

SOLAR-PV POWER CONDITIONING SYSTEM DESIGN SIMULATION

**A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE OF**

B.Sc. in Electrical & Electronics Engineering

By

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**Department of Electrical & Electronics Engineering
Daffodil International University
Dhaka-2014**

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**UNDER THE GUIDANCE OF
Professor Dr. M. Shamsul Alam**

Department of Electrical & Electronics Engineering
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Dhaka-2014



Department of Electrical & Electronics Engineering
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CERTIFICATE

This is to certify that the Thesis Report entitled **SOLAR-PV POWER CONDITIONING SYSTEM DESIGN SIMULATION** submitted by A.S.M. Shakhawat Raihan(101-33-154) & Md. Sium Arefin(101-33-169), **Department of Electrical & Electronics Engineering** at Daffodil International University is an authentic work by them under my supervision and guidance.

Date: 12.04.14

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ABSTRACT

In this paper utilization of MATLAB software for control of photovoltaic power using Maximum Power Point Tracking (MPPT) control mechanism. The main aim of the thesis is the conditioning system of solar-PV using design simulation along with a Maximum Power Point Tracking control mechanism. The MPPT is responsible for extracting the maximum possible power from the photovoltaic and feed it to the load via converter to required magnitude. The perturb and observe method algorithm is utilized for MPPT and use as a code. The algorithm is written in m files of MATLAB and utilized in simulation. Both the DC-DC converter and the DC-AC converter are modeled using Sim Power Systems blocks.

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Chapter 1

INTRODUCTION

1.1 INTRODUCTION

1.2 LITERATURE SURVEY

1.3 MOTIVATION

1.4 OBJECTIVE

1.5 THESIS OUTLINE

Chapter 1

1.1 INTRODUCTION

One of the major concerns in the power sector is the day-to-day increasing power demand but the unavailability of enough resources to meet the power demand using the conventional energy sources. Demand has increased for renewable sources of energy to be utilized along with conventional systems to meet the energy demand. Renewable sources like wind energy and solar energy are the prime energy sources which are being utilized in this regard. The continuous use of fossil fuels has caused the fossil fuel deposit to be reduced and has drastically affected the environment depleting the biosphere and cumulatively adding to global warming.

Solar energy is abundantly available that has made it possible to harvest it and utilize it properly. Solar energy can be a standalone generating unit or can be a grid connected generating unit depending on the availability of a grid nearby. Thus it can be used to power rural areas where the availability of grids is very low. Another advantage of using solar energy is the portable operation whenever necessary.

In order to tackle the present energy crisis one has to develop an efficient manner in which power has to be extracted from the incoming solar radiation. The power conversion mechanisms have been greatly reduced in size in the past few years. The development in power electronics and material science has helped engineers to come up very small but powerful systems to withstand the high power demand. But the disadvantage of these systems is the increased power density. 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.[5][10]

1.2 LITERATURE SURVEY:

The topic of solar energy utilization has been looked upon by many researchers all around the globe. It has been known that solar cell operates at very low efficiency and thus a better control mechanism is required to increase the efficiency of the solar cell. In this field researchers have developed what are now called the Maximum Power Point Tracking (MPPT) algorithms.

Mummadi Veerachary has given a detailed report on the use of a SEPIC converter in the field of photovoltaic power control. In his report he utilized a two-input converter for accomplishing the maximum power extraction from the solar cell. [5]

M. G. Villalva in his both reports has presented a comprehensive method to model a solar cell using Simulink or by writing a code. His results are quite similar to the nature of the solar cell output plots. [3][4]

P. S. Revankar has even included the variation of sun's inclination to track down the maximum possible power from the incoming solar radiations. The control mechanism alters the position of the panel such that the incoming solar radiations are always perpendicular to the panels. [11]

M. Berrera has compared seven different algorithms for maximum power point tracking using two different solar irradiation functions to depict the variation of the output power in both cases using the MPPT algorithms and optimized MPPT algorithms. [10]

Ramos Hernanz has successfully depicted the modeling of a solar cell and the variation of the current-voltage curve and the power-voltage curve due the solar irradiation changes and the change in ambient temperature. [12]

1.3 MOTIVATION:

Photovoltaic power control is one of the burning research fields these days. Researchers are round the clock to develop better solar cell materials and efficient control mechanisms. The challenge of the thesis and the new area of study were the motivations behind the thesis.

1.4 OBJECTIVE:

The basic objective would be to study MPPT and successfully implement the MPPT algorithms in code form and using the Simulink models. Modeling the converter and the solar cell in Simulink and interfacing both with the MPPT algorithm to obtain the maximum power point operation would be of prime importance.

1.5 THESIS OUTLINE:

This thesis has been broadly divided into 6 chapters. The first one being the introduction, chapter 2 is on concept of solar cell. Chapter 3 deals with the operation of converter. Chapter 4 is on maximum power point tracking and study of the various algorithms. In chapter 5 simulation models and simulation results. Conclusion and future work are listed in chapter 6.

Chapter 2

CONCEPT OF SOLAR CELL

2.1 STANDALONE PHOTOVOLTAIC SYSTEM COMPONENTS

2.2 EFFECT OF VARIATION OF SOLAR IRRADIATION

2.3 EFFECT OF VARIATION OF TEMPERATURE

Chapter 2

2.1 Standalone Photovoltaic System Components:

2.1.1 Photovoltaic cell

The theory of photovoltaic cell or photoelectric cell is that converts light to electrical energy by photovoltaic effect by using a semi conductor. If the energy of photon of light is greater than the band gap then the electron is emitted and the flow of electrons creates current. However a photovoltaic cell is different from a photodiode. In a photodiode light falls on a channel of the semiconductor junction and gets converted into current or voltage signal but a photovoltaic cell is always forward biased. [16]

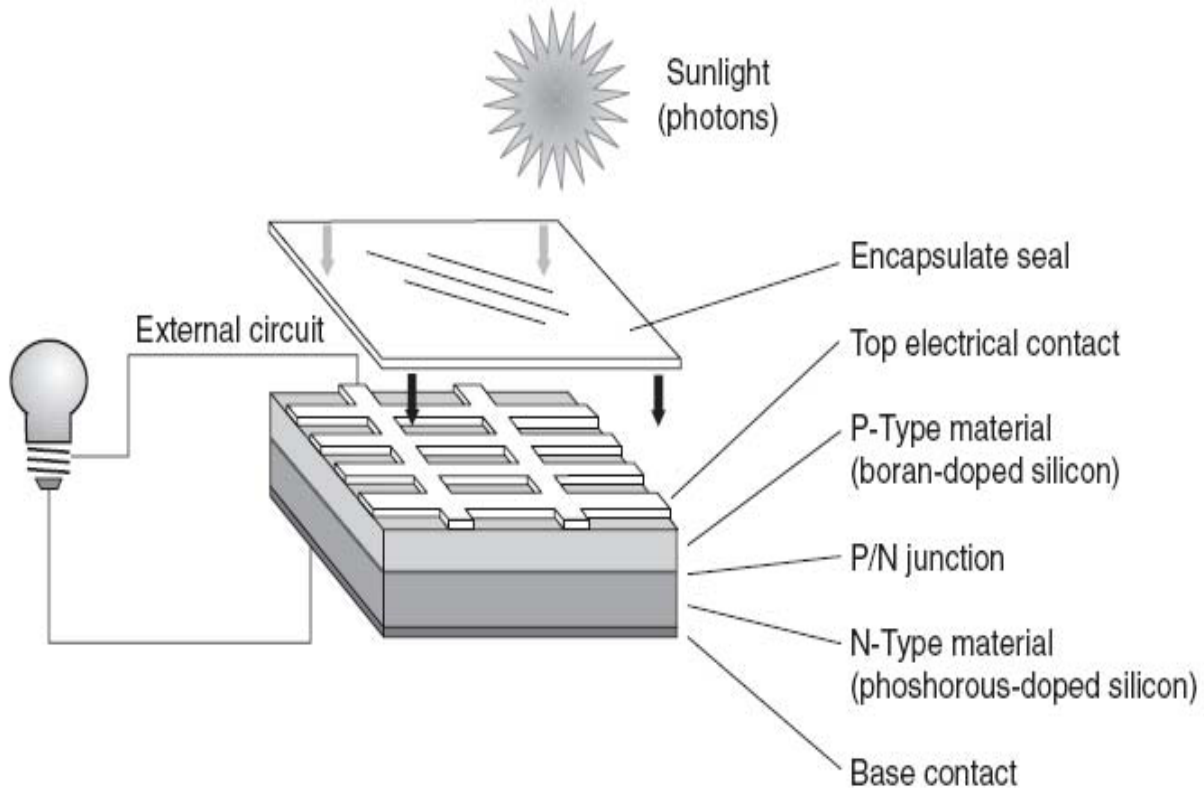


Figure 2.1: Diagram of a Photovoltaic Cell

2.1.2 PV module

Usually a number of PV modules are arranged in series and parallel to meet the energy requirements. PV modules of different sizes are commercially available (generally sized from 60W to 170W). For example, a typical small scale desalination plant requires a few thousand watts of power. [6][16]

2.1.3 PV modeling

A PV array consists of several photovoltaic cells in series and parallel connections. Series connections are responsible for increasing the voltage of the module whereas the parallel connection is responsible for increasing the current in the array. Typically a solar cell can be modeled by a current source and an inverted diode connected in parallel to it. It has its own series and parallel resistance. Series resistance is due to hindrance in the path of flow of electrons from n to p junction and parallel resistance is due to the leakage current.[6] [16][17]

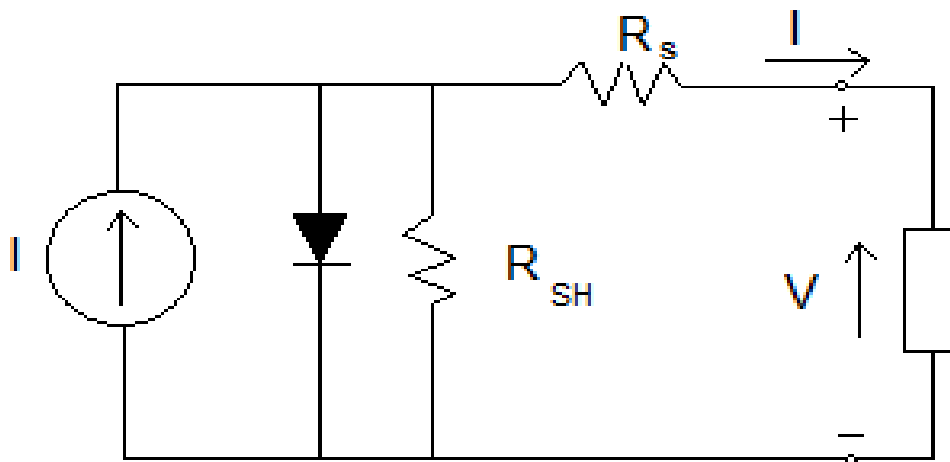
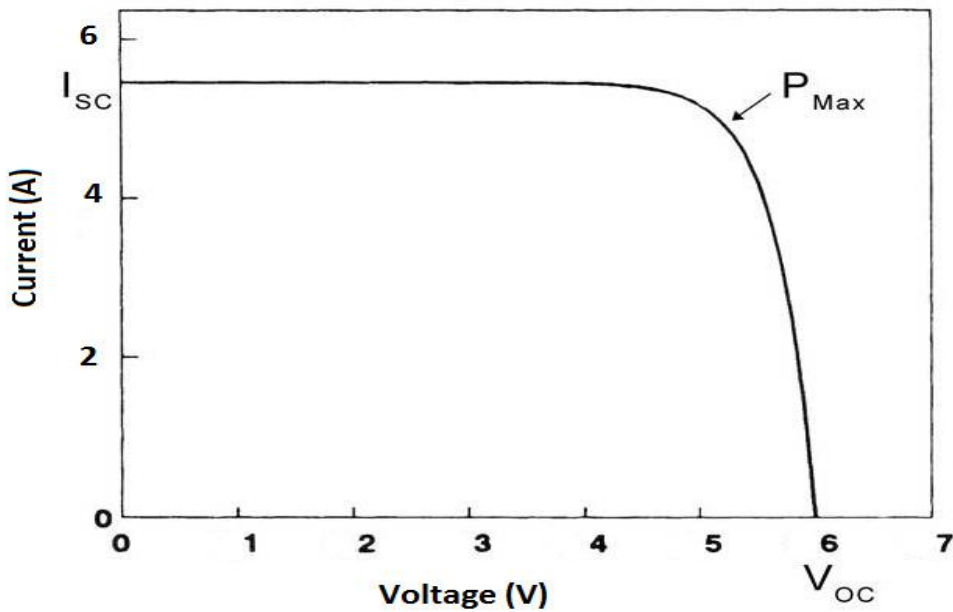


Figure 2.2: Single diode model of a PV cell

In here I is the current source which is flowing through the diode and series resistance R_S . There is also a shunt resistance R_P which is very high power but it is negligible and it is neglected.



The I-V and P-V curves for a solar cell are given in the following figure. It can be seen that the cell operates as a constant current source at low values of operating voltages and a constant voltage source at low values of operating current.

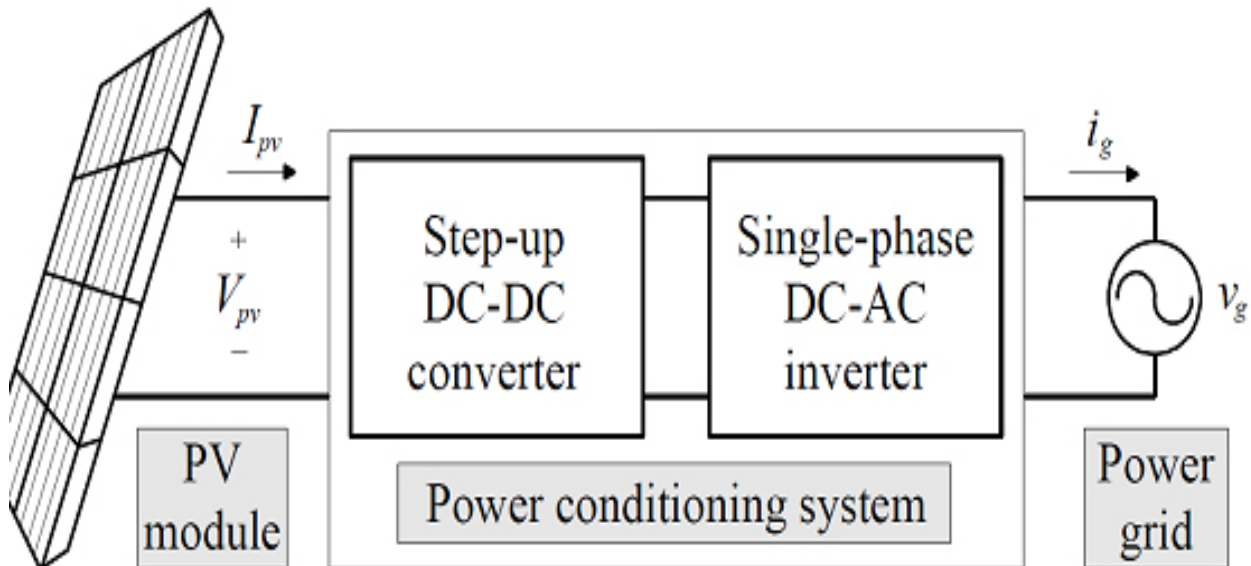


Figure 2.3: Configuration of the PCS for the grid-connected PV module.

2.2 EFFECT OF VARIATION OF SOLAR IRRADIATION:

The P-V and I-V curves of a solar cell are highly dependent on the solar irradiation values. The solar irradiation as a result of the environmental changes keeps on fluctuating, but control mechanisms are available that can track this change and can alter the working of the solar cell to meet the required load demands. Higher is the solar irradiation, higher would be the solar input to the solar cell and hence power magnitude would increase for the same voltage value. With increase in the solar irradiation the open circuit voltage increases. This is due to the fact that, when more sunlight incidents on to the solar cell, the electrons are supplied with higher excitation energy, thereby increasing the electron mobility and thus more power is generated. [17]

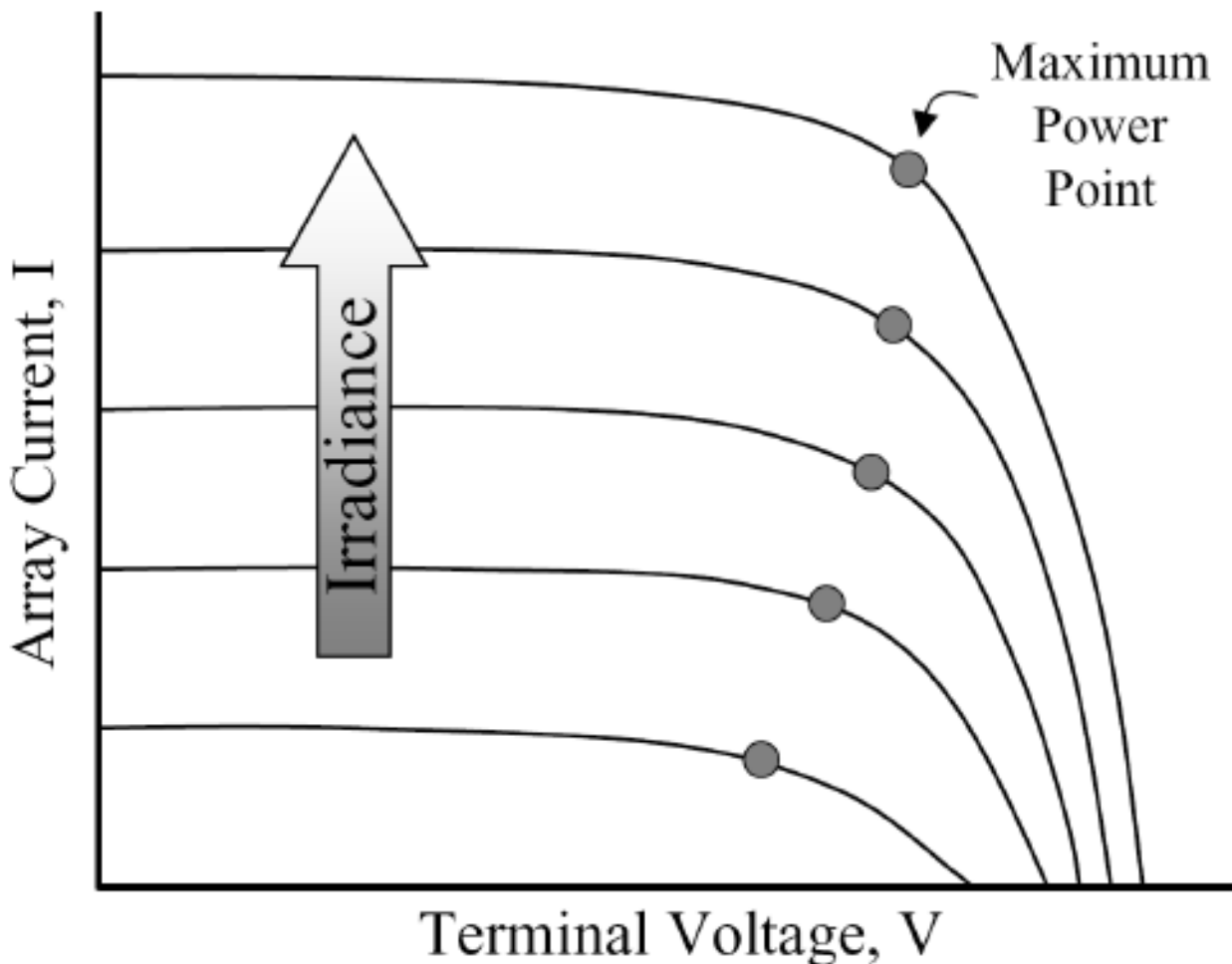


Figure 2.4: I-V curve of a solar cell at irradiation.

2.3 EFFECT OF VARIATION OF TEMPERATURE:

On the contrary the temperature increase around the solar cell has a negative impact on the power generation capability. Increase in temperature is accompanied by a decrease in the open circuit voltage value. Increase in temperature causes increase in the band gap of the material and thus more energy is required to cross this barrier. Thus the efficiency of the solar cell is reduced. [17]

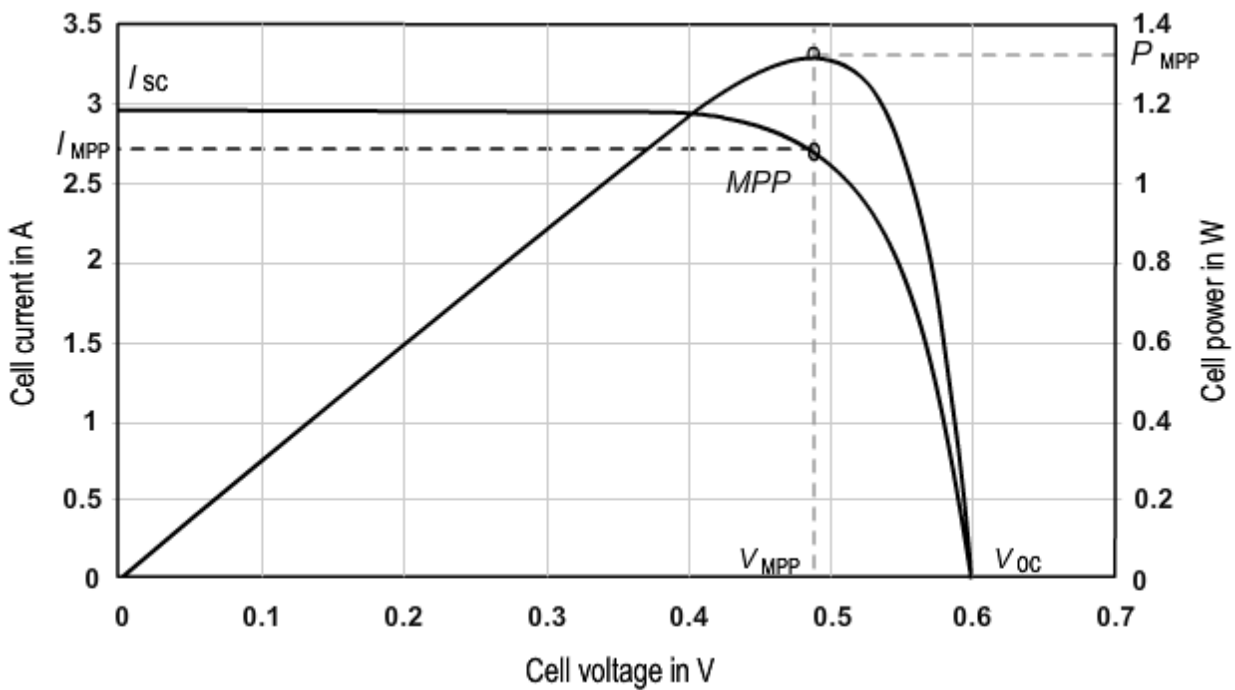


Figure 2.5: P-V I-V curve of a solar cell at given temperature and solar irradiation.

Chapter 3

OPERATION OF CONVERTER

3.1 CONVERTERS

3.2 CONTROL CHARACTERISTICS OF POWER DEVICES

Chapter 3

3.1 CONVERTERS

For the control of electric power or power conditioning, the conversion of electric power from one form to another is necessary and the switching characteristics of the power devices permit these conversions. The static power converters perform these functions of power conversions. A converter may be considered as a switching matrix. The power electronics circuits can be classified into six types:

- 1) Diode rectifiers
- 2) Ac-dc converters (controlled rectifiers)
- 3) Ac-ac converters (ac voltage controllers)
- 4) Dc-dc converters (dc choppers)
- 5) Dc-ac converters (inverters)
- 6) Static switches

The devices in the following converters are used to illustrate the basic principles only. The switching action of a converter can be performed by more than one device. The choice of a particular device will depend on the voltage, current and speed requirements of the converter.

3.1.1 Rectifier:

A diode rectifier circuit converts ac voltage into a fixed dc voltage and is shown in figure below. The input voltage to the rectifier could be either single-phase or three phase. [1]

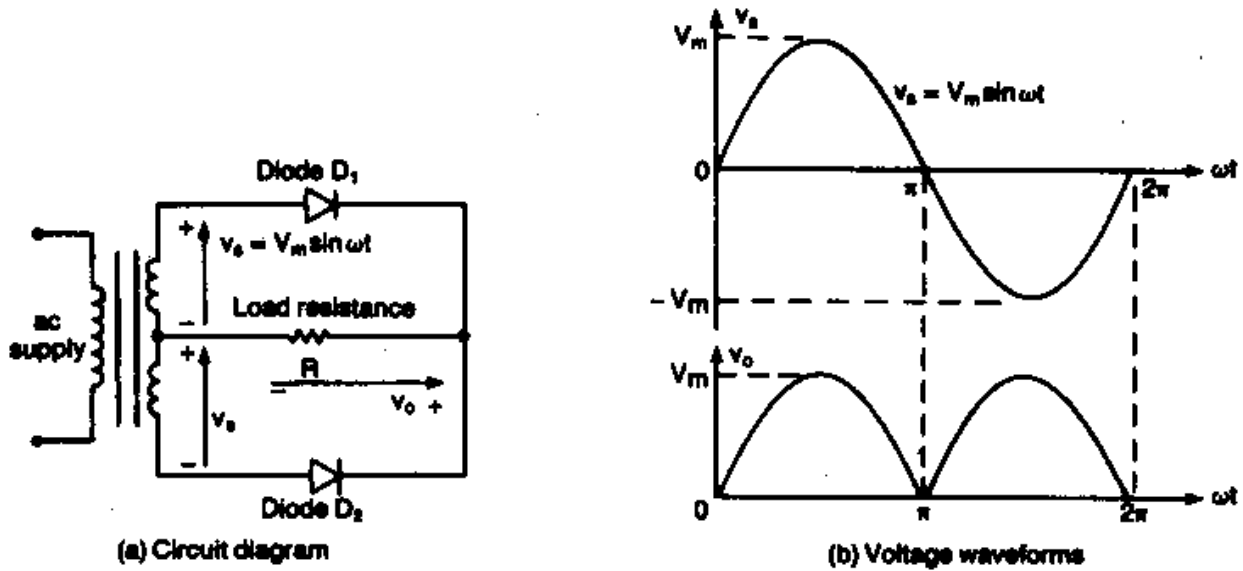


Figure 3.1: Rectifier circuit diagram and its voltage waveforms.

3.1.2 Ac-Dc converters

Ac-Dc Converters: A single phase converter with two natural commutated thyristors is shown in figure below. The average value of the output voltage can be controlled by varying the conduction time of thyristors or firing delay angle α . The input could be a single or three phase source. These converters are also known as controlled rectifiers. [1]

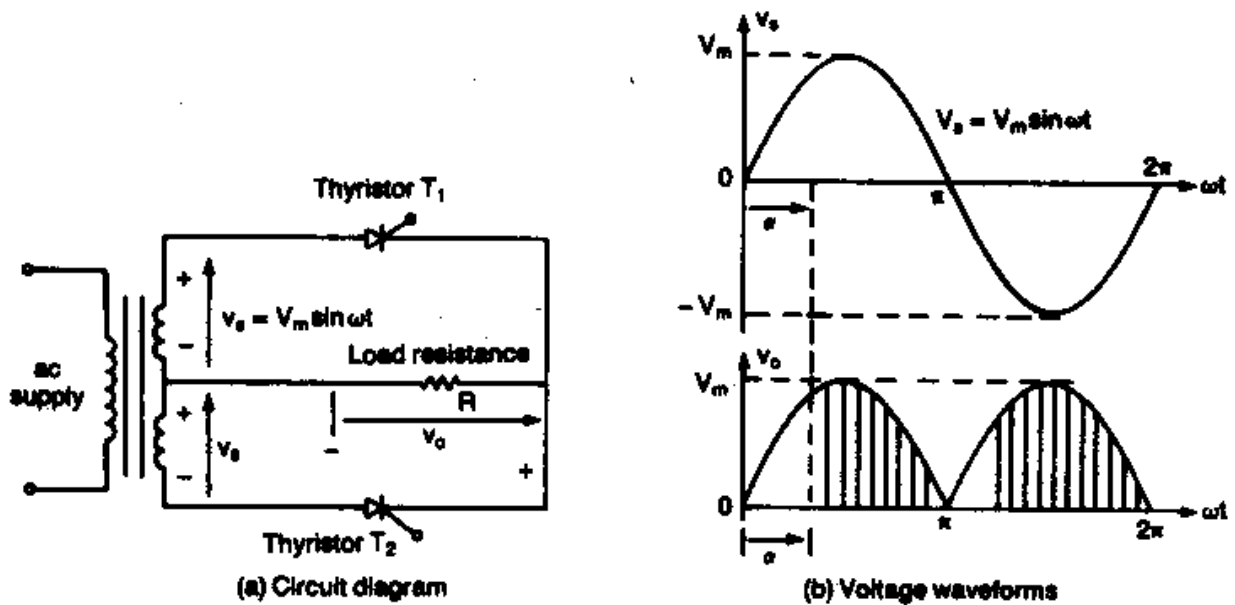


Figure 3.2: AC-DC Converter circuit diagram and its voltage waveforms.

3.1.3 Ac- Ac converters

Ac-Ac Converters: These converters are used to obtain a variable ac output voltage from a fixed ac source and a single phase converter with a TRIAC is shown in figure bellow. The output voltage is controlled by varying the conduction time of a TRIAC or firing delay angle α . These types of converters are also known as ac voltage controllers. [1]

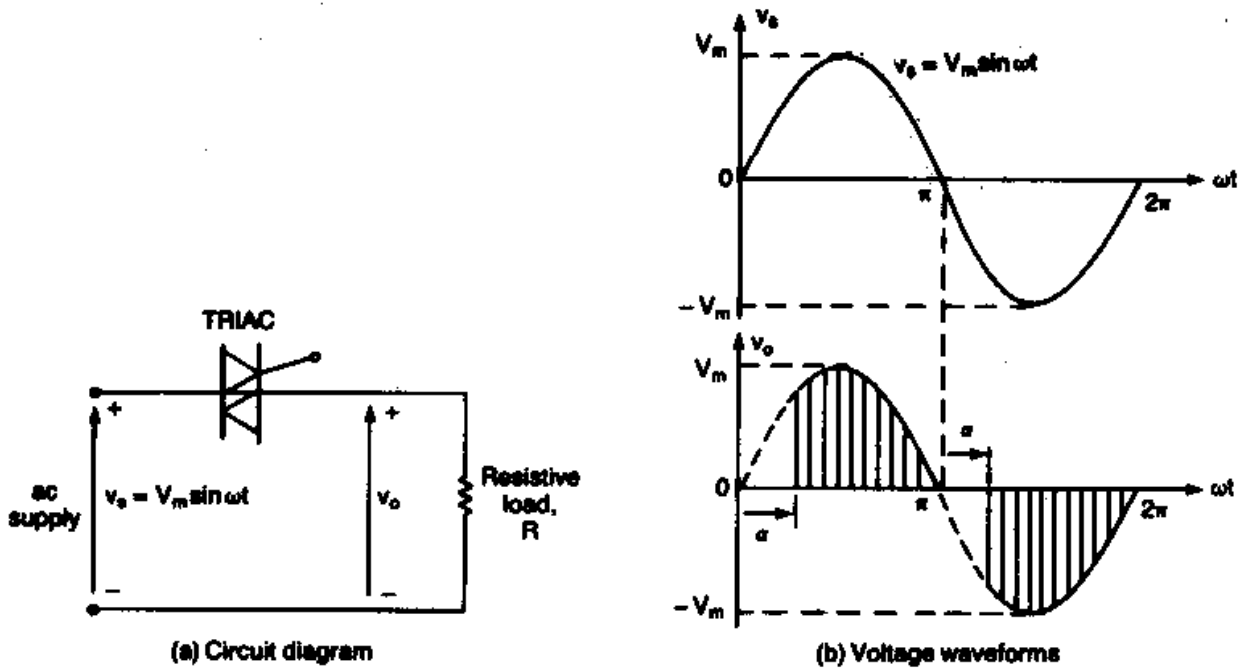


Figure 3.3: AC-AC Converter circuit diagram and it's voltage waveforms.

3.1.4 Dc-Dc converters

A dc-dc converter is also known as a chopper, or switching regulator. The average output voltage v_o is controlled by varying the conduction time t , of transistor Q_1 . If T is the chopping period, then $t_1 = \alpha T$ & is called as the duty cycle of the chopper. [1]

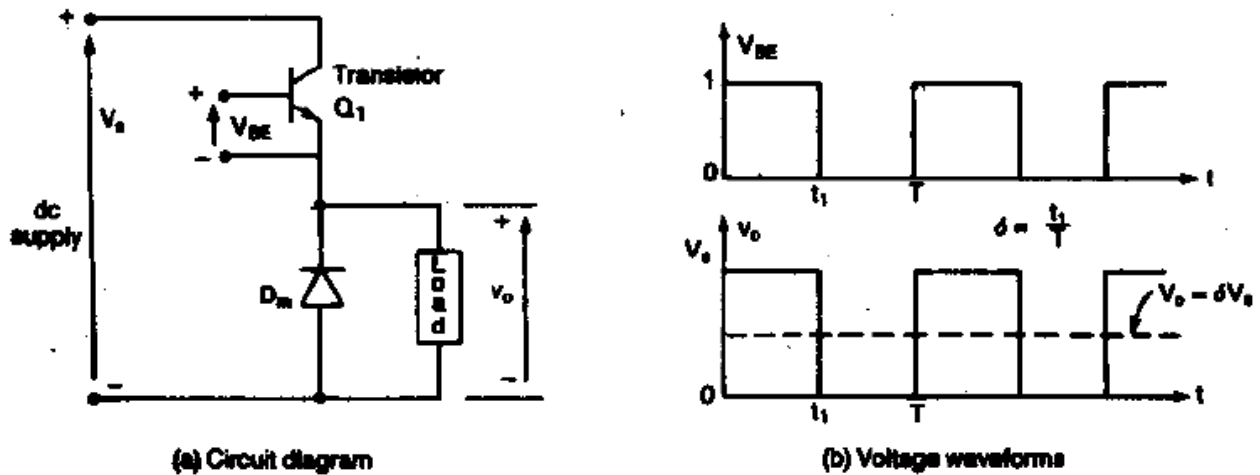


Figure 3.4: DC-DC Converter circuit diagram and its voltage waveforms.

3.1.5 Dc- Ac converters

A dc-ac converter is also known as an inverter. If transistors M_1 and M_2 conduct for one half of a period and M_3 and M_4 conduct for the other half, the output voltage is of the alternating form. The output voltage can be controlled by varying the conduction time of transistors. [1]

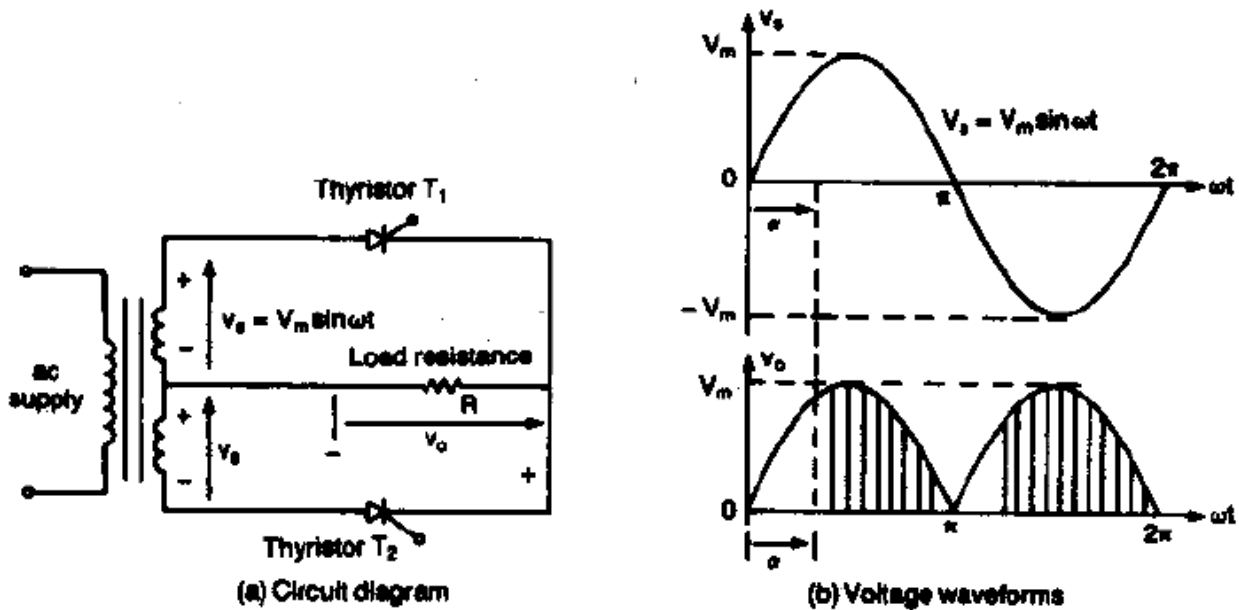


Figure 3.5: DC-AC Converter circuit diagram and its voltage waveforms.

3.1.6 Static Switches:

Since the power devices can be operated as static switches or contactors, the supply to these switches could be either ac or dc and the switches are called ac static switches or dc switches. [1]

The purpose of our thesis, we have to use only two converters. These two converters are-

1. Dc-Dc converters.
2. Dc-Ac converters.

3.2 Control Characteristics of power devices:

The power semiconductor devices can be operated as switches by applying control signals to the gate terminal of thyristors. The required output is obtained by varying the conduction time of these switching devices. Figure in bellow shows the output voltages and control characteristics of commonly used power switching devices. The power semiconductor switching devices can be classified on the basis of uncontrolled turn on and off, controlled turn on and uncontrolled turn off, controlled turn on and off characteristics, continuous gate signal requirement, and pulse gate requirement, bipolar voltage with standing capacity, bidirectional current capability, and unidirectional current capability. [1]

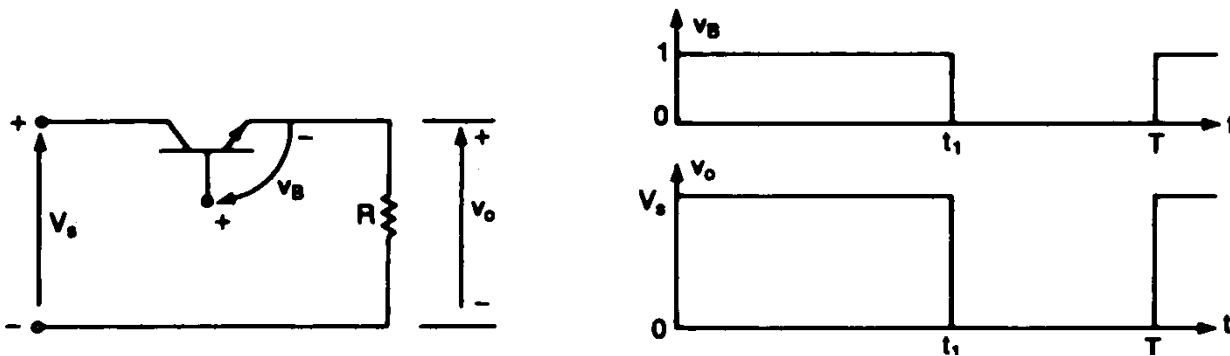


Figure 3.6: Transistor circuit diagram and it's waveforms.

Chapter 4

Maximum Power Point Tracking

4.1 Maximum Power Point Tracking

4.2 Perturb and Observe method

4.3 Incremental Conductance method

4.4 Parasitic Capacitance method

4.5 Constant Voltage method

Chapter 4

4.1 Maximum Power Point Tracking

Maximum power point tracker is a technique that is used to obtain maximum power by using inverter solar battery charger and other devices. As efficiency of a solar cell is very low, to increase the efficiency this method is to be undertaken to match the source and load properly. One such method is the Maximum Power Point Tracking (MPPT). This is a technique used to obtain the maximum possible power from a varying source. In photovoltaic systems the I-V curve is non-linear, thereby making it difficult to be used to power a certain load. This is done by utilizing a boost converter whose duty cycle is varied by using a MPPT algorithm. A converter is used on the load side and a solar panel is used to power this converter. [5][6]

There are many methods used for maximum power point tracking a few are listed below:

- Perturb and Observe method
- Incremental Conductance method
- Parasitic Capacitance method
- Constant Voltage method
- Constant Current method

4.2 Perturb and Observe method

In one method, the controller adjusts the voltage by a small amount from the array and measures power; if the power increases, further adjustments in that direction are tried until power no longer increases. This is called the perturb and observe method and is most common, although this method can result in oscillations of power output. It is referred to as a hill climbing method, because it depends on the rise of the curve of power against voltage below the maximum power point, and the fall above that point. Perturb and observe is the most commonly used MPPT method due to its ease of implementation. Perturb and observe method may result in top-level efficiency, provided that a proper predictive and adaptive hill climbing strategy is adopted. [7]

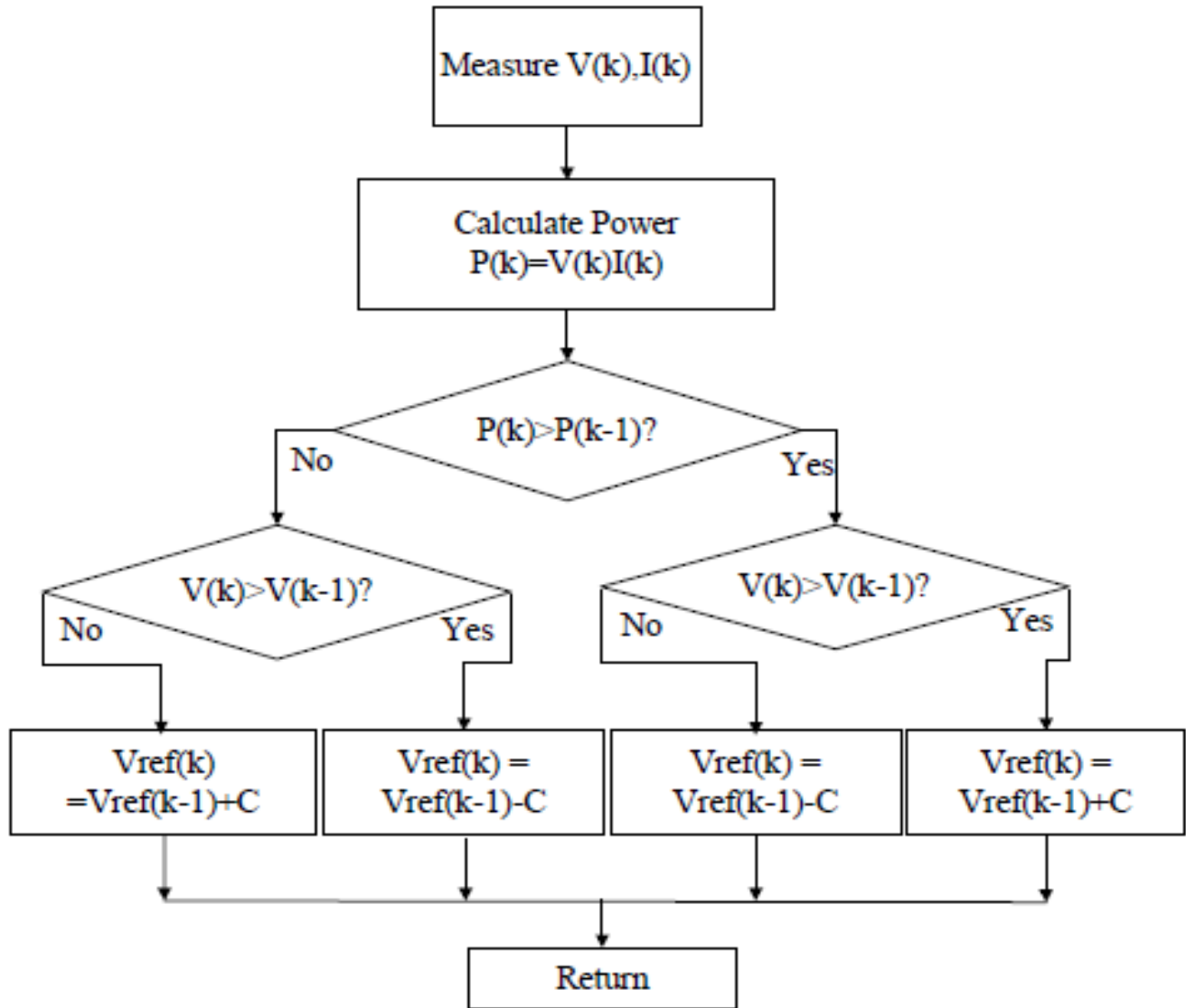


Figure 4.1: Flow chart of perturb & observe

4.3 Incremental Conductance method

In the incremental conductance method, the controller measures incremental changes in array current and voltage to predict the effect of a voltage change. This method requires more computation in the controller, but can track changing conditions more rapidly than the perturb and observe method (P&O). Like the P&O algorithm, it can produce oscillations in power output. This method utilizes the incremental conductance (dI/dV) of the photovoltaic array to

compute the sign of the change in power with respect to voltage (dP/dV). The incremental conductance method computes the maximum power point by comparison of the incremental conductance ($\Delta I/\Delta V$) to the array conductance (I/V). When these two are the same ($I/V = \Delta I/\Delta V$), the output voltage is the MPP voltage. The controller maintains this voltage until the irradiation changes and the process is repeated. [8]

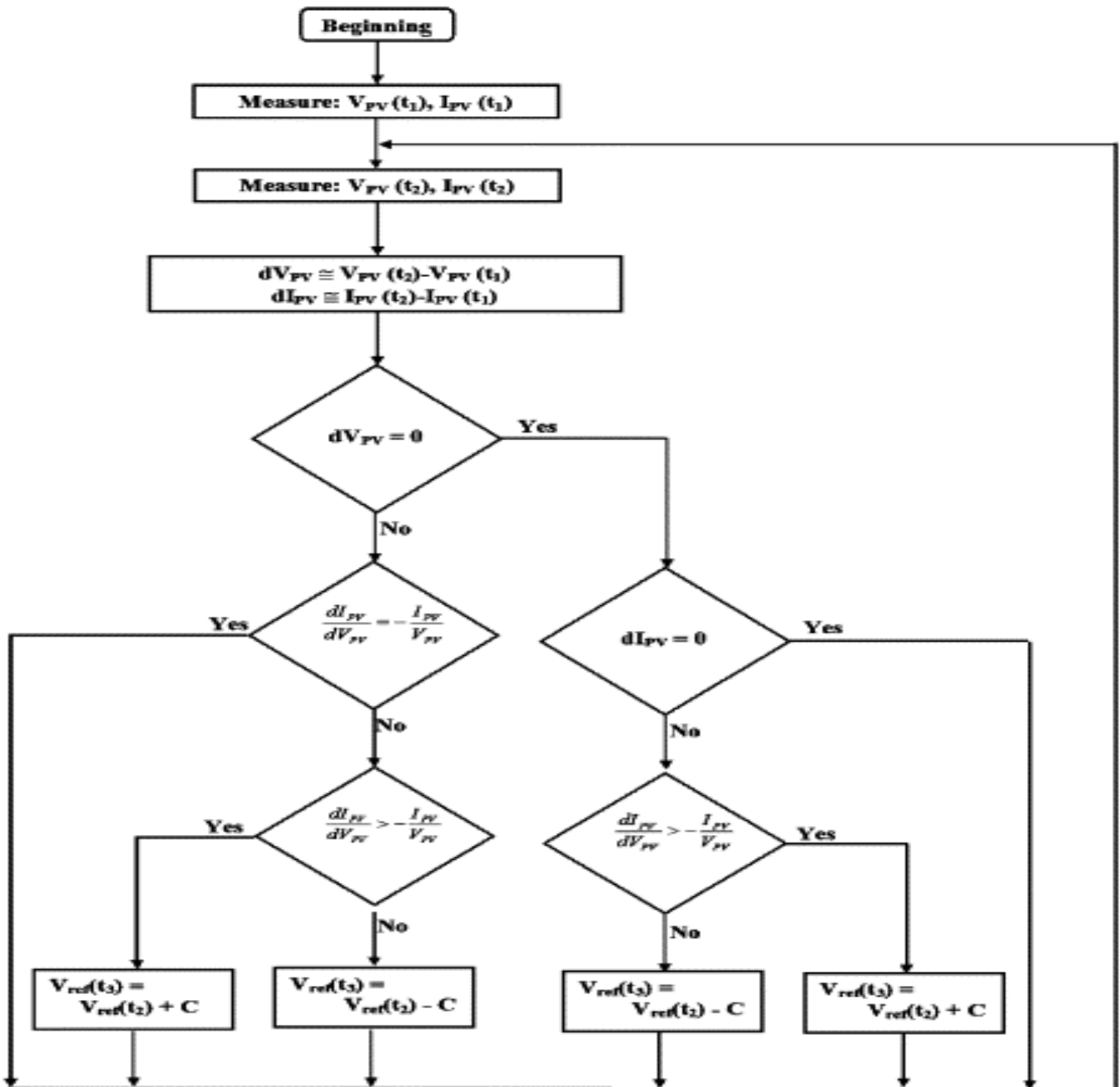


Figure 4.2: Flow chart of Incremental conductance method

4.4 Parasitic Capacitance method

This method is an improved version of the incremental conductance method, with the improvement being that the effect of the PV cell's parasitic junction capacitance is included into the voltage calculation. [7][8]

4.5 Constant Voltage method

This method which is a not so widely used method because of the losses during operation is dependent on the relation between the open circuit voltage and the maximum power point voltage. The ratio of these two voltages is generally constant for a solar cell, roughly around 0.76. Thus the open circuit voltage is obtained experimentally and the operating voltage is adjusted to 76% of this value. [10]

4.6 Constant Current method

Similar to the constant voltage method, this method is dependent on the relation between the open circuit current and the maximum power point current. The ratio of these two currents is generally constant for a solar cell, roughly around 0.95. Thus the short circuit current is obtained experimentally and the operating current is adjusted to 95% of this value. [10]

The methods have certain advantages and certain disadvantages. Choice is to be made regarding which algorithm to be utilized looking at the need of the algorithm and the operating conditions. For example, if the required algorithm is to be simple and not much effort is given on the reduction of the voltage ripple then P&O is suitable. But if the algorithm is to give a definite operating point and the voltage fluctuation near the MPP is to be reduced then the IC method is suitable, but this would make the operation complex and more costly. [7]

As we are working on the Perturb and observe method so we are going to discuss briefly about perturb and observe method with its flow chart.

The perturb-and-observe method, also known as perturbation method, is the most commonly used MPPT algorithm in commercial PV products (K. Chomsuwan et al., 1995; W. Xiao et al., 2004). This is essentially a “trial and error” method. The PV controller increases the reference for the inverter output power by a small amount, and then detects the actual output power. If the output power is indeed increased, it will increase again until the output power

starts to decrease, at which the controller decreases the reference to avoid collapse of the PV output due to the highly non-linear PV characteristic. [14]

Although the P&O algorithm is easy to implement, the utilization efficiency, however, can be further improved (at the cost of a small increase in implementation cost) by employing a hill-climbing MPPT technique such as the perturb and observe (P&O) algorithm. This is a simple algorithm that does not require previous knowledge of the PV generator characteristics or the measurement of solar intensity and cell temperature and is easy to implement with analogue and digital circuits. The algorithm perturbs the operating point of the PV generator by increasing or decreasing a control parameter by a small amount (step size) and measures the PV array output power before and after the perturbation. If the power increases, the algorithm continues to perturb the system in the same direction; otherwise the system is perturbed in the opposite direction. The number of perturbations made by the MPPT algorithm per second is known as the perturbation frequency or the MPPT frequency. The perturb and observe method can produce oscillations of power output around the maximum power point even under steady state illumination.[7] [8] [10]

Chapter 5

SIMULATION & MATLAB CODE

**5.1 SIMULATION MODEL FOR PERTURB & OBSERVE
ALGORITHM**

5.2 DESCRIPTION OF SIMULATION MODEL

5.3 MATLAB CODE

5.4 SIMULATION MODEL RESULTS

5.1 SIMULATION MODEL FOR PERTURB & OBSERVE ALGORITHM:

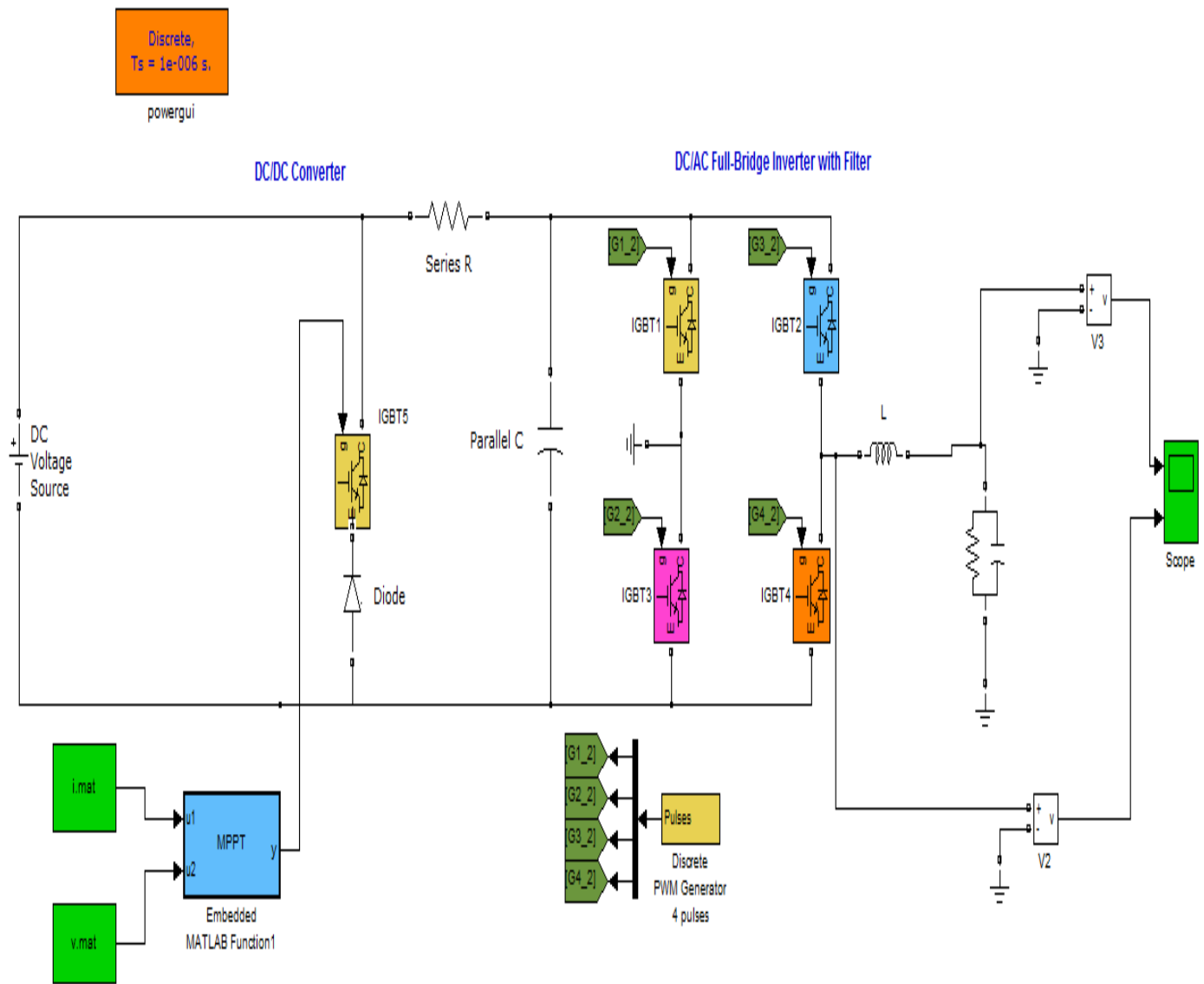


Figure 5.1: Simulation model of solar-PV conditioning system by using perturb & observe method

5.2 Description of the model

This thesis is about to simulate the PV conditioning system with matlab code. Here DC source is used because the solar panel produces DC voltage. The solar panel is represented as DC source and there is a converter which is controlled by the MPPT. A code is being develop in matlab function from which consist of real data and by using it calculate the power, reference voltage and duty cycle which is based on the algorithm of perturb and observe method. This data is load from the workspace by using the fromfile of Simulink. There are two inputs of real data one is for voltage and one is for current. These two data are considering the input (u1 & u2) for the embedded function. From this duty cycle value a pulse is obtained which will work as a pulse in the IGBT of a DC-DC converter. A dc-dc converter is also known as a chopper, or switching regulator. So it's regulate the DC voltage either it should go to load or not by using the pulse of duty cycle which comes from the embedded function block. Then this DC voltage converted into the AC voltage by using the DC-AC converter and finally a filter is being used to obtain pure AC voltage. After run the simulation a scope is used to see the output AC voltage. Practically this AC voltage will send to load. [2][9][11]

5.3 MATLAB CODE:

```
function y = fcn(u1,u2)
%eml#
index=2;
c=0.1;
v_r=0;
d= .22;
dr= .0038;

for k =index:32
    v_k=u1(k,1);
    v_k1=u1(k-1,1);
    i_k=u2(k,1);
    i_k1=u2(k-1,1);
    p_k=(v_k)*(i_k);
    p_k1=(v_k1)*(i_k1);
```



```
if p_k>p_k1

    if (v_k)>(v_k1)
        v_r=v_r+c;
        d=d+dr;

    else
        v_r=v_r-c;
        d=d-dr;

    end

else

    if (v_k)>(v_k1)
        v_r=v_r-c;
        d=d+dr;

    else
        v_r=v_r+c;
        d=d-dr;

    end

end

end

y=d;
```

5.4 SIMULATION MODEL RESULTS:

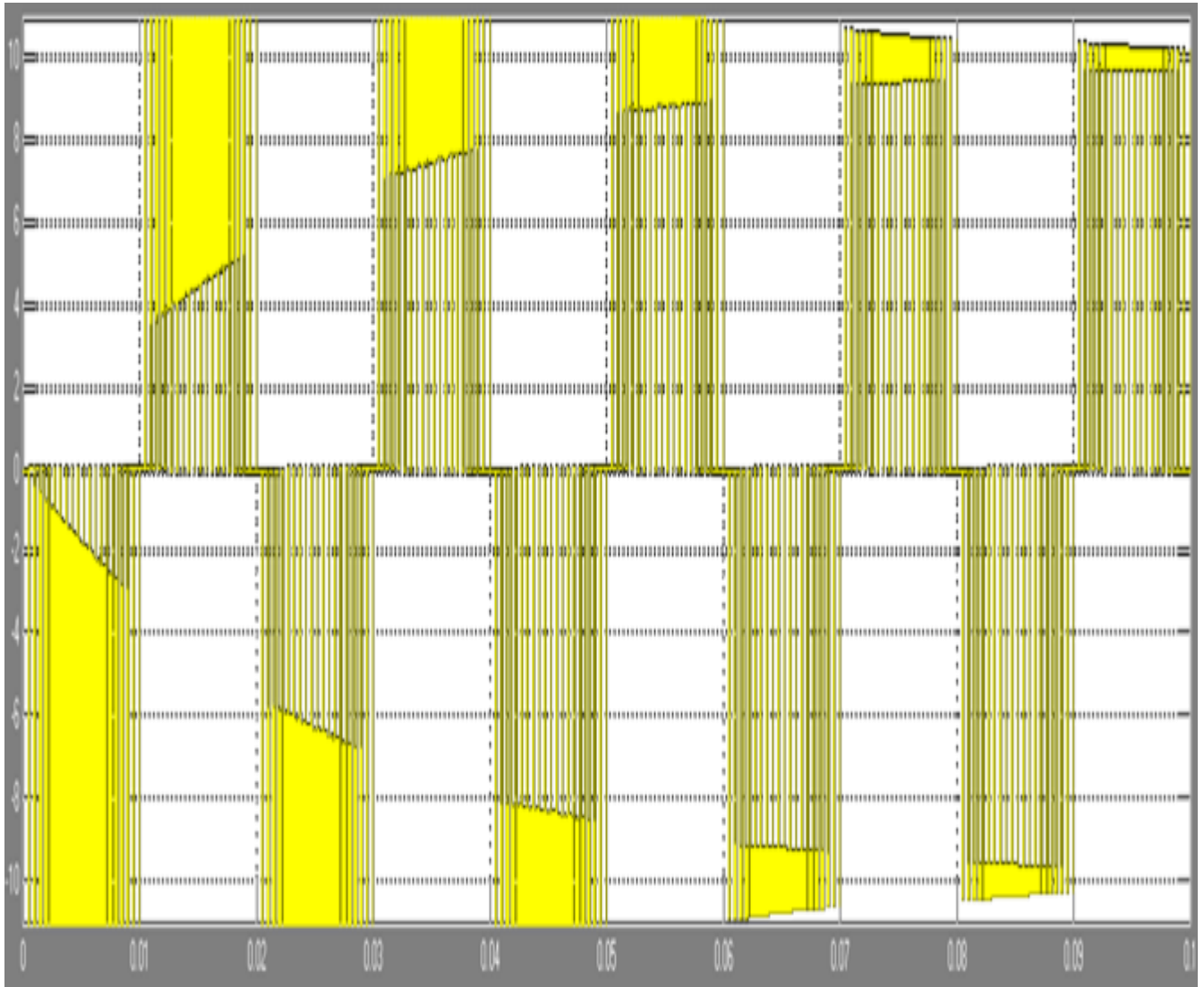


Figure 5.2: Simulation model result before filtering.

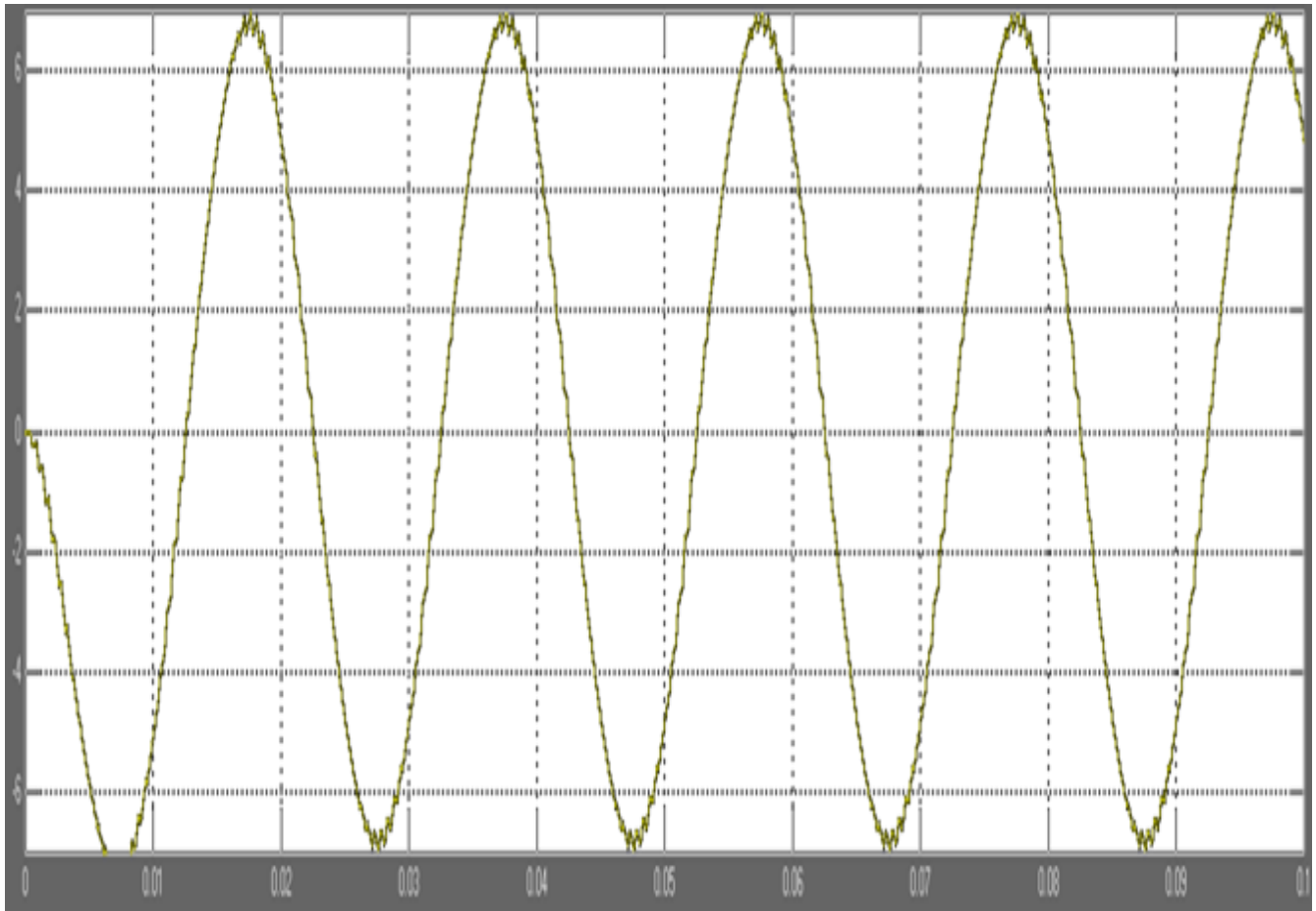


Figure 5.3: Simulation model result after filtering.

Chapter 6

CONCLUSION & FUTURE WORK

6.1 CONCLUSION

6.2 FUTURE WORK

6.1 CONCLUSION:

The model shown in fig was simulated by using SIMULINK and MATLAB in this simulation model a 10V DC source is used. A resistance of .001 ohms is connected with the converter to make the output voltage and current similar. A carrier frequency of 1000 Hz is used by the discrete pulse width modulation generator. From the workspace real data was loaded and by coding in embedded function a duty cycle value obtained which will use as a pulse. This code is made on the algorithm of perturb and observe method.

This pulse is the input of IGBT. The value of the duty cycle switches the converter either the dc voltage flow through the circuit or not by continuously increasing and decreasing. if increase then dc voltage will flow through the model and if decrease then it will not flow.

After flow through dc-dc converter this voltage converts to ac voltage by dc-ac converter. By a filter this voltage became pure ac voltage sine wave. The various waveforms were obtained by using the plot mechanism in MATLAB. There is a small loss of power from the solar panel side to the boost converter output side.

6.2 FUTURE WORK

Improvement to this thesis can be made by tracking the maximum power point in changing environmental conditions. Environmental change can be change in solar irradiation or change in ambient temperature or even both. This can be done by using Simulink models to carry out MPPT instead of writing it code in Embedded MATLAB functions. In the Simulink models the solar irradiation and the temperature can be given as variable inputs instead of constant values as done here.

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