DESIGN OF SOLAR TRACKING SYSTEM OF PV PANELS

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1. Solar system – Design
2. Renewable energy resources.
3. Solar energy

IN THE NAME OF ALLAH, THE MOST MERCIFUL AND BENIFICIENT

DEDICATED TO

MY BELOVED PARENTS, TEACHERS,FRIENDS

AND

Dr. S. M. BHUTTA (LATE).

CERTIFICATE

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DECLARATION

I certify that research work titled "Design of Solar Tracking System of PV Panels" is my own work and has not been presented elsewhere for assessment. Moreover, the material taken from other sources has also been acknowledged properly.

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Muhammad Kashif

230-FET/MSEE/S10

Abstract

In the technological era where inventions are at the bloom, there exit a need of non renewable energy resources. In Pakistan there is a dire need of energy which can be acquired through sun in the form of solar energy. The conversion of solar energy to electricity is performed by solar cells. There exists an operating point associated with solar cells at which the power generated is maximized at any given point in time. A maximum power point tracker (MPPT) is required to track this maximum power operating point. A wide range of systems exists to meet this purpose. This thesis explores the use of a single-phase controlled rectifier, with back stepping control to track the maximum power from a string of solar arrays.

Acknowledgement

I would like to thank Dr. Saeed Badshah who advised me to do research in solar energy. He along with professional consultants on solar energy Dr.Kamal and Dr.S.M.Bhutta helped me alot to complete my research. I would also like to thank my worthy teachers who taught me with excellence and professionalism. I really like to appreciate efforts of Dr. Ihsan as a graduate students mentor he guided me throughout degree program. I would also like to thank my classmates and Lab associates for cheerful meetings. At the end I would say thanks to my family for all the support without them I could not come so far.

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CHAPTER 1. INTRODUCTION

1.1 INTRODUCTION

In Pakistan, conventional energy resource is decreasing day by day with increase in cost ,and now it's our responsibility to diverge power sector to renewable resources. Due to increase in oil prices, it is becoming very difficult for a normal citizen to pay high tariffs electricity bills. Electricity bills can be reduced by converting power sector to renewable resources with solar energy being one of the major renewable resource. Mostly the utilization of energy is in hold and industry, and for house hold utilization normally conventional power resources are consumed which are costly so the use of renewable resources like solar should be encouraged. [1-3].

Power Demand has increased a lot due to industrial boom and use of modern electrical appliances that's why use due to declining conventional power generating resources it's becoming costly so the need for renewable resources like solar must be encouraged.[2].

Use of conventional resources like oil, gas and coal is widely used in power generation as it has the capability of adoption in peak load conditions but it has environmental effects, use of thermal resources cause emission of carbon dioxide, which is harmful for the environment. Therefore the need to use renewable resources is very important for minimizing demage to environment, Pakistan is a country with huge solar resource and with fast growing industry demand for renewable energy is increasing and solar is sorce of energy the easiest solution. [2, 4]

Solar energy can be used as a single unit to fulfil house hold requirements which will help in saving electricity cost.[2, 4].

Various incentives are provided nationally and internationally to encourage the use of solar energy.it is estimated roughly that total 67.4GW had been installed in solar energy sector at the end of 2011,which help in generating 85TWh/year.[5].

Table 1-1: Solar photovoltaic power generation in various countries[5]

Year	USA (MW)	Europe (MW)	Japan (MW)	Worldwide (MW)
2000	140	150	250	1000
2010	3000	3000	5000	14000
2020	15000	1500	30000	70000
2030	25000	30000	72000	140000

Table 1-2: Photovoltaic Power Worldwide[5]

YEAR	PV POWER (GW)
2005	5.4
2006	7.0
2007	9.6
2008	15.4
2009	22.9
2010	39.7

2011	**67.4**

The focal point of this thesis is Maximum Power Point Tracking (MPPT) for solar PV panels specifically in Pakistan and generally all over the globe where there is solar potential. A MATLAB Simulink based model has been designed for such a purpose to promote solar power generation.

1.2 PAKISTAN ENERGY CRISIS

Economic and industrial growth of every nation is supported by power sector, as it is the energy, which runs the industrial equipment as well as household utilization. Unfortunately, in Pakistan the main sources of energy are conventional that is oil and gas which are costly and due to it's huge cost power-generating companies are unable to pay oil prices which cause circular debt due to subsidy. Due to increase in power demand the gap between power generation and available capacity is increasing day by day, and is essential to use renewable resources like solar power which has effective cost and environment friendly [1, 3, 6].

Pakistan power sector need reforms to minimize energy shortages as well as losses. Because of oil and gas shortage and political constraints in WAPDA and KESC and corruption which has resulted in load shedding. If those constraints are not being solved it will become very difficult to minimize power shortages and corruption. [3, 7].

Currently Pakistan is facing about 3000 – 6000 MW of power short fall, considering the load of industry about 1500 – 2000 MW which has been shut down due to high tariff and power unavailability the energy short fall would have reached 8000 MW.

Power industry also face losses due to non payable amount of bills by certain consumers and also due to subsidy given in power sector in oil and gas sector which cause circular debt, which has resulted a loss of Rs. 300 billion per year which is a huge burden on national economy.[7].

1.3 PROBLEM STATEMENT

To Design a Tracking System for Solar Power Generation using PV Panels, this improves Efficiency of PV panels.

- Design of PV panel in MATLAB.
- Design of Embedded tracking system by using Maximum Power Point tracking phenomena.
- Design power converter Module in MATLAB.

1.4 METHODOLOGY

Efficiency improvement of solar PV panels will be done for generalized PV panels, by designing MATLAB model of the whole system consisting of, PV panel, Maximum Power Point Tracking design, Inverters design; results will be displayed using MATLAB graphs based on data collected for different solar energy potential sites.

1.5 SCOPE OF PROJECT

After the solar MPPT system is design, it will help use solar energy more efficiently; also, the design of inverters will help efficiency improvement and will encourage consumers to use solar energy for power utilization in public as well as private sector.

1.6 PROPOSED SOLUTION

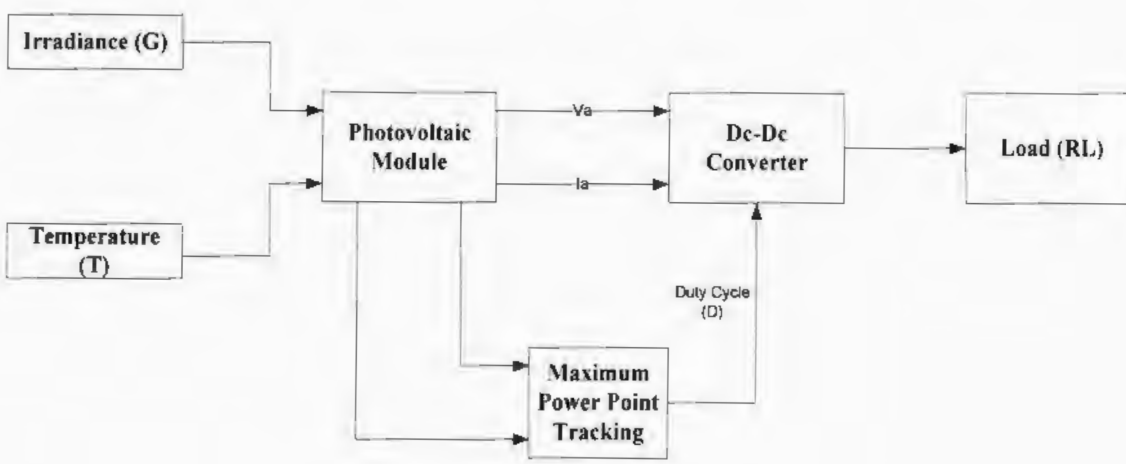

Figure 1-1 Block diagram of MPPT Technique Proposed and designed.

CHAPTER 2. SOLAR PV PANELS

2.1 SOLAR CELLS

Solar Photovoltaic cells convert sunrays into electricity directly. In other words, solar cell generates electricity or direct current by converting solar radiation. Process of converting Sunlight to electricity is called the PV effect. This effect was discovered in 1954, when scientists discover an element in sand (silicon) created an electric charge when exposed to light. [1, 8] For getting more power from solar PV, design of solar cells is mostly made flat- plate. Second type of solar cells is called thin-film solar cell, which is made from non-silicon materials, and this material referred as amorphous silicon material like cadmium telluride. Thin-film solar cell has thin layers of semiconductor materials, which are in micrometers. [5, 8] Third type of solar cells is made from different types of materials besides silicon, by using conventional printing press technology, conductive plastic and solar dyes. Some solar cell manufacturers now use plastic lenses and mirror for concentrating sunlight on PV material to improve efficiency of solar cell[5] .

2.2 BASIC STRUCTURE OF SOLAR CELL

Structure of PV cell or P-N junctions made from some kind of metal substrate. Metal substrate collects charge, so it should be in a metal contact with reasonably large layer of P-type material on it and a smaller layer of N type material [9]as shown in Figure (2-1).

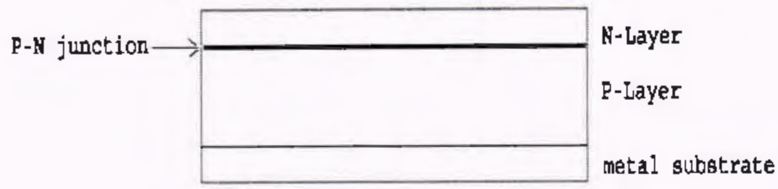

Figure 2-1 Structure of PV cell.

The sunlight falls on top surface of the cell, the depth of the N layer is thin therefore, light penetrates up to the junction. The thin layer collects charges to lay a grid of metal, more extensive grid helps to block more sun light, so it is not necessary to cover the whole surface, and rather it is like collection of metal substrate that is laid on the surface. It collects the charge from the top level and then it is connected to the some kind of load through the bottom level[10].

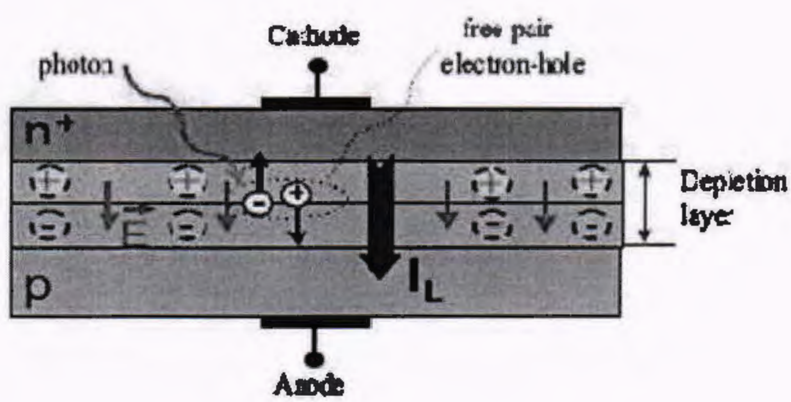

Figure 2-2 Basic structure of PV cell.[11]

When P-N junction is created and PV effect occur, the electron pairs are created and these pairs go to different directions as well but before they are collecting by the contacts they may also recombine, as a result less current is generated, to ensure there is minimum recombination. To avoid this recombination make single crystals that mean arrange all the panels in the line array then there is no reform and nothing acts as a recombination centre.[12] Photovoltaic energy Conversation

Photovoltaic cell converts solar energy into electrical energy directly. In other methods, first solar energy is converted to thermal energy then this thermal energy is used to run turbine and convert this thermal energy into electrical energy. [12]

2.3 FERMI LEVEL AND P-N JUNCTION

In P type or N type semiconductor material, there is a band gap between the conduction band and valance band. Normally the band gape in case of silicon is about 1.107 Electron volts (eV). If electrons are in conduction band, they act as conducting holes. If holes are in valance band, they act as conducting electrons. The average energy of the electrons is given by a Fermi level. Fermi level would be a level in between conduction band and valance band as shown in Figure 2-3.[12]

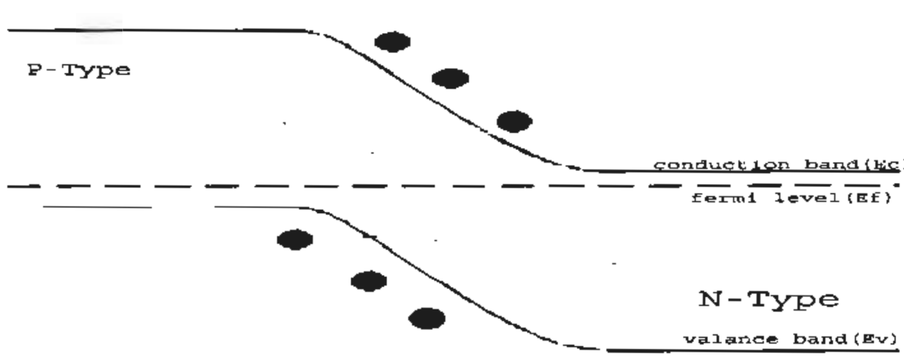

Figure 2-3 Fermi level

In P Type semiconductor material the Fermi level is closer to the valance band and in N type semiconductor material it is closer to conduction band. Fermi level is represent the average energy of the material.

The basic theory of P-N Junctions such that the Fermi level becomes equal and as a result, the band bends like bow, so the Fermi level becomes equal. Due to this band bending the electrons, find difficulties to go up hill and holes to go downhill. In photovoltaic cell, this property is essentially used to create charges but in addition of sunlight which is not in the normal diode. The sun light must be fall into a place, which is very close to the band bending, and this is band called Rays Region. [12, 13]As a result, the sunlight is incident upon material and the electrons will observe the sunlight, if photon energy is bigger than the band gap energy then the electron is knock off from their position to make them free resulting in movement of electrons to conduction band and holes in valance band as shown in Figure 2-4.

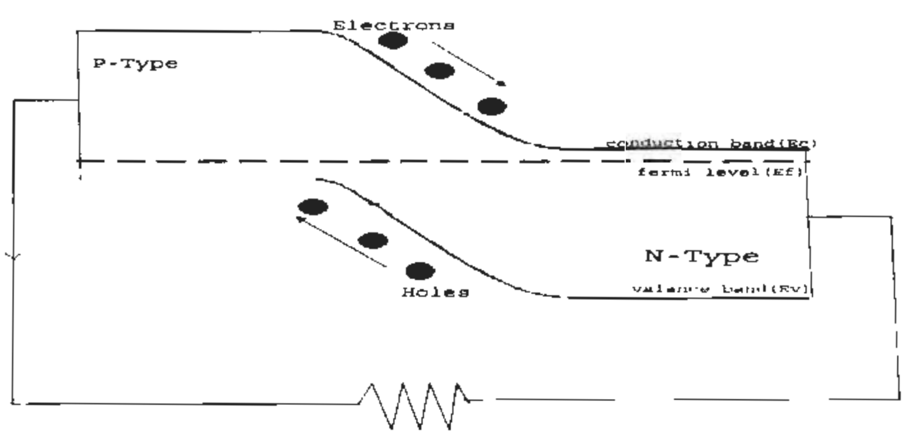

Figure 2-4 Flow of electrons and holes.

The creation of electron pair has to be created close to the bending region, which means that a large amount of area should be exposed to the sun light.

2.4 TYPES OF SOLAR CELL

In fact almost all the photo voltaic cell commercially manufactures are single crystalline solar cell but it is a fact that they are so much expensive and therefore some companies prefer to make it cheaper.

There are three main types of Solar cells.

Table 2-1 : Solar Cell Types and Efficiency

TYPE OF SOLAR CELL	EFFICENCY OF CELL
The Single crystal Solar Cell.	20 - 27%
Poly-crystalline Solar Cell.	10 - 15%
Amorphous Silicon Solar Cell.	2 - 5%

2.5 Efficiency of Solar cell

It is necessary to choose the material that has proper band gape. Silicon is good for this purpose and Germanium is reasonably good than other materials. There are other materials, which are considerable germanium.

The introductive levels of the solar cells are made up of Silicon, which has band gap energy of about 1.107Electron volt. Now in the single crystal solar cell has largest efficiency and it has normally the efficiency would be 20 to 25%.

Hundred percent conversation of solar energy to electrical energy is not possible. There are many methods to increase efficiency of solar cell. The most commonly used method is MPPT (Maximum Power Point Tracking). A different and improved algorithm is developed to improve efficiency of solar PV using MPPT technique. [14]

2.6 MANUFACTURING OF PV PANELS

There is no need to refine 100% normally some amount of impurities can be allowed for reducing the production cost. This is done by taking a cross-able heating, moulted material is used to start the formation of crystal and there is a metal contact at the bottom of it, there is silicon seed which is just touching the surface of the moulted silicon now it will cool down slowly. When it become slightly lesser than the melting temperature then silicon start to solidify and seed is settled there and as a result crystal start to grow called as silicon ingots.[4, 10]

Silicon ingots are always in the form of circular cylinder, due to very natural process. It is very difficult to make it like a square shape. Now this cylinder or ingot cut into very thin slices about one millimetre and each of these used in solar cell. Each individual cell producing a voltage approx. 0.8 volts which is not sufficient for battery charging, So No. of cells is connected in series to produce a voltage of 30 volts.

2.7 MODELING OF PV PANELS

A constant current source called PV cells, which is parallel connected to P-N junction, the source current I_{ph} results the excitation of excess of carrier electron from solar radiation. I_S is a saturation current of diode and R_L is the load resistance as shown in Figure 2-5 [10, 15].

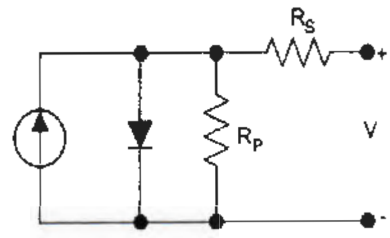

Figure 2-5 Equivalent circuit of solar

The current depend upon the amount of solar energy, called photo current (I_{PH}).The series resistance is the resistance through bulk Material not only that the resistance between the bulk materials it is combination of all the resistance in the path of electron flow in solar cell. So diode current will be

$$Id = Io\left(e^{\frac{q.Vd}{\gamma kT}} - 1\right) \quad (2.1)$$

Moreover, the load current will be

$$Iph - Id = Il \quad (2.2)$$

The electron and hole pairs get separated but before they are separated and flows to the external load they are combined inside and electron and hole pairs generated. Actually related to the amount of solar radiation that is received on the surface of the cell. There is more recombination and obviously, it is not the fault of solar radiation that will not be reflected here. R_{sh} represent the recombination of the electron hole pair, which is load so here we have simple equivalent model of photo voltaic cell and load is represented by R_L and now we make relationship between the voltage and current that is seen by the load in equation as

$$Iph - Io\left(e^{\frac{q.Vd}{\gamma kT}} - 1\right) = Il \qquad (2.3)$$

Now when R_{Sh} is connected then load current will be

$$Iph - Io\left(e^{\frac{q(Vl+IlRs)}{\gamma kT}} - 1\right) = Il \qquad (2.4)$$

And

$$\frac{(Iph - Il)}{Io} = \left(e^{\frac{q(Vl+IlRs)}{\gamma kT}} - 1\right) \qquad (2.5)$$

$$\ln\left(\frac{Iph-Il}{Io} + 1\right) = \frac{q(Vl+IlRs)}{\gamma kT} \qquad (2.6)$$

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Where q is electron charge,

d is diode voltage,

R_s is constant and it has different value for different diode,

k is Boltz Mann constant,

T is absolute temperature.

In equation (2.6) we have *VL* and IL so therefore it gives a relationship between voltage and current seen by the load,

$$\ln\left(\frac{Iph-Il}{Io} + 1\right)\gamma\frac{\gamma kT}{q} = VlRsIl \qquad (2.7)$$

Now we exclude *VL*

$$Vl = \ln\left(\frac{Iph - Il}{Io} + 1\right)\gamma\frac{\gamma kT}{q} - IlRs \qquad (2.8)$$

This is only possible because we ignore shut resistance otherwise it is not possible now if we have open circuit I_L& I_s are zero as shown in equation 2.9.

$$V = \ln\left(\frac{Iph}{Io} + 1\right)\gamma\frac{\gamma kT}{q} - Rs \qquad (2.9)$$

I_o is constant here and I_{ph} is dependent on variable solar energy. Mostly the photovoltaic cell means a single cell, which has voltage of 0.8 volts. Panel is the collection of the cells and cell mean a single cell so here we Assumes as both cell or a panel so now we write its equations as

$$Iph - Id - Ish = Il \qquad (2.10)$$

Putting values in equation (2.10) then

$$Iph - Io\ \left(e^{AVd} - 1\right) - \frac{Vd}{Rsh} = Il \qquad (2.11)$$

Here

$$A = \frac{q}{\gamma kT}$$

Putting the value of V_d in equation (2.11) then

$$Iph - Io\ \left(e^{A(Vl+IlRs)} - 1\right) - \frac{Vl+IlRs}{Rsh} = Il \qquad (2.12)$$

2.8 SOLAR TRACKING.

Output power of solar PV panels is rated under ideal conditions, but the DC output of panel depends on sunlight and sunlight affected by tilt angle, tracking and shading. Tracking system increase the efficiency of PV panel, a dual axis tracker can increase efficiency by 35-40%. Weather condition is also affect the efficiency of PV panel, because increase in temperature also reduces panel's output current.[12]

At any specific location on earth, at given isolation level and temperature, output power of the PV cell maximum at one point and this point is called maximum power point (MPP). It is our desire to operate PV cells at this point, but the shading and the ageing of PV cells also affect on maximum power point locus and output electrical load also changed by the time. To get this maximum power point operation, a tracking system is required to match varying source and varying electric load. This tracking system or matching network is called the maximum power point tracking (MPPT). Maximum power point tracking network must ensure that PV panels or arrays operate at maximum power point, regardless of weather conditions and change in electric load.[15]

There are many algorithms are used for achieving MPP tracking, but Perturb and observation **and** Incremental conductance algorithm are used mostly. Solar energy is used for different purposes like battery charging, feed to grid station and it is also used in tracking system.

2.9 MATLAB SIMULATION:

A general PV module is chosen for MATLAB simulation. This module has 36 multicrystalline solar cells in series and provides more than 50W of power at output. Table 2-2 shows Electrical specifications of module.[15]

Table 2-2 Electrical characteristics.

Maximum Power (Pmax)	64W
Maximum Power Voltage (Vmpp)	17.4V
Maximum Power Current (Impp)	3.11A
Open Circuit Voltage (Voc)	21.7V
Short Circuit Current (Isc)	3.31A
Max System Voltage	600V
Temperature Coefficient of Voc	$-8.21*10^{-2}V/C^{o}$
Temperature Coefficient of Isc	$1.33*10^{-3}A/C^{o}$

Figure 2-6; first part shows the plot of solar cell current and voltage characteristics at various temperatures simulated with MATLAB.

Figure 2-6; 2nd part shows the plot of solar cell power, voltage curves at various temperatures, and Irradiations simulated with MATLAB.

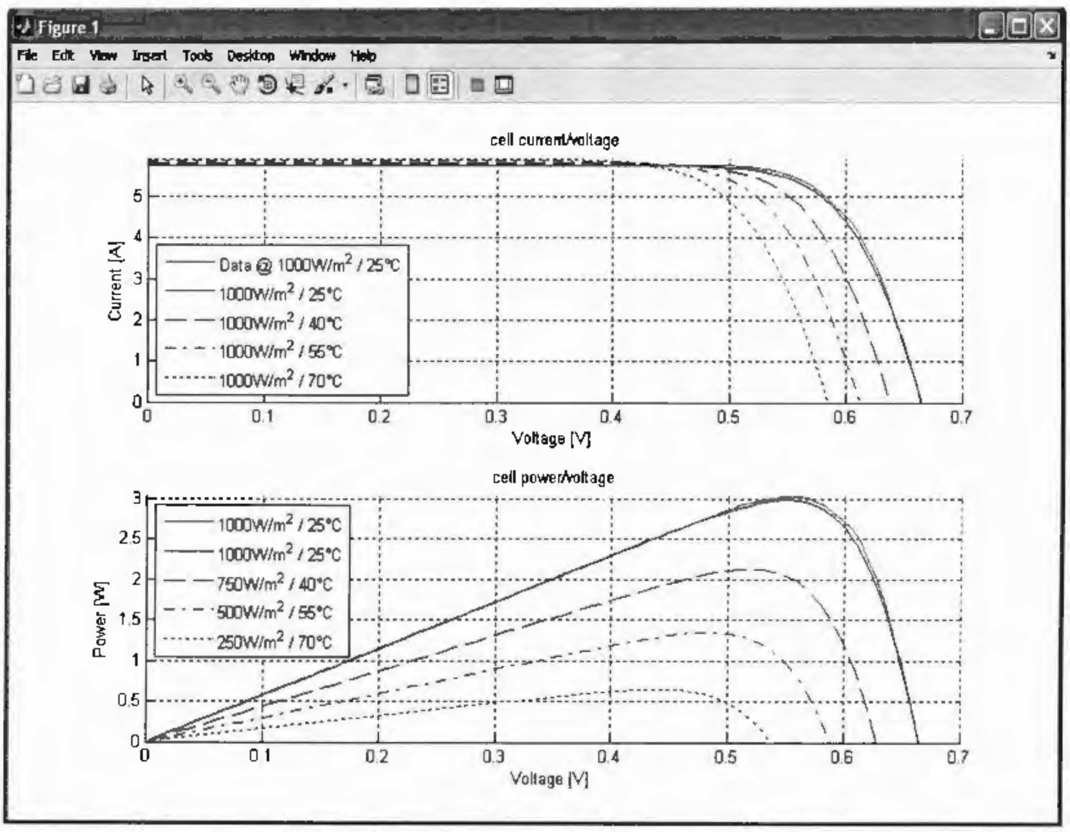

Figure 2-6 Solar cell characteristics.

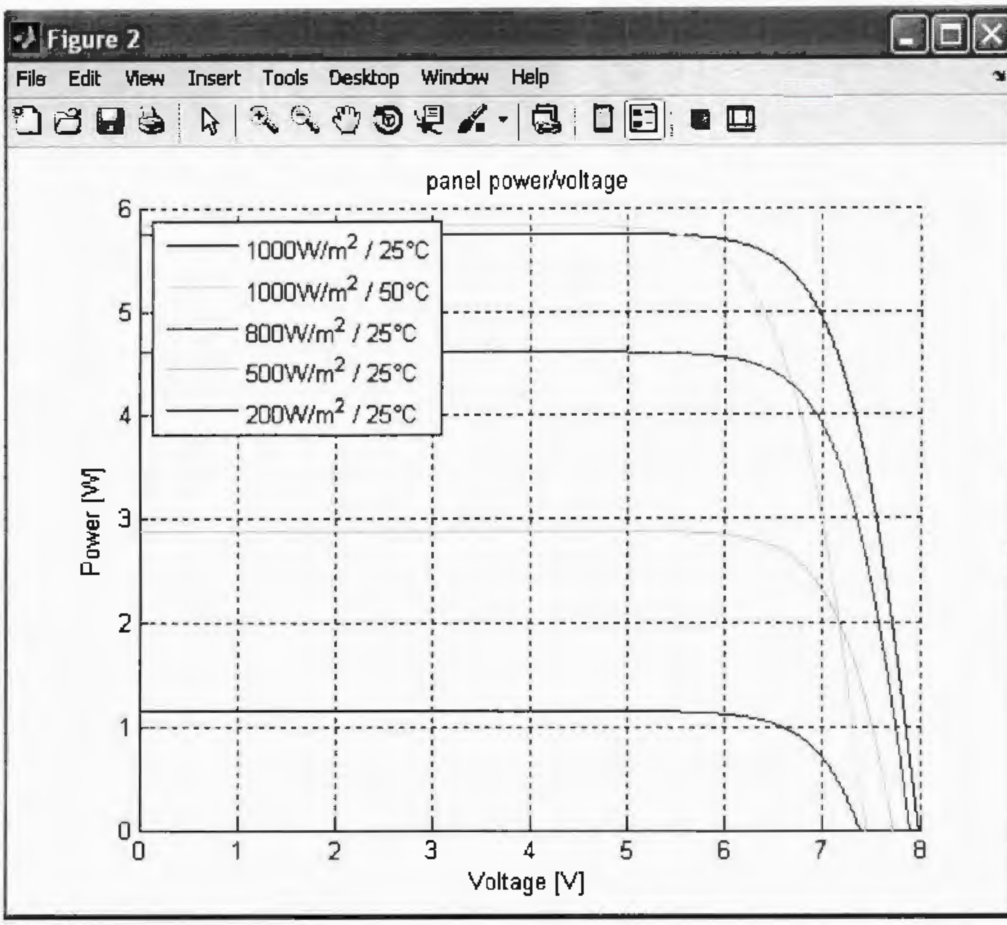

Figure 2-7 Show the power curve at various temperatures and irradiations simulated with MATLAB.

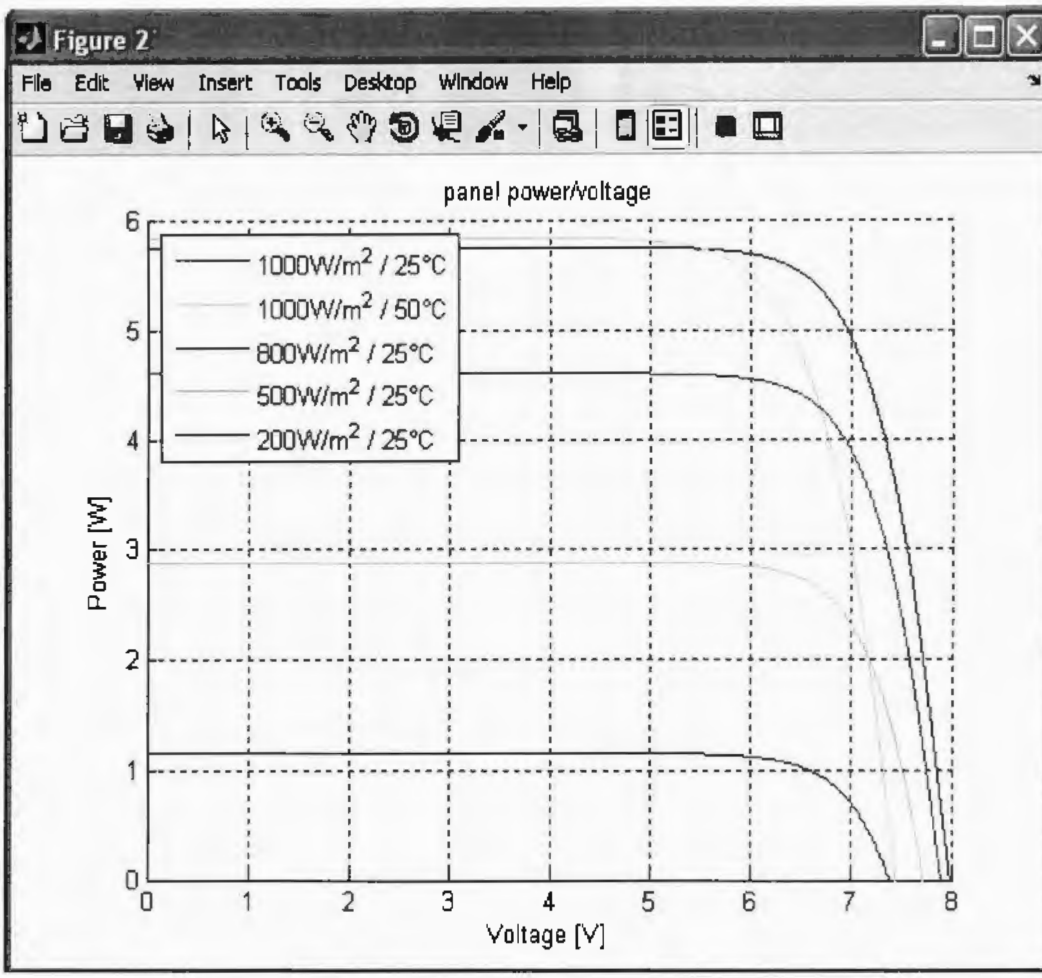

Figure 2-8 Power curve of PV module

2.9.1 Simulation of Solar PV Panel in MATLAB

We know that

$$Iph = G * Isc \tag{2.13}$$

Where G is irradiance (1G=1000W/m^2), Isc is short circuit current, and Isc in solar cell is

$$Isc = Isc_{Tr} * [1 + \left(a * \left(Ta - Tr\right)\right) \qquad (2.14)$$

Where Ta is reference temperature in Kelvin, Ta is temperature of module in Kelvin; "a" is increases in temperature [1]. Output voltage at reference temperature is

$$Vt_{Tr} = \frac{(n * k * Tr)}{q} \qquad (2.15)$$

Where n is diode quality factor in ideal condition and value of n is 1,k is Boltzmann constant, q is amount of charge, Va is Module operating voltage (V). Output voltage at actual temperature is

$$Vt_{Ta} = \frac{(n * k * Ta)}{q} \qquad (2.16)$$

So

$$I = Isc - Io\left(e^{\frac{q(V+IRs)}{nkT}} - 1\right) \qquad (2.17)$$

$$dI = 0 - Io.q\left(\frac{(dV+Rs.dI)}{nkT}\right).\left(e^{\frac{q(V+IRs)}{nkT}}\right) \qquad (2.18)$$

$$Rs = -\frac{dI}{dV} - \frac{\frac{nkT}{q}}{Io.\left(e^{\frac{q(V+IRs)}{nkT}}\right)} \qquad (2.19)$$

At open circuit condition V=Voc and I=0 then equation (2.19)

$$Rs = -\frac{dV}{dI} - \frac{\frac{nkT}{q}}{Io.\left(e^{\frac{q(Voc)}{nkT}}\right)} \tag{2.20}$$

Where dV/dIis slope of I-V curve at Voc, Voc is open circuit voltage of solar PV cell, KC50T datasheet gives a value of Rs of single cell is 5.1mΩ.

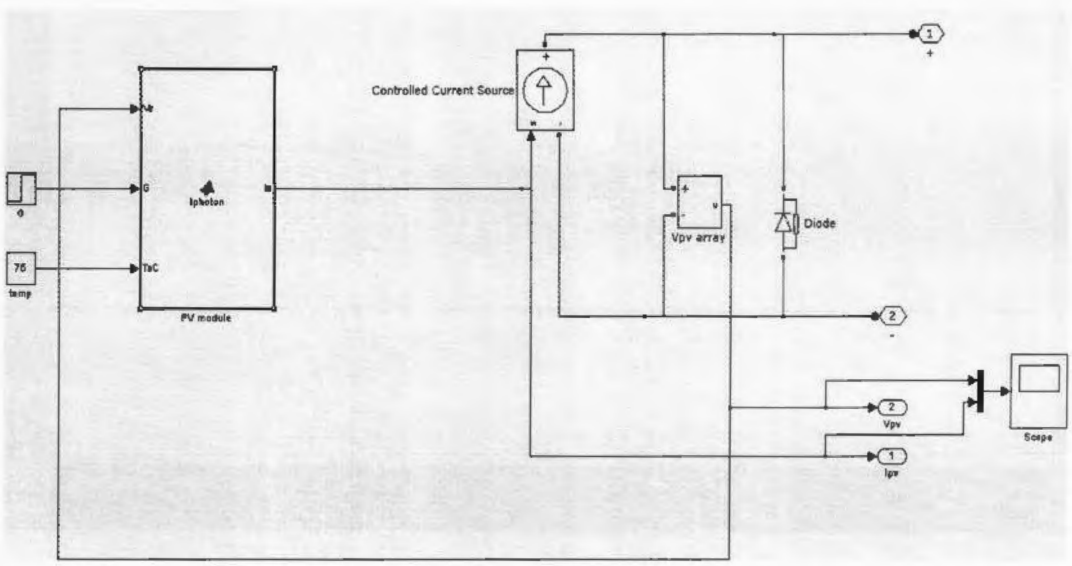

Figure 2-9 Simulink model of PV module.

k is Boltzmann constant (1.381e-23)

q is electron charge (1.602e-19)

n is diode ideality factor (1 <n <2) and (n= 1.3)

Eg is Energy gap which is 1.12eV (Si), 1.42 (GaAs)

Ns is number of cells

Step 2 putting values.

Initialize Ia with zeros and take values of Temperature, short circuit current and open circuit voltage.

T1 normalised temperature in Kelvin [K] = (273 + 25)

Voc_T1 is Open-current voltage at T1 [V] = (0.665)

Isc_T1 is Short-circuit current at T1 [A] = (5.75)

Step 3 Computation

- *Short circuit current*

$$\mathrm{Isc} = \mathrm{Isc}_{\mathrm{Tr}} * (1 + (a * (\mathrm{Ta} - \mathrm{Tr})))$$

$$Iph = G * Isc$$

- *Computing Rs*

Take dV / dI at Voc

$$\mathrm{Xv} = \left(\frac{\mathrm{Ir}_{\mathrm{Tr}}}{\mathrm{Vt}_{\mathrm{Tr}}}\right) * e^{\frac{\mathrm{Voc}_{\mathrm{Tr}}}{\mathrm{Vt}_{\mathrm{Tr}}}}$$

So,

$$\mathrm{Rs} = -\,\mathrm{dVdI}_{\mathrm{Voc}} - \frac{1}{\mathrm{Xv}}$$

- *Calculating saturation Io*

Current at reference temperature is

$$Ir_{Tr} = \frac{Isc_{Tr}}{(e^{\frac{Voc_{Tr}}{Vt_{Tr}}} - 1)}$$

So,

$$Ia = Iph - Ir * \left(e^{\left(\frac{Vc+Ia*Rs}{Vt_{Ta}}\right)} - 1\right)$$

At open circuit condition V=Voc and I=0 then equation (2.19)

$$Rs = -\frac{dV}{dI} - \frac{\frac{nkT}{q}}{Io.\left(e^{\frac{q(Voc)}{nkT}}\right)} \tag{2.20}$$

Where dV/dIis slope of I-V curve at Voc, Voc is open circuit voltage of solar PV cell, KC50T datasheet gives a value of Rs of single cell is 5.1mΩ.

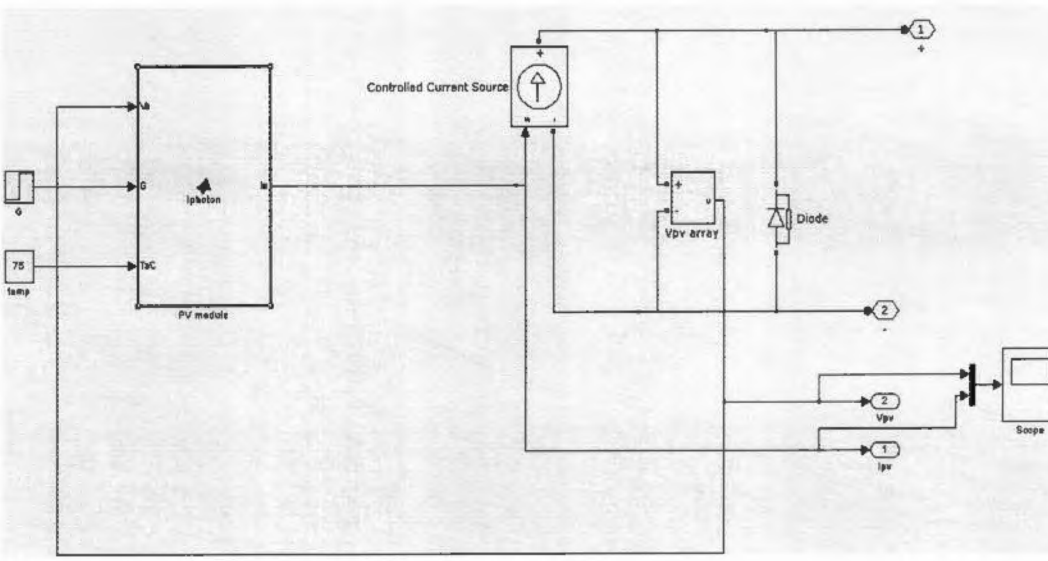

Figure 2-9 Simulink model of PV module.

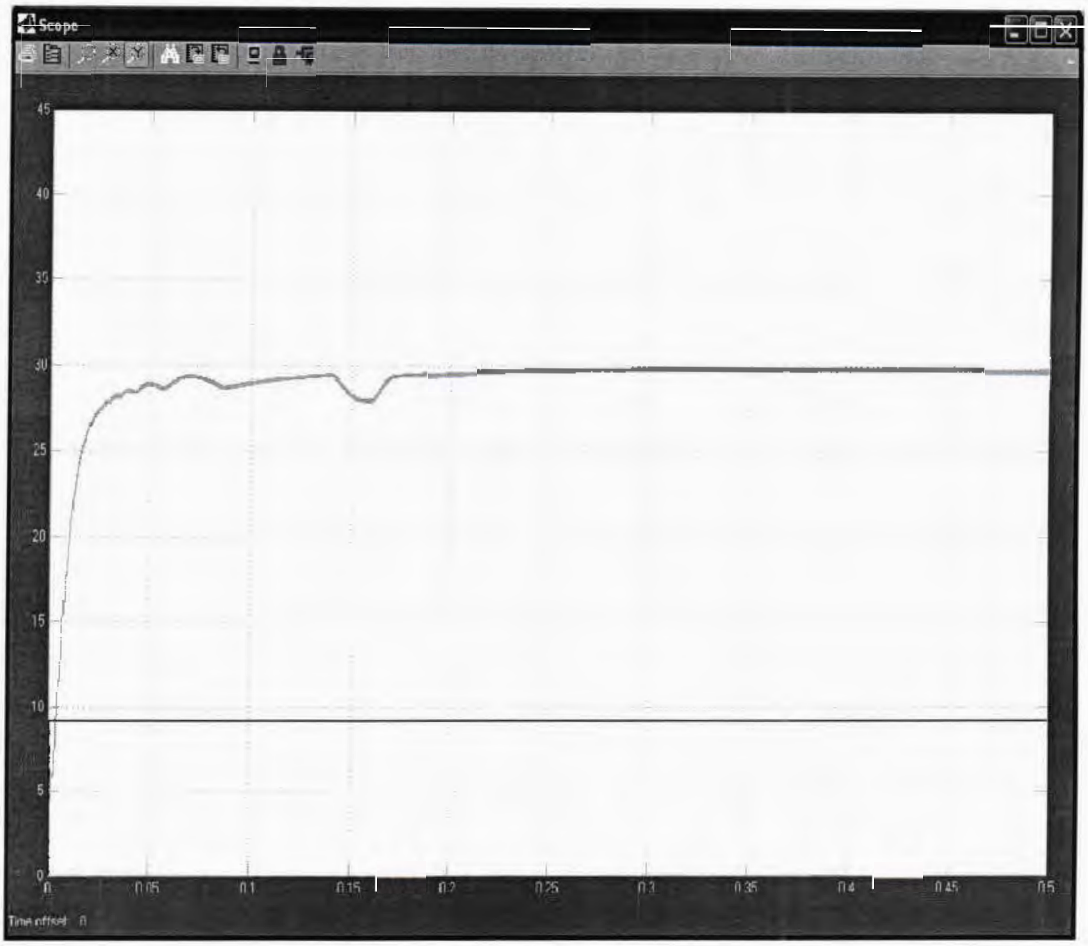

Figure 2-10 Output curve of PV panel

2.10 METHODE

Step 1 Initialization of Variables.

In first step initialize variables Ia, Va, G, k, q and n

These parameters obtained from the Generalize solar panel

Where

Ia is Module operating current (A)

Va is Module operating voltage (V)

G is irradiance (1G = 1000 W/m^2)

TaC is temp of module in Celsius

k is Boltzmann constant (1.381e-23)

q is electron charge (1.602e-19)

n is diode ideality factor (1 <n <2) and (n= 1.3)

Eg is Energy gap which is 1.12eV (Si), 1.42 (GaAs)

Ns is number of cells

Step 2 putting values.

Initialize Ia with zeros and take values of Temperature, short circuit current and open circuit voltage.

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Voc_T1 is Open-current voltage at T1 [V] = (0.665)

Isc_T1 is Short-circuit current at T1 [A] = (5.75)

Step 3 Computation

- *Short circuit current*

$$Isc = Isc_{Tr} * (1 + (a * (Ta - Tr)))$$

$$Iph = G * Isc$$

- *Computing Rs*

Take dV / dI at Voc

$$Xv = \left(\frac{Ir_{Tr}}{Vt_{Tr}}\right) * e^{\frac{Voc_{Tr}}{Vt_{Tr}}}$$

So,

$$Rs = -dVdI_{Voc} - \frac{1}{Xv}$$

- *Calculating saturation Io*

Current at reference temperature is

$$Ir_{Tr} = \frac{Isc_{Tr}}{(e^{\frac{Voc_{Tr}}{Vt_{Tr}}} - 1)}$$

So,

$$Ia = Iph - Ir * \left(e^{\left(\frac{Vc+Ia*Rs}{Vt_{Ta}}\right)} - 1\right)$$

CHAPTER 3. POWER ELECTRONICS MODULE

3.1 DC-DC CONVERTERS

There are three basic types of dc-dc converters topologies

a) Buck Converter Topology.

b) Boost Converter Topology.

c) Buck-Boost Converter Topology.

3.2 BUCK CONVERTER

A simple dc-dc buck converter circuit is shown in figure 3-1. Only a simple switch is shown in this circuit, for which an electronic device is belonging to transistor or IGBTs are generally used. A diode D_F is freewheeling diode, which is used to allow current through it when switch S is turned off. This circuit is also called step down chopper, because the output voltage of the circuit is lower than input voltage. [13, 16, 17]

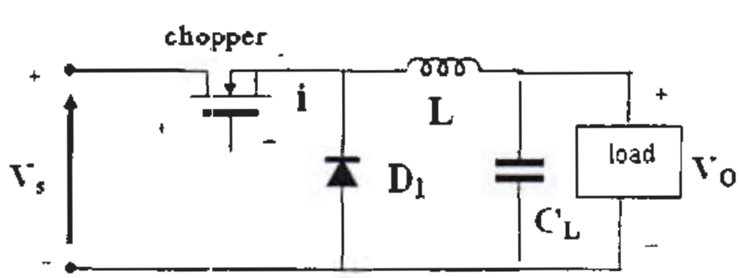

Figure 3-1 Buck converter[11]

The output voltage and current waveforms of the circuit are shown in figure3-2.output voltage of the circuit is same as input voltage of this circuit[vo = Vs] when switch is turned ON, during $T_{on} \leq t \geq 0$ this is called ON period.[13, 17]

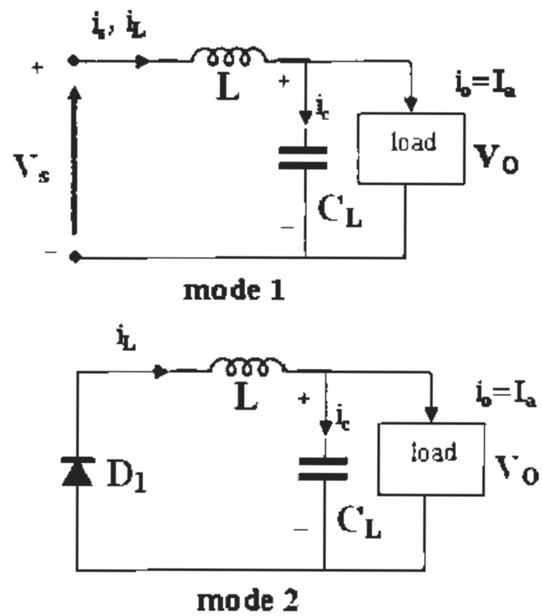

Figure 3-2 Equivalent circuit[11]

When switch is OFF [Toff = T − Ton] now diode D_f conducts or forward bias and time period is [$T = T_{ON} + T_{off}$]

Average output voltage of the circuit is

$$Vo = \frac{1}{T} . \int_0^T vo\, dt \tag{3.1}$$

$$Vo = \frac{1}{T} . \int_0^{Ton} Vs\, dt \tag{3.2}$$

$$Vo = Vs\left(\frac{Ton}{T}\right) \tag{3.3}$$

$$Vo = k. Vs \tag{3.4}$$

Where k is duty ratio

$$k = \frac{Ton}{T} = \frac{Ton}{Ton+Toff} \qquad (3.5)$$

Moreover, the range of k is between 0 and 1(1.0 ≤ k ≥ 0.0).

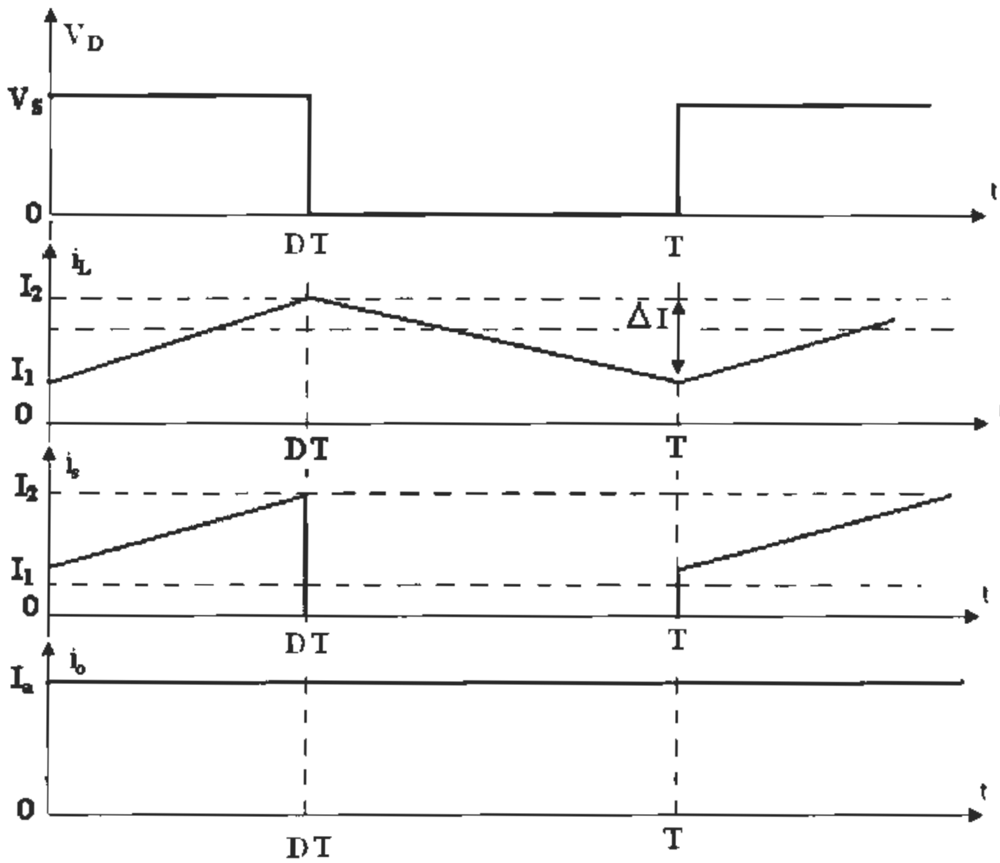

Figure 3-3 Output voltage and current[11]

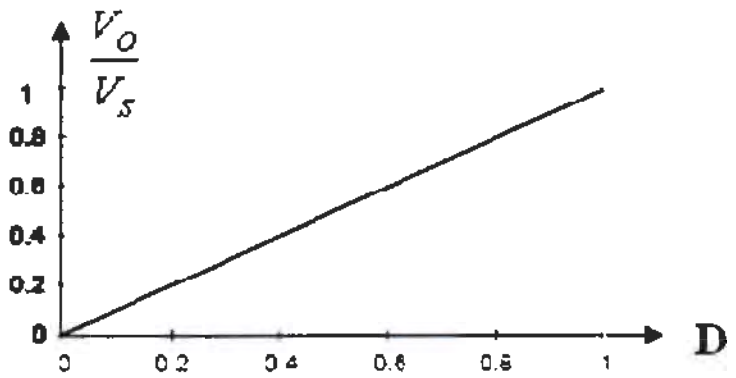

Figure 3-4 Depend on duty cycle (D)[11]

Load current of the circuit is continuous but output voltage is variable, output voltage must be increases when the duty ratio is increased.

3.3 BOOST CONVERTER

A boost converter circuit is shown in figure 3-5. Only a simple switch is shown in this circuit, for which an electronic device is belonging to transistor or IGBTs is generally used. An inductor is used in series with the load. Position of the diode and switch in this circuit is totally different with their position in buck converter (figure 3-1).[11, 13, 17]

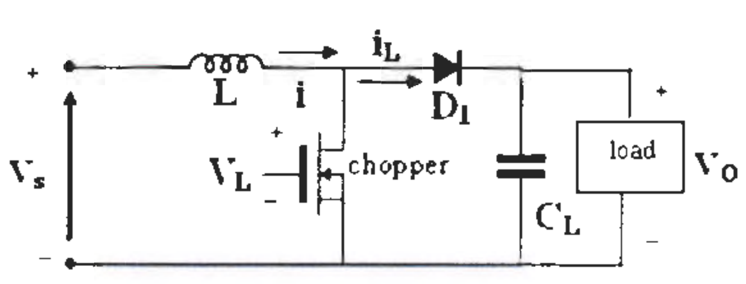

Figure 3-5 Boost Converter.[11]

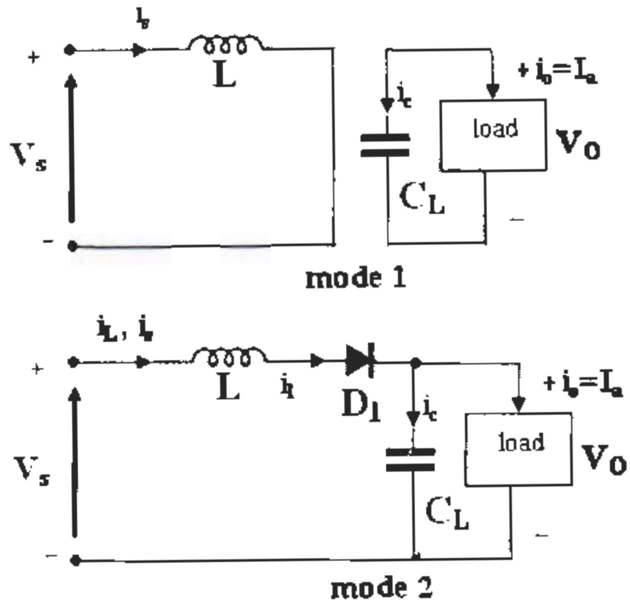

Figure 3-6 Equivalent circuit[11]

When switch is ON, output voltage of the circuit is zero and the equations of the circuit are,

$$Vs = L.\frac{dis}{dt} \tag{3.6}$$

$$\frac{Vs}{L} = \frac{dis}{dt} \tag{3.7}$$

When switch is OFF, output current (i_o) is equal to source current (i_s) and the equations of the circuit are,

$$Vs = Vo + L.\frac{dis}{dt} \tag{3.8}$$

$$\frac{dis}{dt} = \frac{Vs - Vo}{L} \tag{3.9}$$

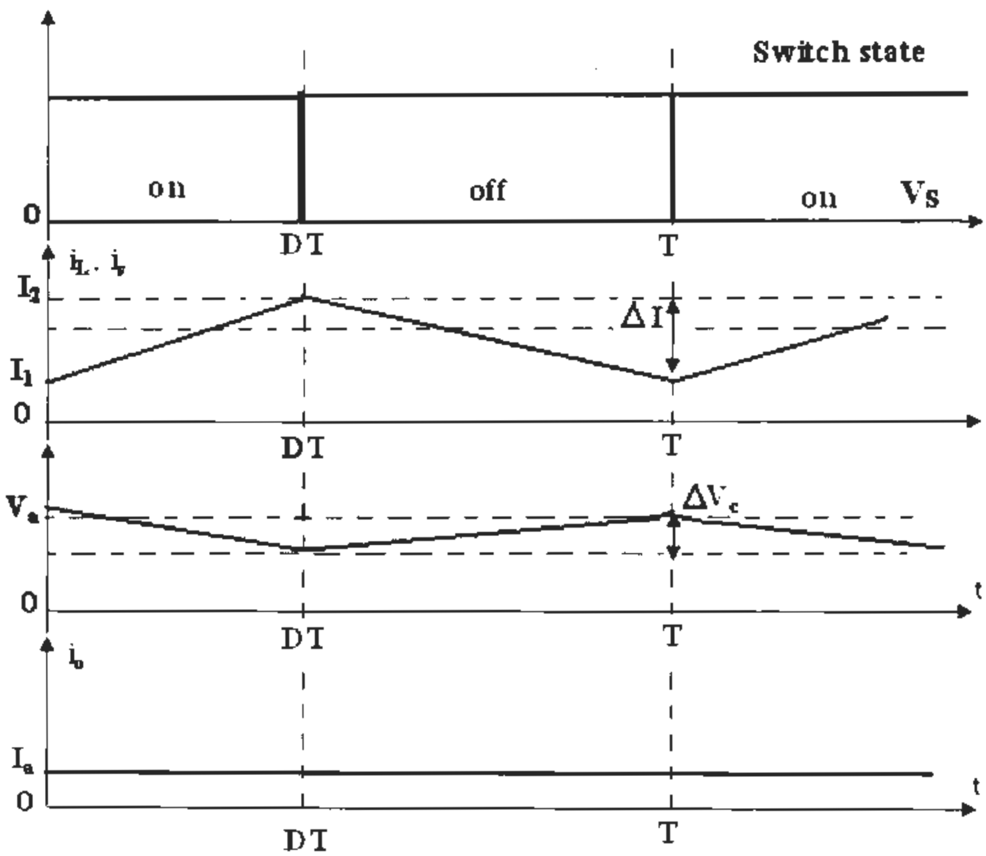

Figure 3-7 Output voltage and current curves.[11]

During the time interval T_{ON} then,

$$I_2 - I_1 = I_{max} - I_{min} = \left(\frac{Vs}{L}\right) T_{on} \qquad (3.10)$$

Similarly, during time interval T_{off} then,

$$I_2 - I_1 = I_{max} - I_{min=} \left[\frac{Vo-Vs}{L}\right] T_{off} \qquad (3.11)$$

By equating these two equations,

$$\left[\frac{Vo-Vs}{L}\right] T_{off} = \left(\frac{Vs}{L}\right) T_{on} \qquad (3.12)$$

And

$$Vo = Vs\left(\frac{T}{T_{off}}\right) = Vs\left(\frac{T}{T-T_{on}}\right) = Vs\left(\frac{1}{1-(T_{on}/T)}\right) = Vs\left(\frac{1}{1-k}\right) \quad (3.13)$$

Where

$$k = \frac{Ton}{T} = \frac{T_{on}}{T_{on}+T_{off}} \quad (3.14)$$

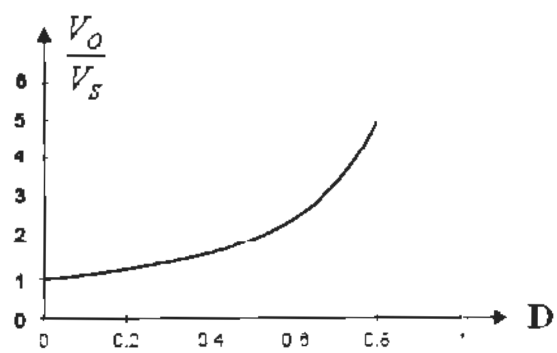

Figure 3-8 Depend on duty cycle (D).[11]

3.4 BUCK-BOOST CONVERTER

Basic dc-dc buck-boost converter circuit is shown in figure 3-9.Only a simple switch is shown in this circuit, for which an electronic device is belonging to transistor or IGBTs is generally used. A diode (D) is use in series with the load. The connection of the diode is compared with its connection in a boost converter (Figure 3-5) and inductor (L) is connected in the parallel with load, before the diode (D) and after the switch (S). The load is resistive. A capacitor (C) is connected in parallel with the load. [15,16]The polarity of the output voltage (Vo) is opposite to the input voltage.

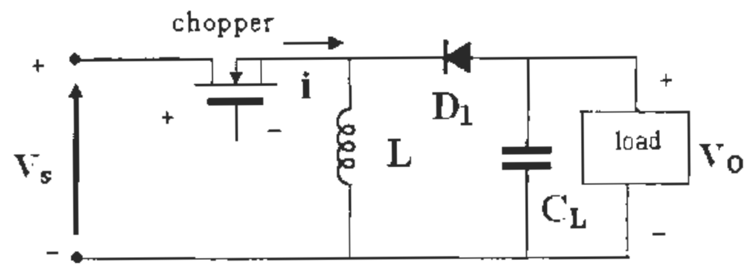

Figure 3-9 Buck- Boost converter[11]

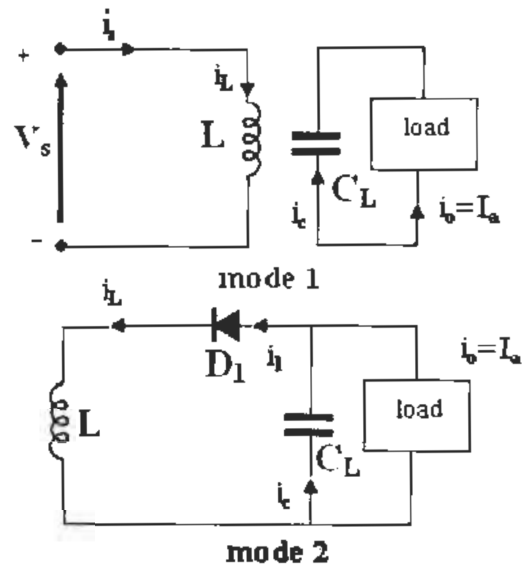

Figure 3-10 Equivalent circuit[11]

When switch (S) is ON, and equation for the circuit at this time is,

$$Vs = L.\frac{d_{il}}{dt} \tag{3.15}$$

$$\frac{Vs}{L} = \frac{d_{il}}{dt} \tag{3.16}$$

When, the switch (S) is OFF. The inductor current tends to decrease.

The equation for the circuit is,

$$Vo = L.\frac{d_{il}}{dt} \quad (3.17)$$

$$\frac{Vo}{L} = \frac{d_{il}}{dt} \quad (3.18)$$

Current varies linearly in inductor from I_{L1} to I_{L2}.So,

$$I_{l2} - I_{l1} = \left(\frac{Vs}{L}\right) T_{on} \quad (3.19)$$

When switch "S" is OFF. Then,

$$I_{l2} - I_{l1} = \left(\frac{Vo}{L}\right) T_{off} \quad (3.20)$$

$$Vo = Vs\left(\frac{T_{on}}{T_{off}}\right) = Vs\left(\frac{T_{on}}{T-T_{on}}\right) = Vs\left(\frac{\frac{T_{on}}{T}}{1-\left(\frac{T_{on}}{T}\right)}\right) = Vs\left(\frac{k}{1-k}\right) \quad (3.21)$$

$$k = \frac{T_{on}}{T} = T_{on}/(T_{on} + T_{off}) \quad (3.22)$$

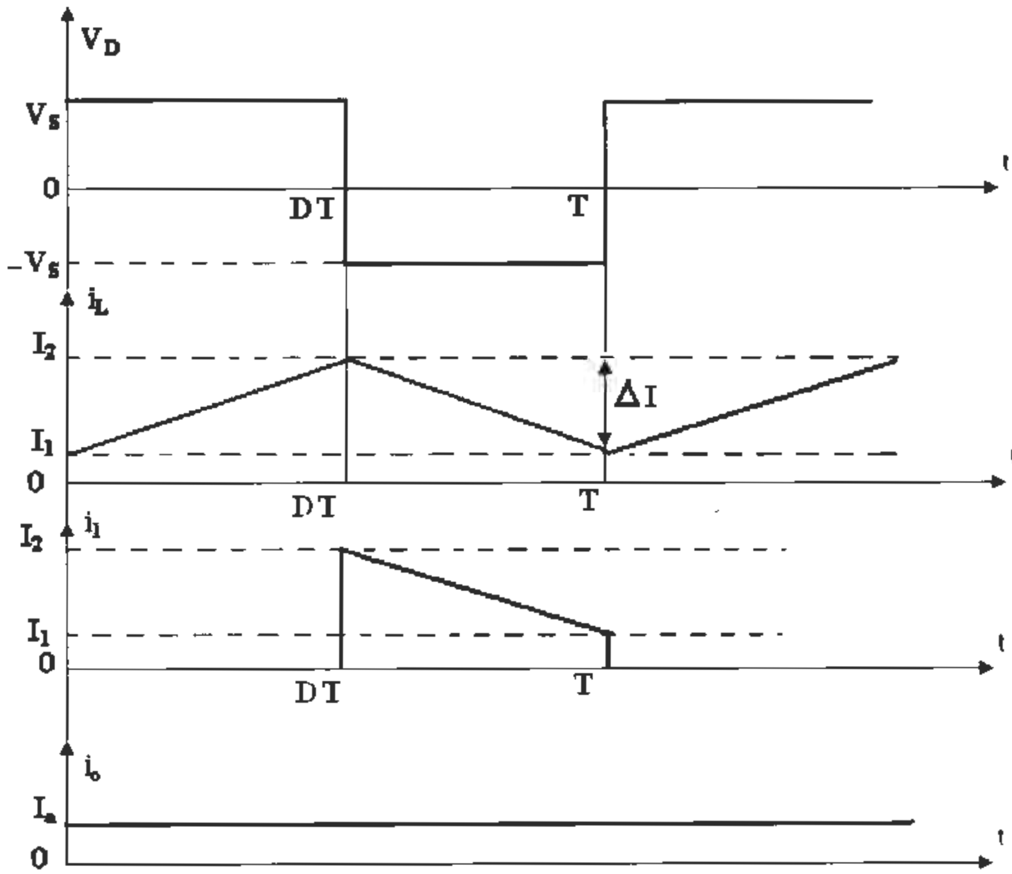

Figure 3-11 Current of Inductor (IL)[11]

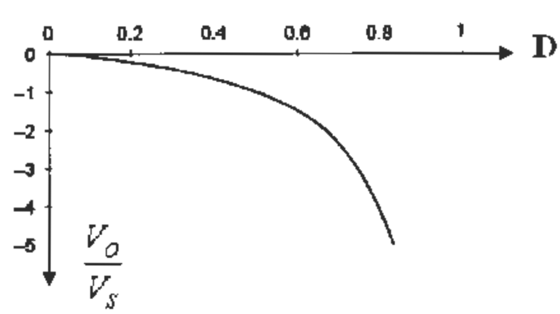

Figure 3-12 Depend on duty cycle (D)[11]

3.5 BUCK-BOOST CONVERTER MODELING

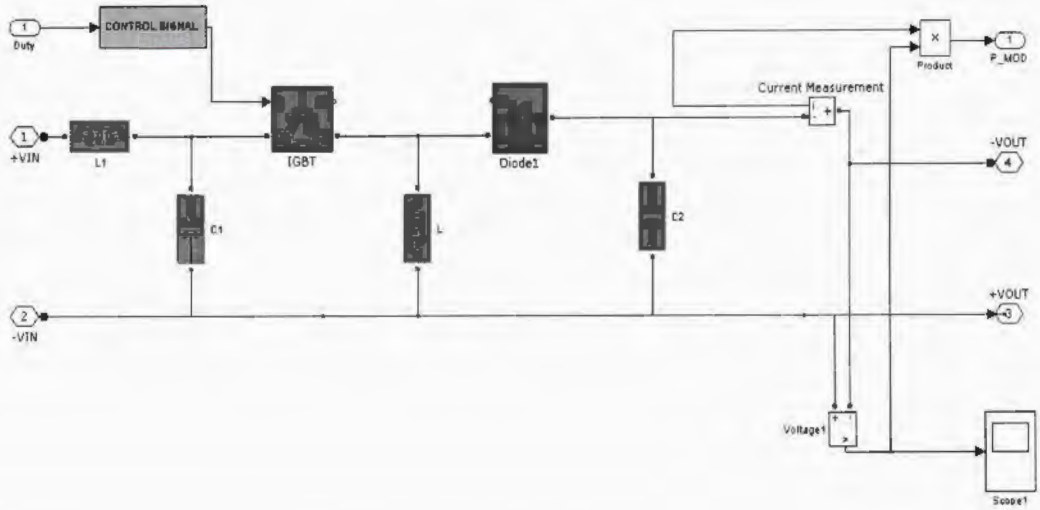

Figure 3-13Buck-Boost converter Simulink model

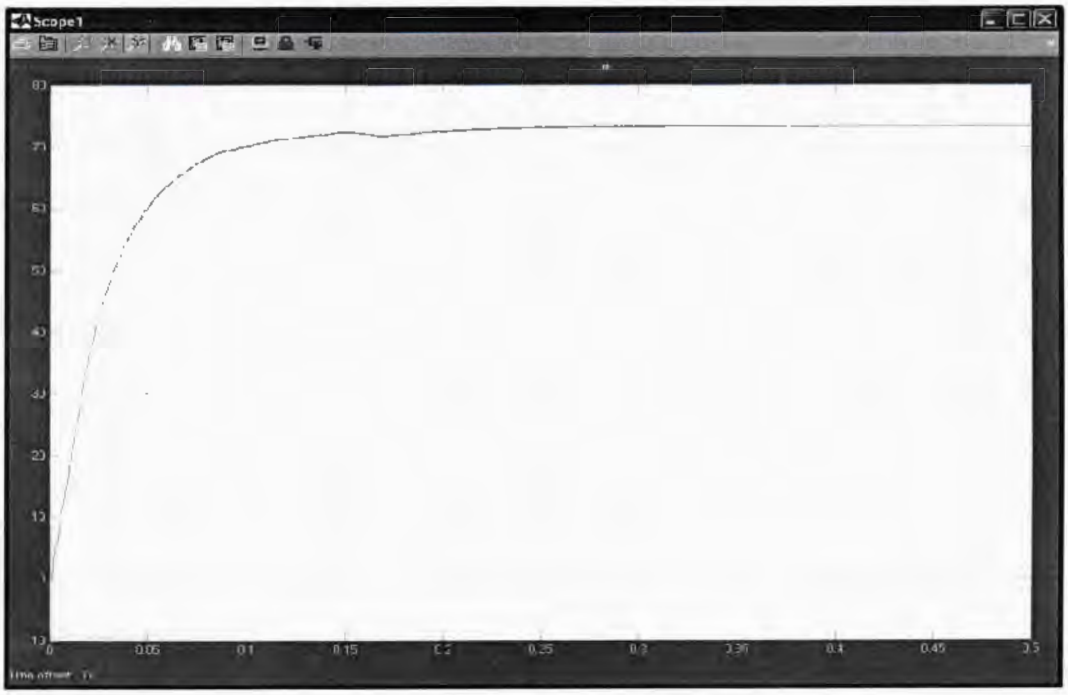

Figure 3-14 Output of Buck-Boost converter

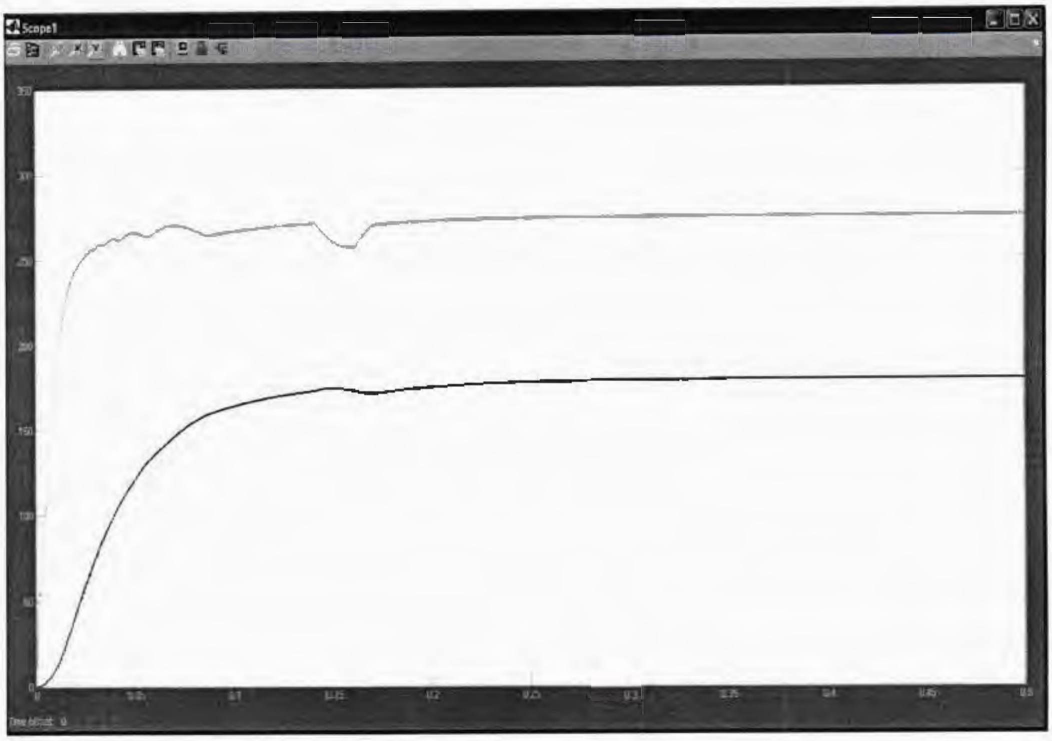

Figure 3-15 Output Curve

A flow chart for control buck-boost converter duty cycle (D) is shown in figure (3-16). This flowchart explain, first of all, perturb and observation algorithm measure the panel output voltage and current, after that measure power Pa and its variation in this power (d Pa). After this step if variation in panel power is greater than zero then duty cycle must be in same direction otherwise duty cycle in reverse direction.

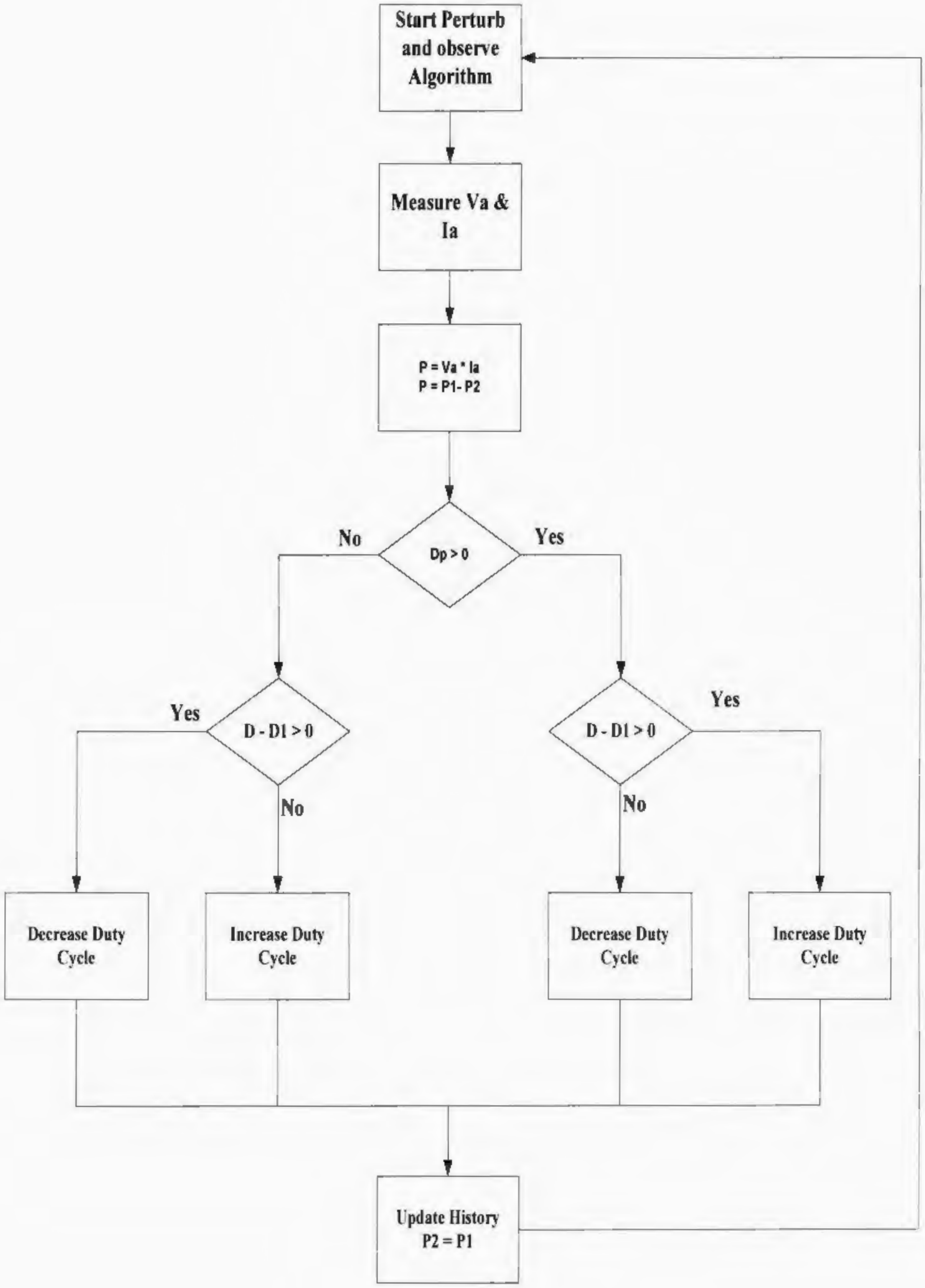

Figure 3-16 Flow Chart for Control Duty cycle with Perturb & Observation Algorithm.

CHAPTER 4. MAXIMUM POWER POINT

4.1 MAXIMUM POWER POINT IN I-V CURVE:

In above figures there are different combinations like voltage/current and power/current curves according to change in temperature and different values of irradiance. However, other factors like shades on PV panel and angle of panel etc. also affect on efficiency of solar PV panel. It means total number of curves is innumerable. It depends on possible combinations due to environmental effect on it.

4.2 STRATEGIES FOR MAXIMUM POWER POINT TRACKING:

There are three different strategies mostly used for obtaining maximum power point.

- Perturb and observe.
- Incremental conductance.
- Current Sweep Method.

4.2.1 Perturb and observe

Hill climbing method or perturb and observation method, is very easy to understand and it's also easy to implement. Therefore, in maximum power point tracking this method mostly used. One other reason is structure of this algorithm is so simple and need just few parameters. The perturb and Observe has measure current and voltages of the PV panel constantly and calculate its power also and observe movement in power and achieve the maximum power point. The controller adjusts the output power at maximum power point[18].

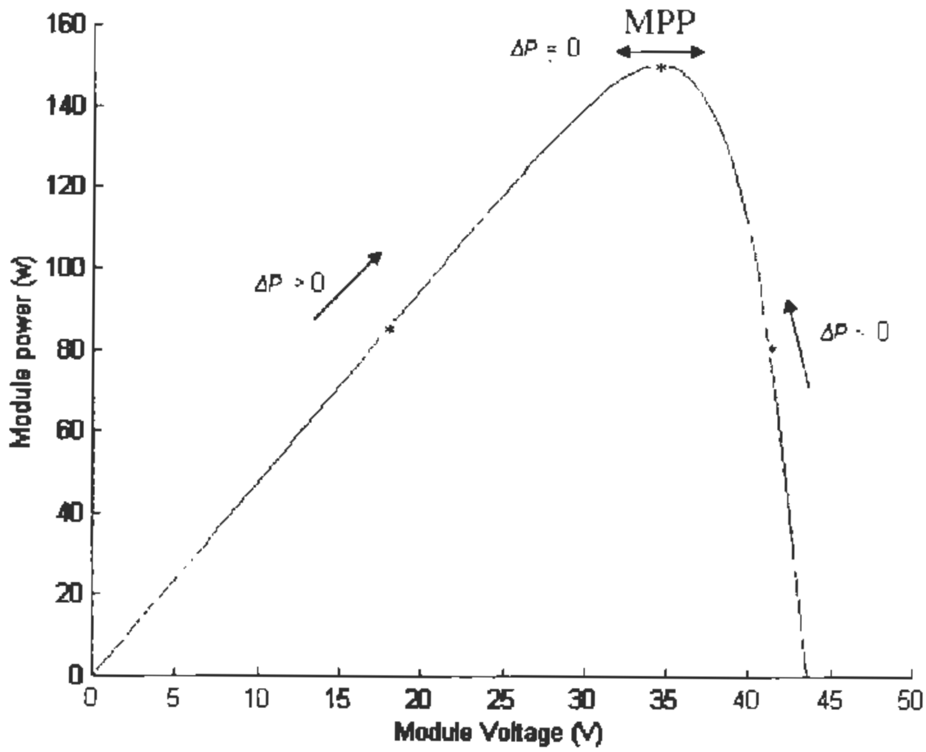

Figure 4-1 Power & Voltage of module.[11]

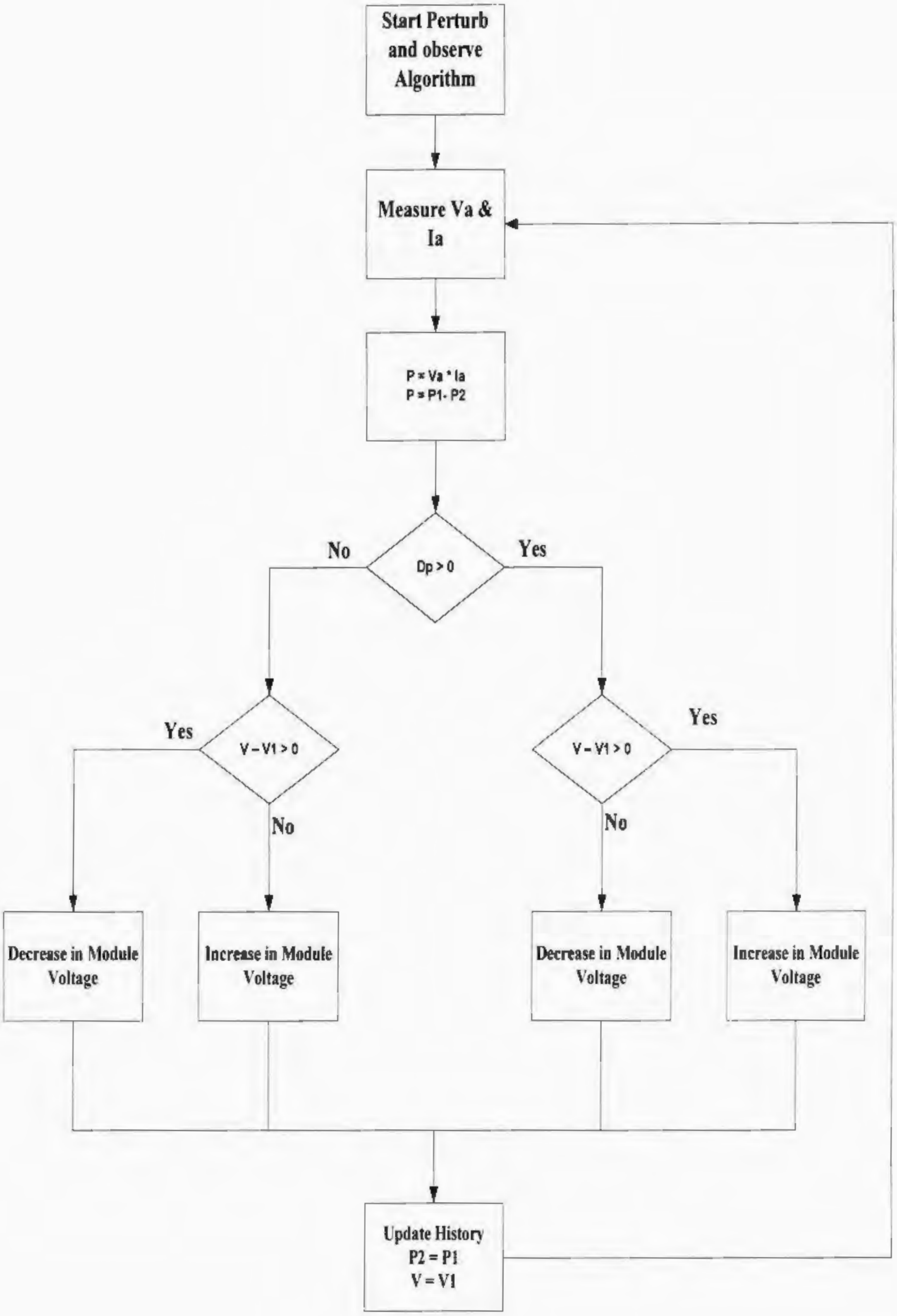

Figure 4-2 Perturb and observe algorithm

4.3 SIMULATION OF MPPT IN MATLAB

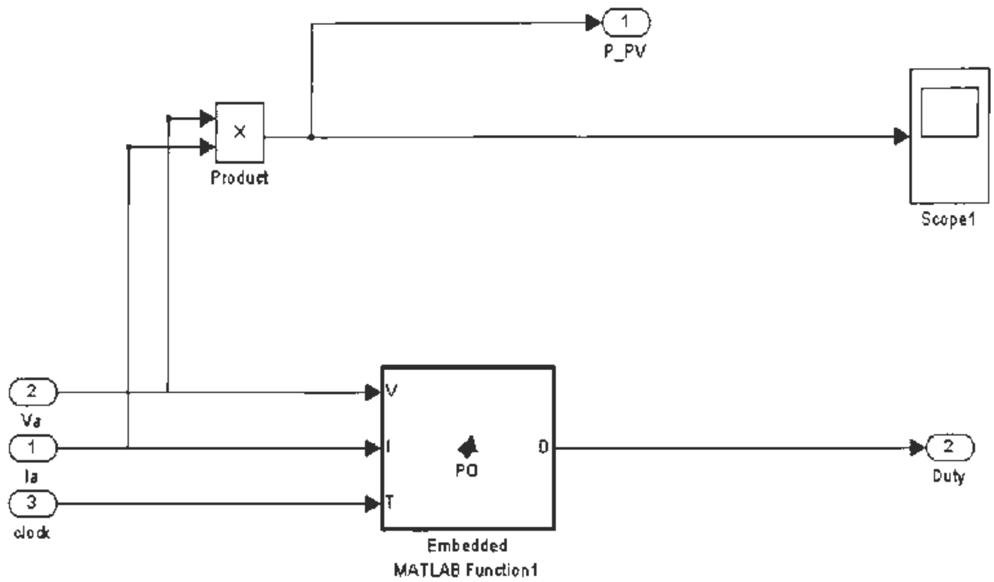

Figure 4-3 Maximum Power Point Tracking model.

Figure 4-4 Graphs for Maximum Power Point Tracker output.

CHAPTER 5. RESULTS AND OBSERVATIONS

5.1 OBSERVATIONS:

The results of simulation show that the modelling of the PV module by using equivalent circuit in moderate complexity gives an accurate matching with the datasheet of above PV module data. At 25°C of temperature and 1KW/m^{2}of irradiance, power output is 64Watts of maximum power of module and simulated value of two modules is about 64.85Watts, so modelling is 99.99% accurate.

5.2 EFFECT OF TEMPERATURE:

Temperature of solar PV panel has effect on its efficiency. we can observe in figure 3-5 that the voltage are become low at higher temperature, in other words we can say that the temperature is directly effect on terminal voltage. The terminal voltage increases with decreasing temperature. It is due to mobility of electrons and holes in semiconductor material. Therefore, when temperature increases then electrons and holes mobility in semiconductor material is decreases.

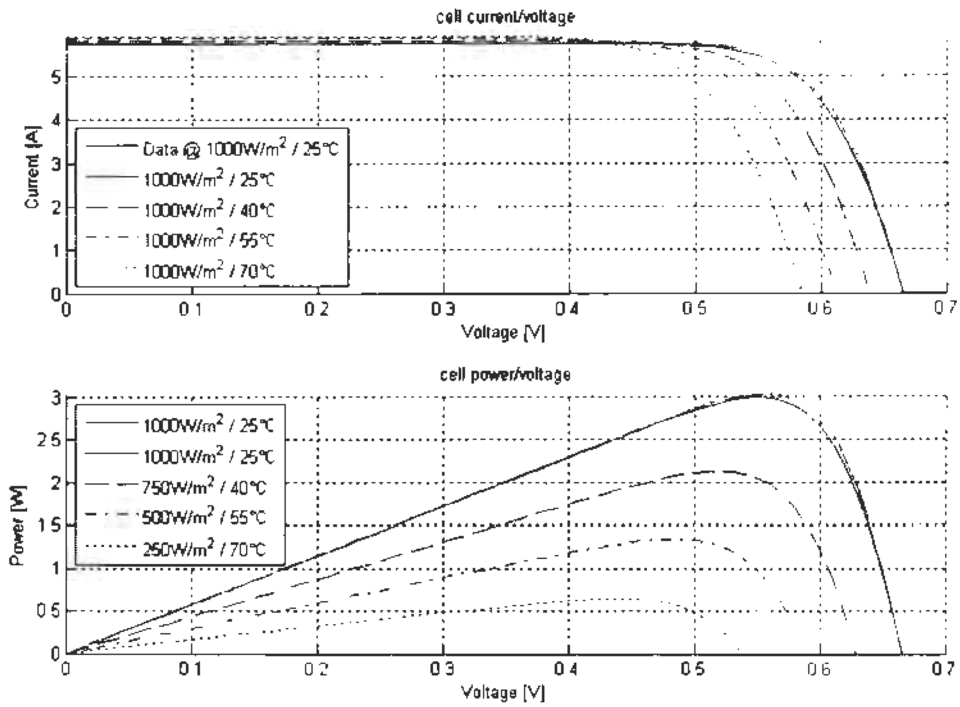

Figure 5-1 Effect of Temperature

The band gap energy of semiconductor material is also varies with temperature variations. Band gap will increase by increasing temperature at semiconductor material. If energy gap is increased then electrons and holes required more energy to move from valance band to conduction band, it means more photons will absorbed by electrons in the valance band but few electrons move towards conduction band and efficiency of solar cell is decreased.

In general, silicon crystal PV cell efficiency will be decreases almost 0.5% for every degree C^o increase in temperature.

5.3 EFFECT OF IRRADIANCE:

Irradiance is also a very important changing factor in solar PV panel's performance. Irradiance is amount of solar energy, which is absorbed by a PV panel over its area.

Unit of Irradiance is Watt/m^2 and in ideal condition Irradiance of solar PV panel is obtain 1000W/m^2 or 1KW/m^2,this value of irradiance is depend on location and angle of the sun rays.

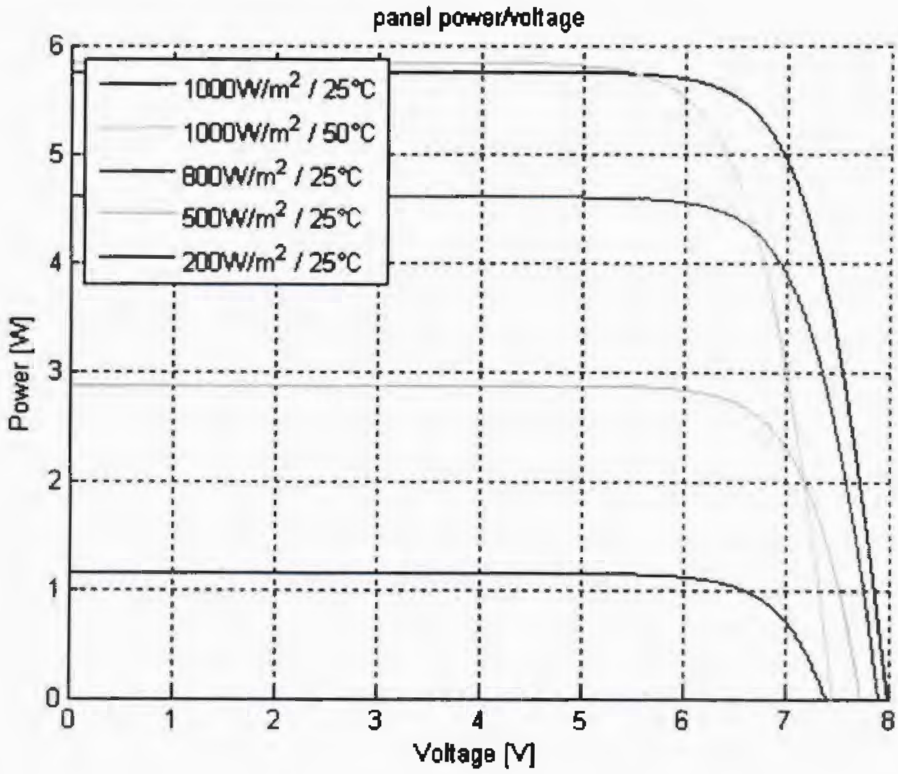

Figure 5-2 Effect of Irradiance.

It can be observe in figure 5-2 that irradiance directly effect on output power of PV panels, in other words output power of the PV panel directly proportional to the Irradiance of solar. In solar PV panels the output current is directly proportional to the flux of photons, it means if the light intensity is low then the output current is also low but there is minimal change in output voltage by varying irradiance and that is negligible change in voltage. If the light intensity will increase then output current will also increase. Therefore, we can observed, if the sun is bright an intensity of light is high then performance of PV panels will increase.

5.4 RESULTS

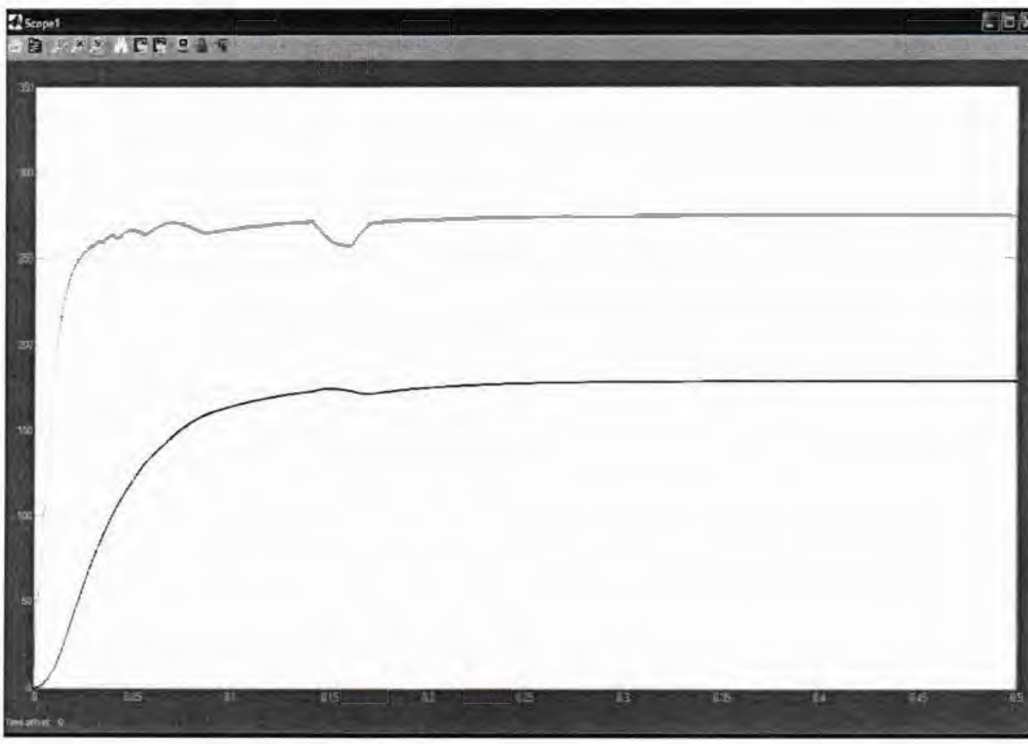

Figure 5-3 Output Of Simulation.

The following flowchart explains the operation of the simulated system.

Output voltage and current can be calculated by following equations.

$$Vo = \left(\frac{1}{1-D}\right) Va$$

$$Io = (1-D)Ia$$

This simulation carry out in similar manner as previously, Perturb and Observation algorithm designed to achieve the goal of gaining maximum power from the Solar PV panel, by adjusting the duty cycle (D) of the Buck-Boost converter.5.47

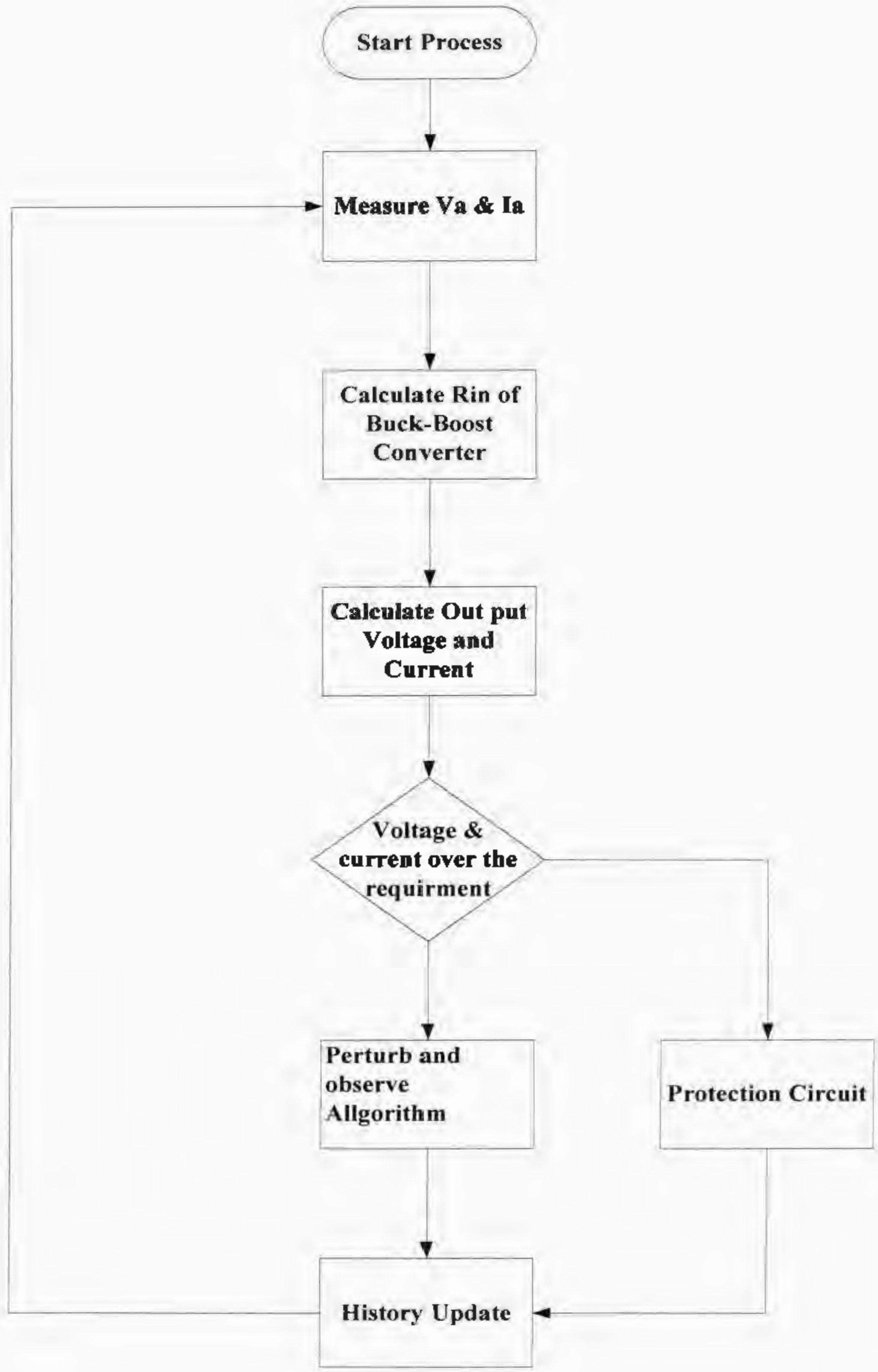

Figure 5-4 Flow chart of simulation for Maximum Power Point Tracking.

5.5 FUTURE RECOMMENDATIONS AND CONCLUSIONS.

Although a model is designed for MPPT but further enhancements could be done to make the system work more efficiently. Some components in the design could be made to make the design perfect and could be implemented in practical scenarios. MPPT algorithm is simulated to achieve maximum power transfer; the Perturbation and Observation (P&O) algorithm. However, MPPT has some limitations; one of its main drawbacks is that there is no regulation on the output while it is tracking a maximum power point. It cannot regulate both input and output at the same time. If the application requires a constant voltage, it must employ batteries to maintain the voltage constant. In addition to that, if the value of the load resistance changes the duty cycle of the converter changes even if the input is the same; this means that the design of the converter must satisfy the specifications of the source and the load at the same time. Thus, it is very important to select the appropriate size of the load, so that the full capacity of the PV module and array is utilized.

A more realistic model of the DC-DC converter would involve diode losses, switching losses in a Power switch, and resistive losses in inductors and capacitors.

Special attention will be devoted to minimizing losses in all system parts, through the use of different converter topologies.

Use of efficient power converters can also improve system efficiency as using power converters cause harmonic distortions so a proper mechanism for the reduction of harmonic distortions can be designed, which will help in improving system efficiency.

Use of solar PV panels manufactured with international standards and high quality will result in improved and efficient energy production, which can improve system efficiency. Although incremental conductance is able to provide marginally better performance, the increased complexity of the algorithm will require more expensive hardware, and therefore may have an advantage over perturb and observe only in large PV arrays.

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