&O) algorithm:-</u>



3.6 SIMULATIONS PLOTS AND RESULTS

Fig:-13 Simulink model of MPPT using P&O algorithm (a)masked and (b)unmasked

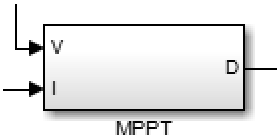


Fig 13. (a)

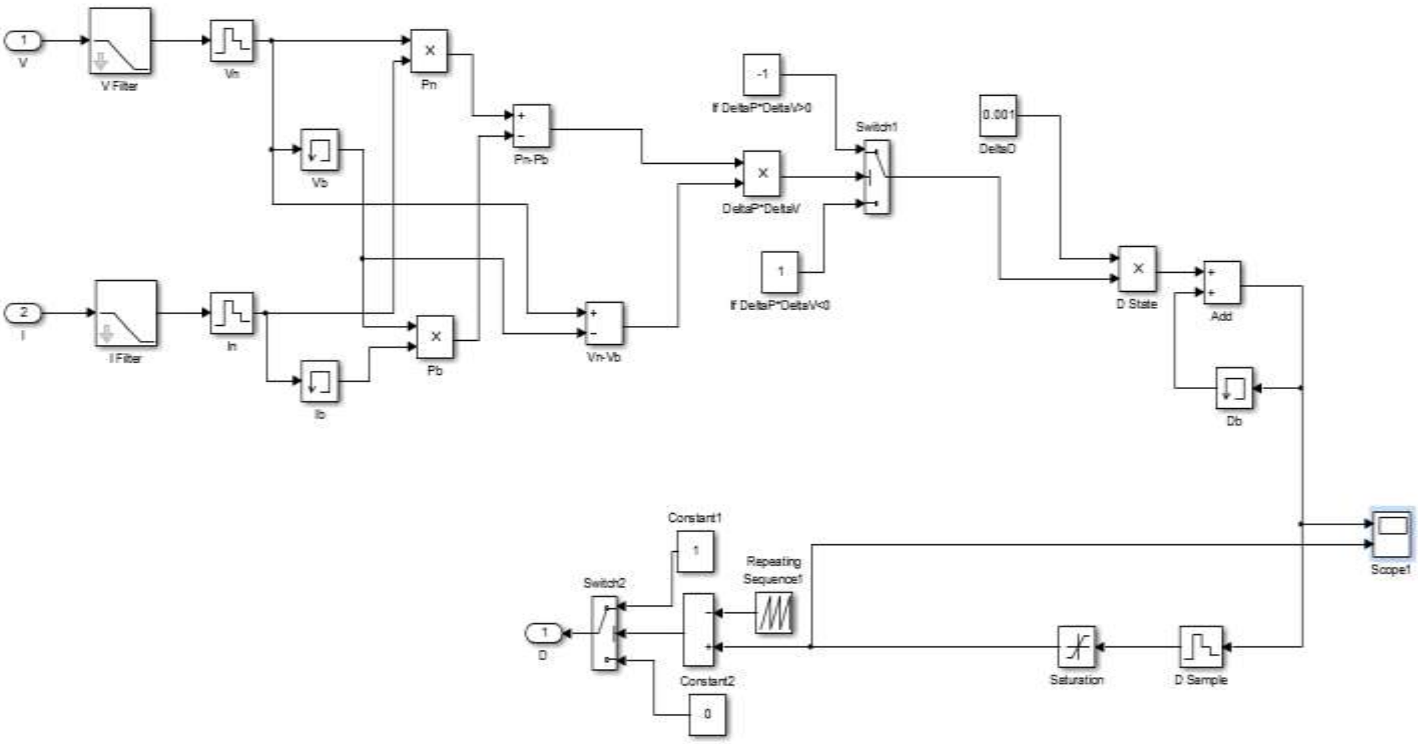


Fig 13. (b)

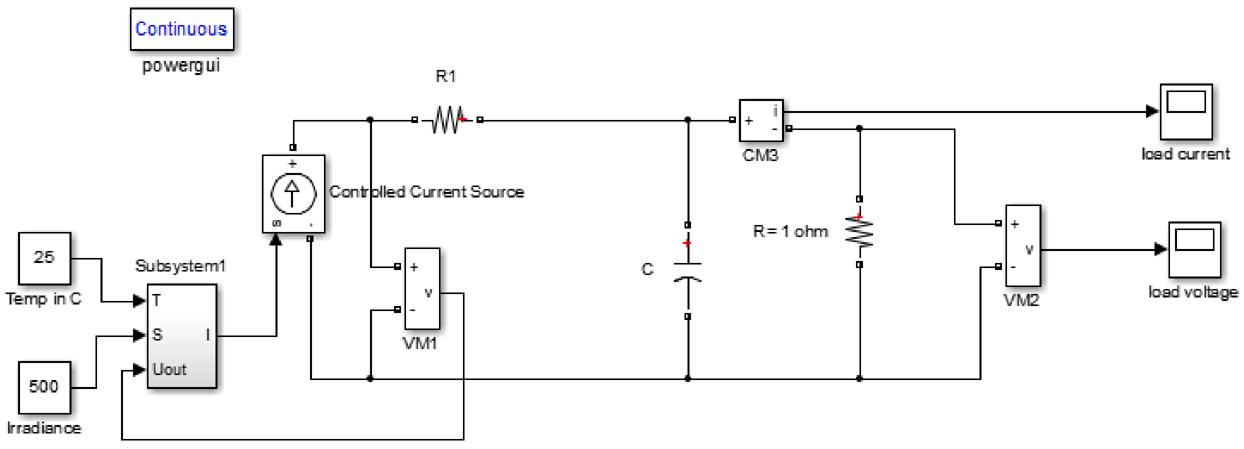


Fig. 14:- Simulink Model of Solar Cell without MPPT

Input Parameters :-

Temperature in deg Celsius =25 ,Incident Solar Radiation in Watt per meter square: - 500

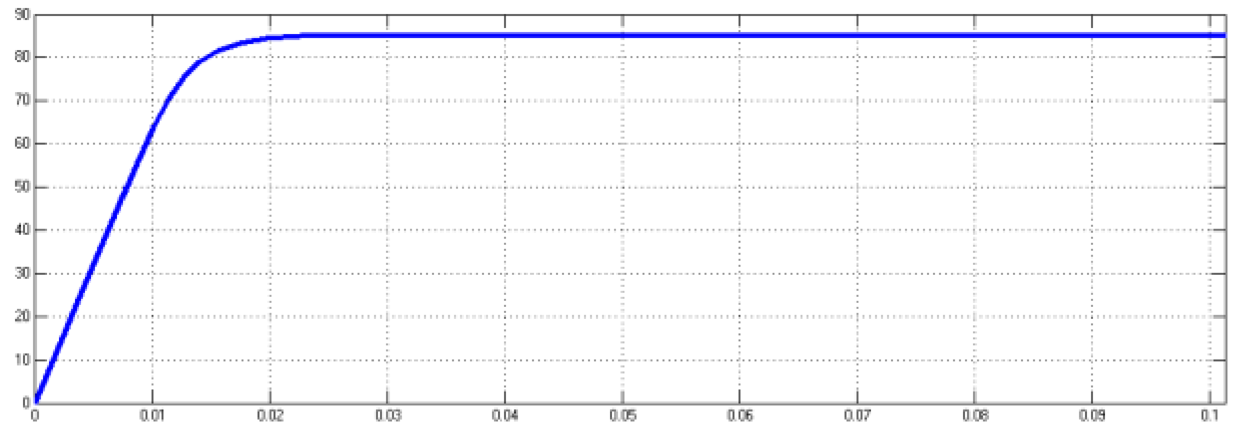


Fig. 15:- Plot of **Open Circuit** Voltage (V) vs. time(s) of Solar Cell without MPPT

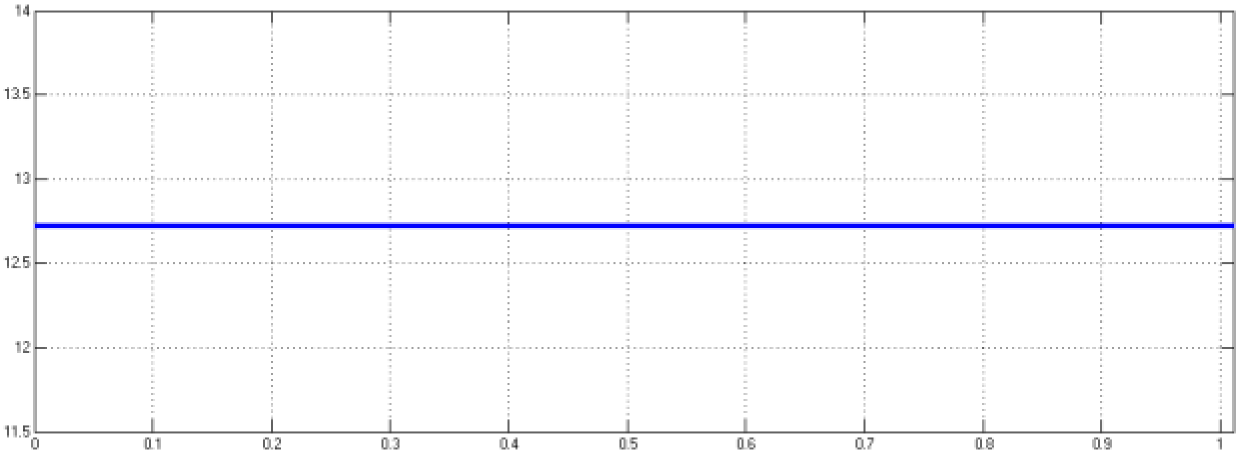


Fig. 16:- Plot of **Short Circuit** Current (A) vs. time(s) of Solar Cell without MPPT

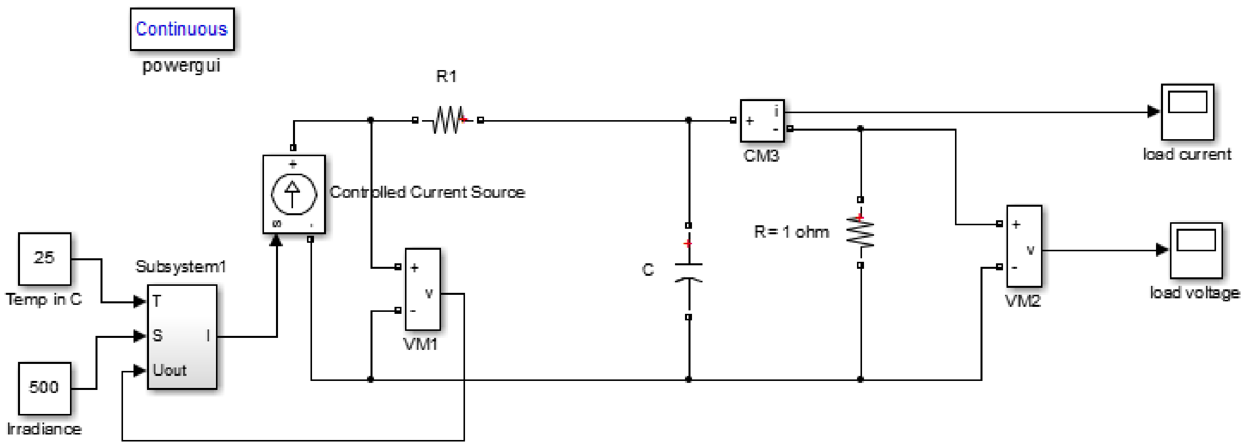


Fig. 17:- Simulink Model of Solar Cell without MPPT

<u>Input Parameters :-</u>

Temperature in deg Celsius =25

Incident Solar Radiation in Watt per meter square: - 500

<u>Circuit parameters :-</u>

R1 = 1 ohm

C= 0.002 F

Load resistance R = 1 ohm

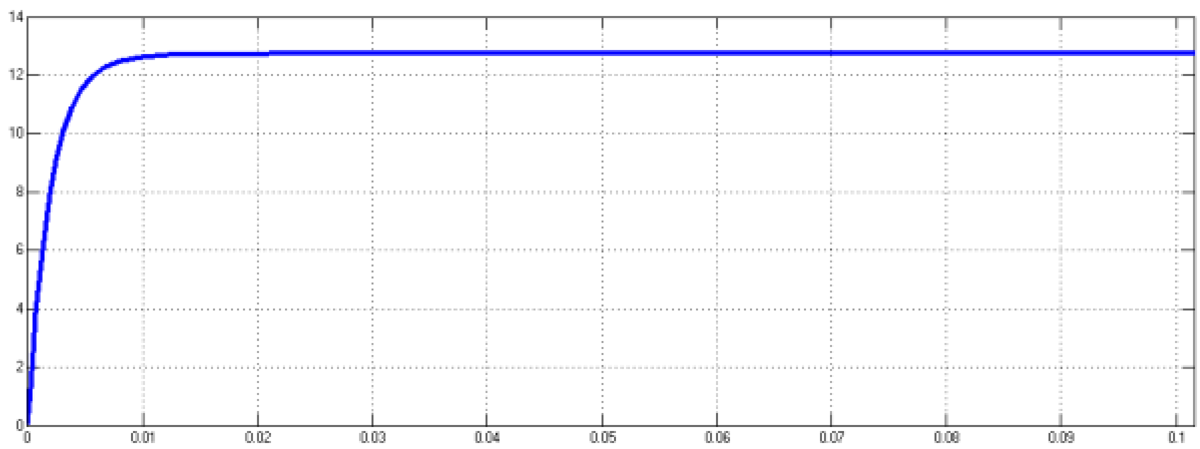


Fig. 18:- Plot of Load Voltage(V) Vs time(s) of Solar Cell without MPPT

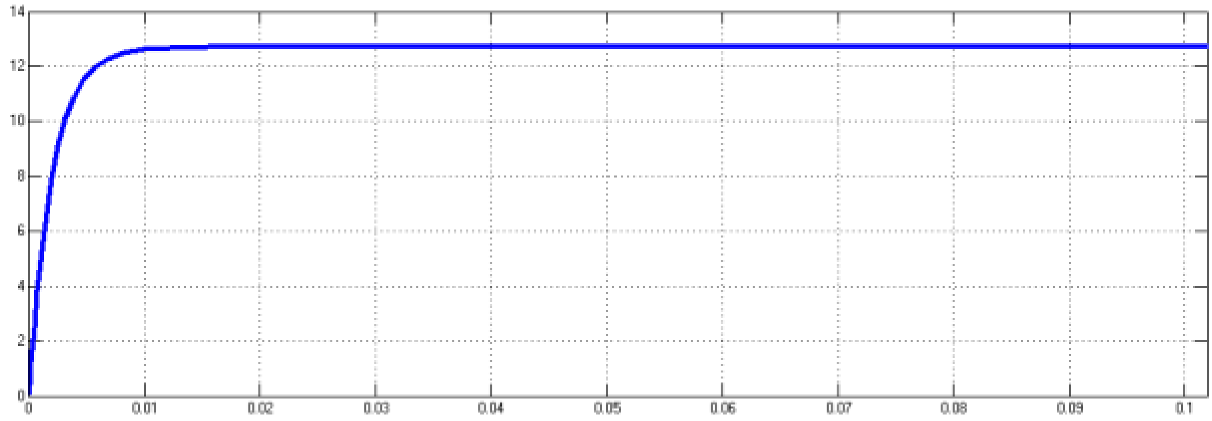


Fig. 19:- Plot of Load Current (A) Vs time (s) of Solar Cell without MPPT

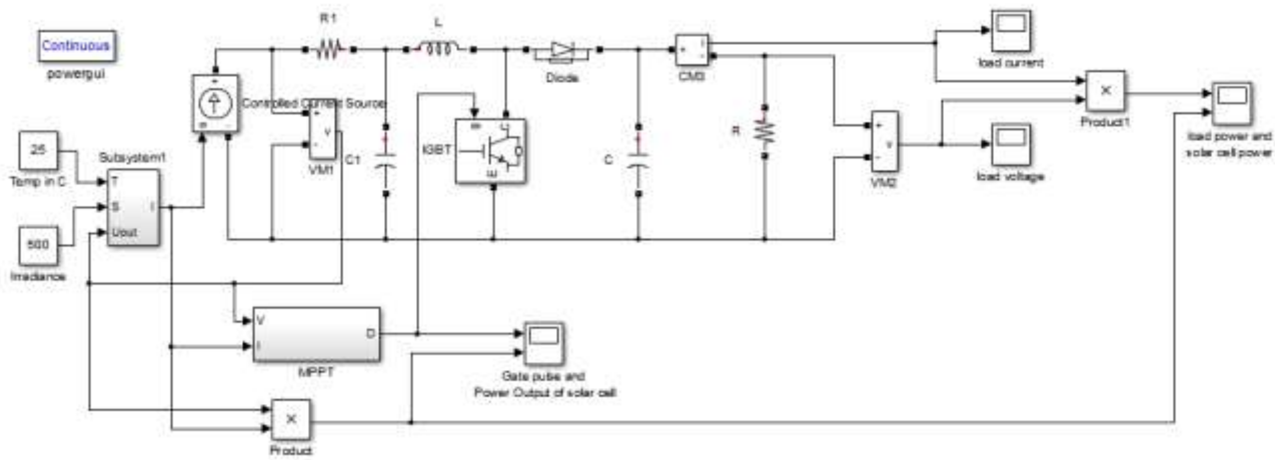


Fig. 20:- Simulink Model of Solar Cell with MPPT and Boost Converter

<u>Input Parameters :-</u>

Temperature in deg celcius =25

Incident Solar Radiation in Watt per meter square :- 500

<u>Circuit parameters :-</u>

R1 = 1 ohm

C= 0.002 F

Inductance L = 0.01 H

Load resistance R = 1 ohm

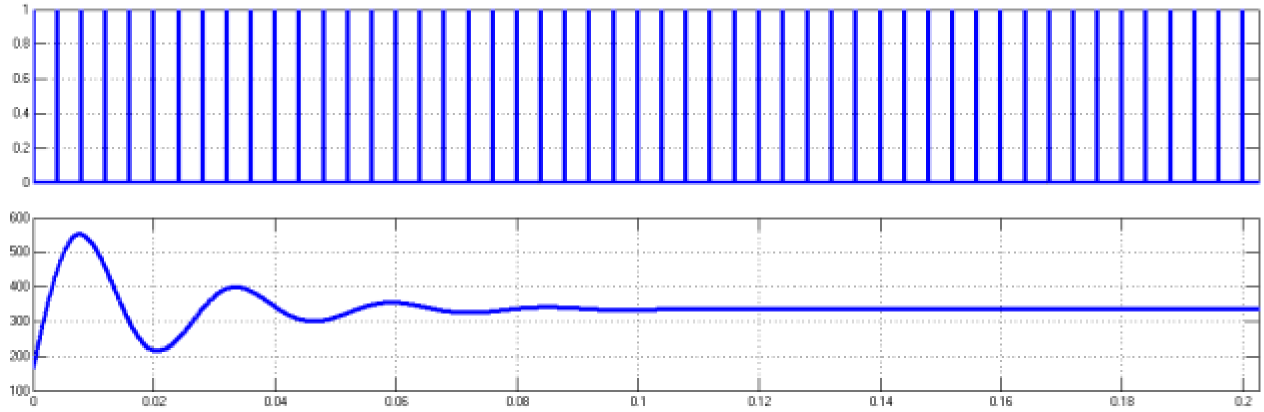


Fig. 21:- (a) Plot of the Gate pulse Output From MPPT (b) Plot of the Power Output of The PV module

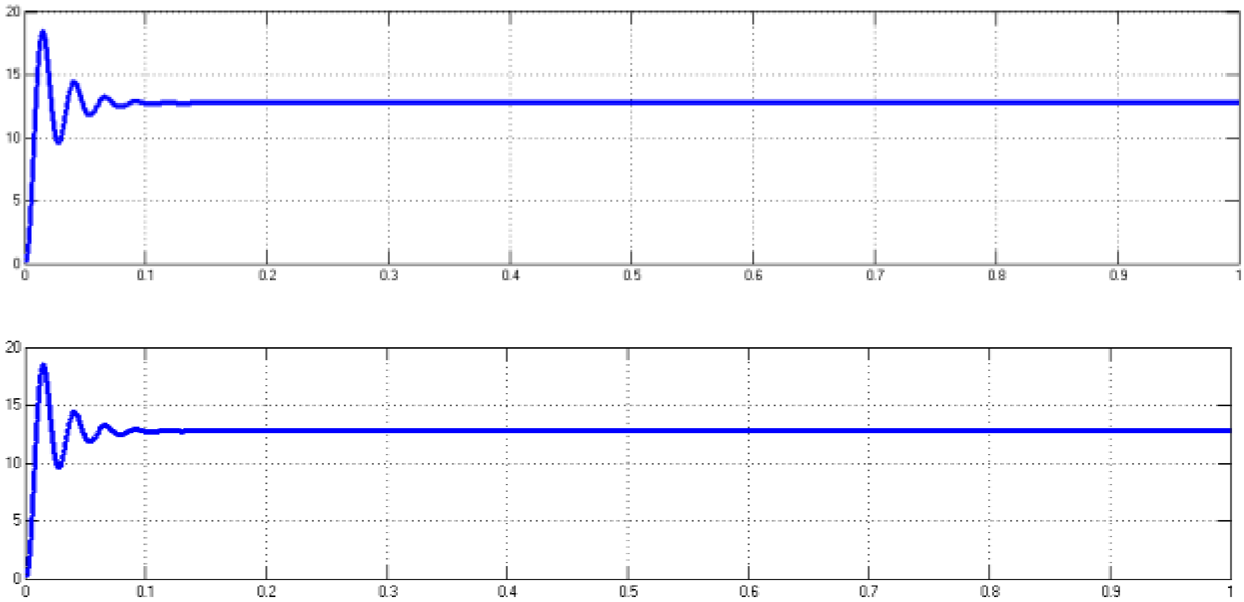


Fig. 22:- (a) Plot of the Load Voltage Vs Time (b) Plot of the Load Current Vs Time

Comparison between the Power output of the Two models one without MPPT and other with MPPT and Boost Converter

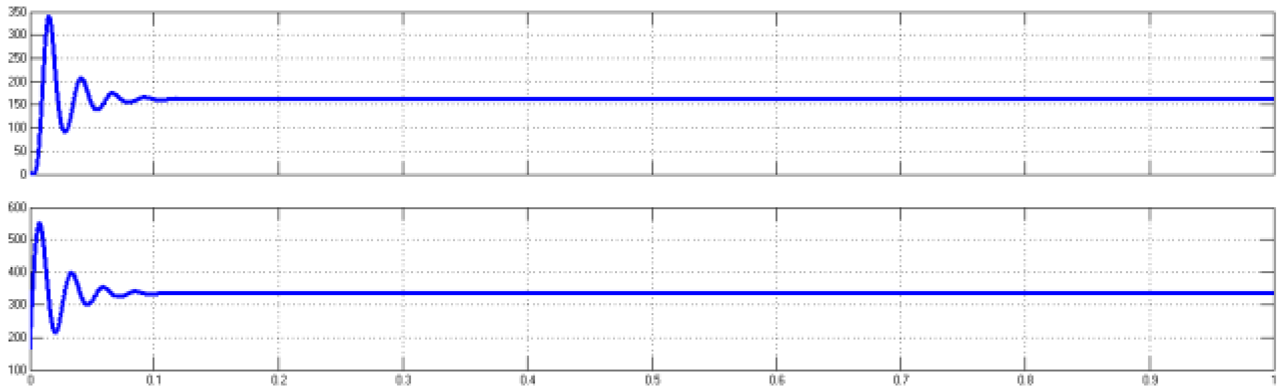


Fig 23:-Plot of the Power output vs time of the PV model (a) without MPPT (b) with MPPT and Boost converter

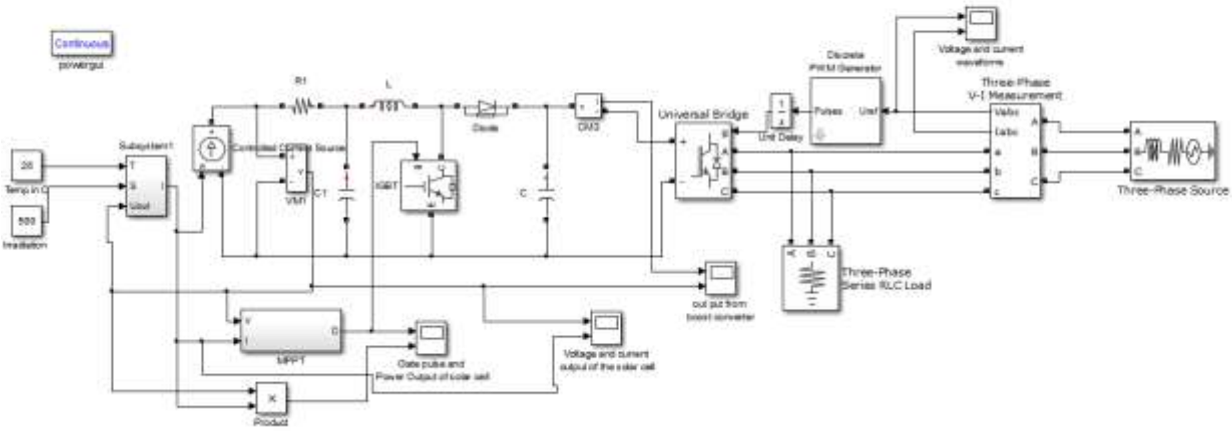


Fig. 24:- Simulink Model of Solar Cell with MPPT and Boost Converter connected to the Grid [12]

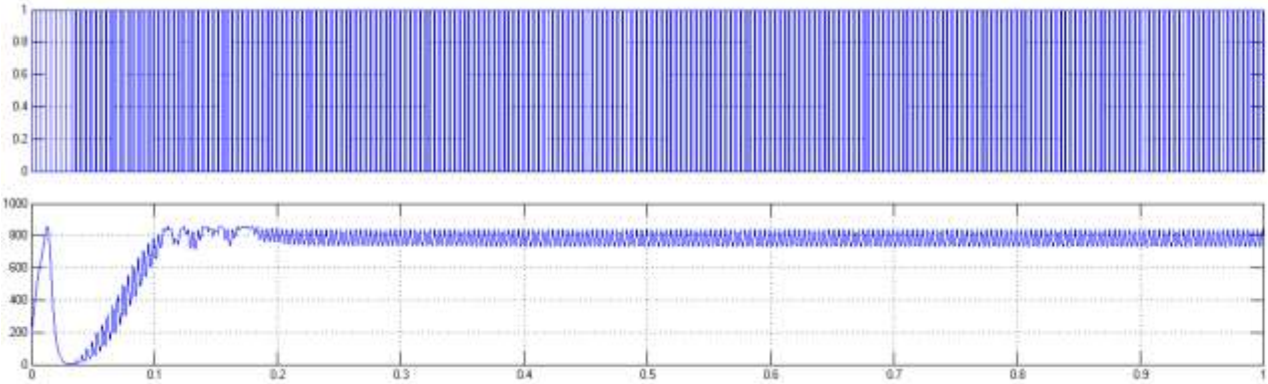


Fig. 25:- Plot of (a) Gate pulse and (b) Power Output of the Solar Cell vs time

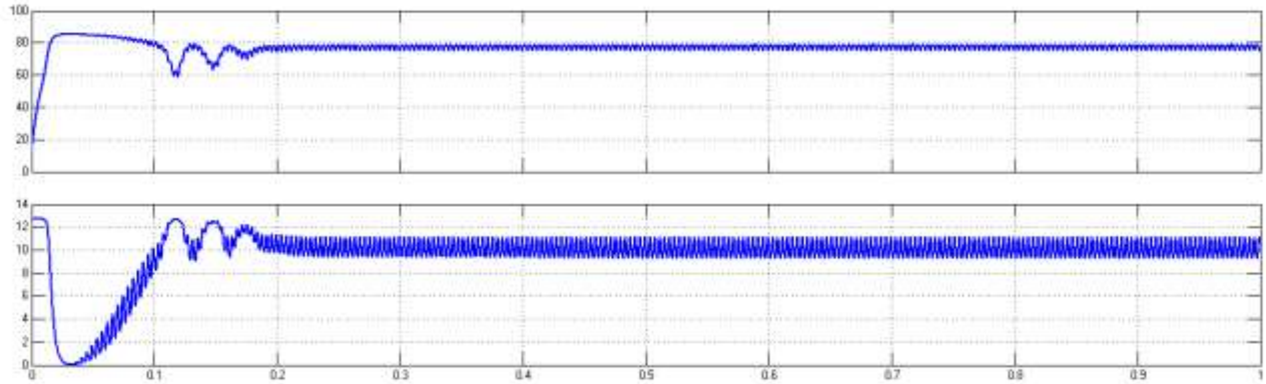


Fig. 26:- Plot of (a) Voltage and (b) Current waveforms of the Solar Cell vs time

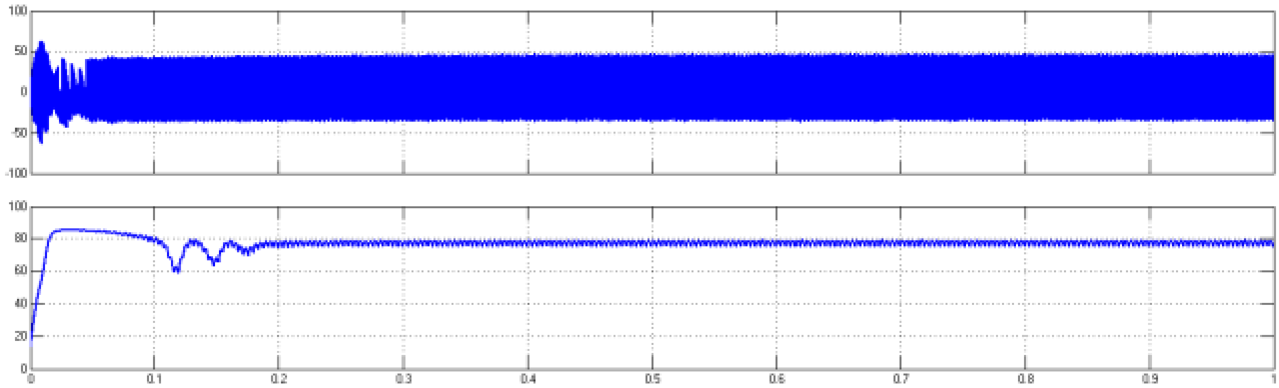


Fig. 27:- Plot of (a) Current and (b) Voltage Output from Boost Converter of the Solar Cell vs time

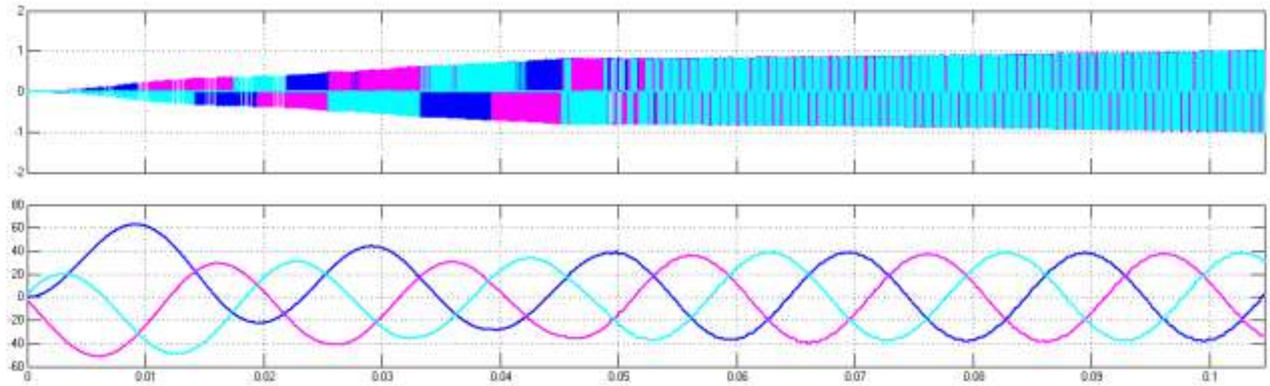


Fig. 28:- Plot of (a) Voltage output from the PWM generator and (b) Current Output from Grid connection wrt time

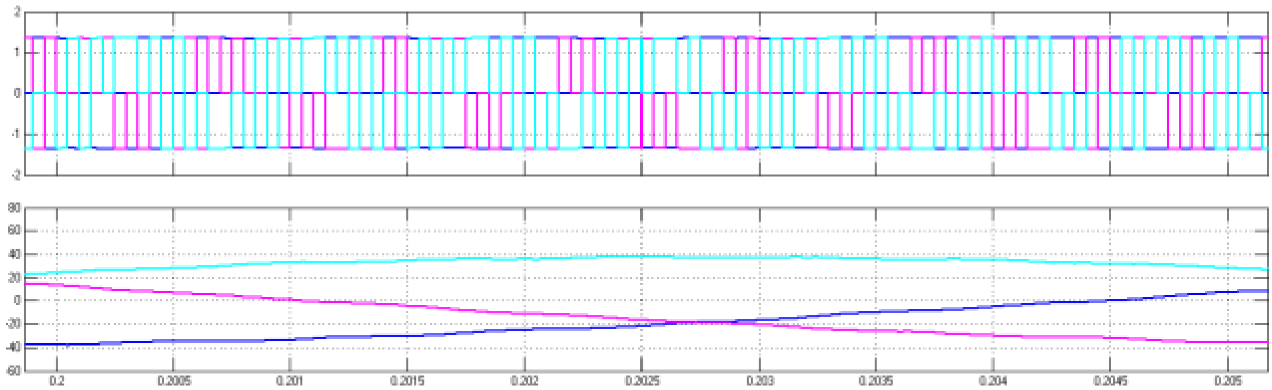


Fig. 29:- Zoomed Plot of (a) Voltage output from the PWM generator and (b) Current Output from Grid connection wrt time (0.2s to 0.205s)

Chapter 4
CONCLUSION & FUTURE WORK

4.1 CONCLUSION

The no-load voltage and the short circuit current of the solar module are found to 85V and 12.7 A respectively. The power output of the module when a resistive load of 1 ohm (which made the output current and voltage waveforms look similar) was used was calculated to be 150W. There after interfacing MPPT and boost converter the DC power extracted was raised to 320W. The frequency of operation was 10 KHz which was set by using a repeating saw tooth generator. For generating the pulse signal a repeating sequence generator was used in the MPPT to provide gate pulse to the IGBT switch. A slight change in the incident solar radiation alters the position of the maximum power point the PvsV curve as a result the duty cycle has to be constantly changed in accordance with the solar incident radiation [11]. Use of a constant value of Duty ratio will make the system less efficient as the peak power point may not be tracked [11]. A three phase Load with Phase to phase Y (grounded) nominal phase to phase voltage (Vrms) 300V with nominal frequency of 50 Hz and active power consumption of 0.001 W was used . The three phase source was taken to be 300v phase to phase and frequency of 50 Hz. Type of the source is also Y grounded. The output of the boost converter is fed to the universal bridge that acts like an inverter circuitry. A discrete PWM generator was used to give triggering signal to the inverter [12]. A sinusoidal three phase current wave form with peak value of around 40Amps is obtained. Matlab and Simulink have been used for various plots and value calculations. The waveforms obtained from the Simulink models have been shown for comparison. Small values of error are still appearing in the curves accounting to power losses (mostly switching loss or loss in the boost converter circuitry mainly due to loss in capacitor or inductor [12]).

4.2 FUTURE WORK

Future work to this project will include the removal of harmonics [12] in the grid connection system as well as operation of the PV system in variable environmental and physical conditions like change in solar irradiation or sudden altering in atmospheric temperature. Further improvement can be made by enhancing the energy exchange with the local electrical grid in order to stabilise the energy curve. Design of more generalised solar cell with variable inputs of incident solar radiation and atmospheric temperature can be designed using Simulink instead of predefined constant values.

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