AUTOMATIC PEAK POWER TRACKER FOR SOLAR PV MODULES USING dSPACE^{R} SOFTWARE.

A

Thesis

Submitted in partial fulfillment of the

Requirement for the award of the Degree of
MASTER OF TECHNOLOGY

In
ENERGY

By

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July –2005

DECLARATION

I hereby declare that the work which is being presented in this thesis entitled **"Automatic Peak Power Tracker For Solar PV Modules Using dSPACE^{R} software"** in partial fulfillment of the requirement for the award of the degree of **Master of Technology in " Energy ".**

The work has been carried out at Energy centre, Maulana Azad National Institute of Technology Bhopal. It is an authentic record of my work carried out under the guidance of **Dr.S.Rangnekar**,

I have not submitted the matter embodied in this thesis for the award of any other degree.

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ACKNOWLEDGEMENT

It gives me immense pleasure to express my deepest sense of gratitude and sincere thanks to my highly respected and esteemed guide **Dr.S.Rangnekar,** Professor, and Head of Energy Centre , MANIT, for her revered guidance throughout my dissertation work, which made this task a pleasant job. It was real pleasure to work under her guidance.

I extend my sincere thanks to **Mrs. Rekha. Jain** Co-ordinator Energy Centre MANIT, Bhopal, for her keen interest, continued encouragement and support.

I am also indebted to my parents and well wishers who are taking lot of pains for progress in my life and for their sacrifices, blessings and constant prayers for my advancement.

I express my thanks to **Dr.K.S.Sayyan** *Director*, **Dr. R.P. Singh,** *Dean (Academic)* for their kindness and providing me the facilities of the institute to use for my work.

I am also thankful to all the staff members of Energy Centre of MANIT Bhopal, for their co-operation.

I express my indebtedness to my friends **Mr.S.P.Chincholkar**, **Mr.Saurabh.Mishra, Mr.Umesh.Ubnare, Mr.Sourabh.Jain, Mr.U.S.Rao, Miss.Mamta. Dhoke, Miss.Jaya.Pagare , Mr.Nitin Khare, Mr.Pushpraj.Shrivastava, Mr. Zia-ul-Haq Kholi. and Mr.Ramesh.Vaddi** for their help and valuable suggestions to complete my thesis work and also for tolerating my mistakes and immaturity.

At last but not least, I am also thankful to those, who have directly or indirectly, helped me, and encouraged me to complete my thesis. I feel sorry for not able to express my appreciation to each of my well-wishers and ask forgiveness for my improper behavior with any one who was intending to help me.

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ABSTRACT

Renewable energy sources plays an important role in electricity generation. Various renewable energy sources like wind, solar, geothermal, ocean thermal, and biomass can be used for generation of electricity and for meeting our daily energy needs.

Energy from the sun is the best option for electricity generation as it is available every where and is free to harness. On an average the sunshine hour in India is about 6hrs annually also the sun shine shines in India for about 9 months in a year. Electricity from the sun can be generated through the solar photovoltaic modules (SPV). The SPV comes in various power output to meet the load requirement.

Maximization of power from a solar photo voltaic module (SPV) is of special interest as the efficiency of the SPV module is very low. A peak power tracker is used for extracting the maximum power from the SPV module .The present work describes the maximum power point tracker (MPPT) for the SPV module connected to a resistive load. A Personal Computer (PC) is used for control of the MPPT algorithm. The power tracker is developed and tested successfully in the laboratory. The simulation studies are carried out in MATLAB^R /SIMULINK^R . Data acquisition, monitoring and control is done by dSPACE^R software and digital signal processor card on PC. The measured parameters such as panel voltage, current and power are displayed on the monitor of the pc.

The MPPT system has been tested on Solar PV Module rated 38Wpeak at 16.6V and 2.2 A and at 25^0 degree Celsius and 1000W/m^2 of TATA BP Solar INDIA

Nomenclature

V	Voltage	***V***
Vo	Output voltage	***V***.
Vi	Input voltage	***V***.
dV	Voltage error	***V***.
v_d	Voltage across diode	***V***.
I	Current	***A***.
I_{ph}	Photon generated current	***A***.
I_d	Current through diode	***A***.
I_L	Load current	***A***.
ΔI	Current ripple	***A***.
R	Resistance	***Ω***.
R_o	Output resistance	***Ω***.
R_i	Input resistance	***Ω***.
R_L	Load resistance	***Ω***.
C	Capacitance	***μF***.

L	Inductance	***µH.***
D	Duty cycle ratio.	
ΔD	Change in duty cycle ratio.	
G	Insolation level	$\boldsymbol{W/m^2}$**.**
P	Power	***W.***
dP	Power error	***W.***
t	dc/dc converter on switching period	***ms***.
t_{on}	On period of converter	***ms***.
t_{off}	Off period of converter	***ms***.
k	Stefan Boltzman constant. $1.38x10^{-23}$	***J/K***
T	Temperature in	***K.***
q	Electronic charge	***C***.
f	frequency of the converter	***kHz.***

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CHAPTER 1.

Introduction to Maximum/Peak Power Point Tracking (MPPT).

1.1 Introduction

Renewable energy sources play an important role in electric power generation. Various renewable sources such as solar energy, wind energy, geothermal etc. are harness for electric power generation. Solar Energy is a good choice for electric power generation. The solar energy is directly converted into electrical energy by solar photovoltaic module.

The photovoltaic modules are made up of silicon cells. The silicon solar cells which give output voltage of around 0.7V under open circuit condition. When many such cells are connected in series we get a solar PV module. Normally in a module there are 36 cells which amount for a open circuit voltage of about 20V. The current rating of the modules depends on the area of the individual cells. Higher the cell area high is the current output of the cell. For obtaining higher power output the solar PV modules are connected in series and parallel combinations froming solar PV arrays. A typical characteristic curve of the called current (I) and voltage (V) curve and power (W) and voltage (V) curve of the module is shown is shown in fig.1

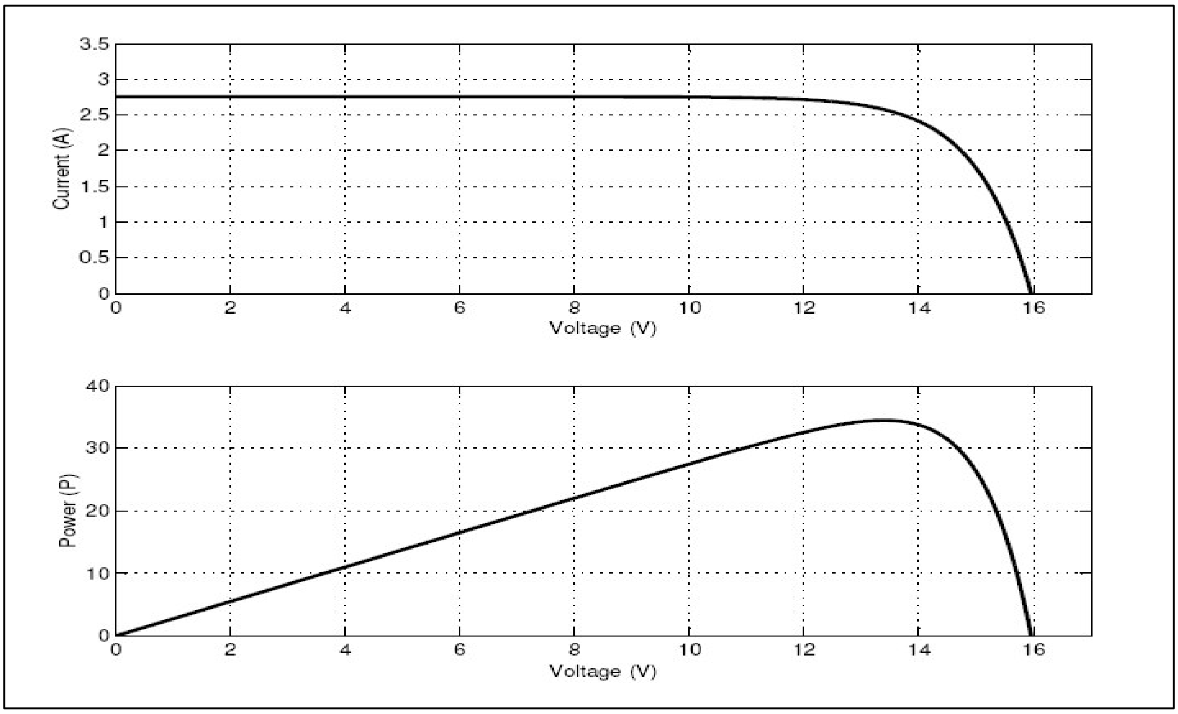


Fig.1 Characteristics of a typical solar PV module.

1.2 Need for maximum power point tracking

Power output of a Solar PV module changes with change in direction of sun, changes in solar insolation level and with varying temperature as shown in the fig. 2&3.

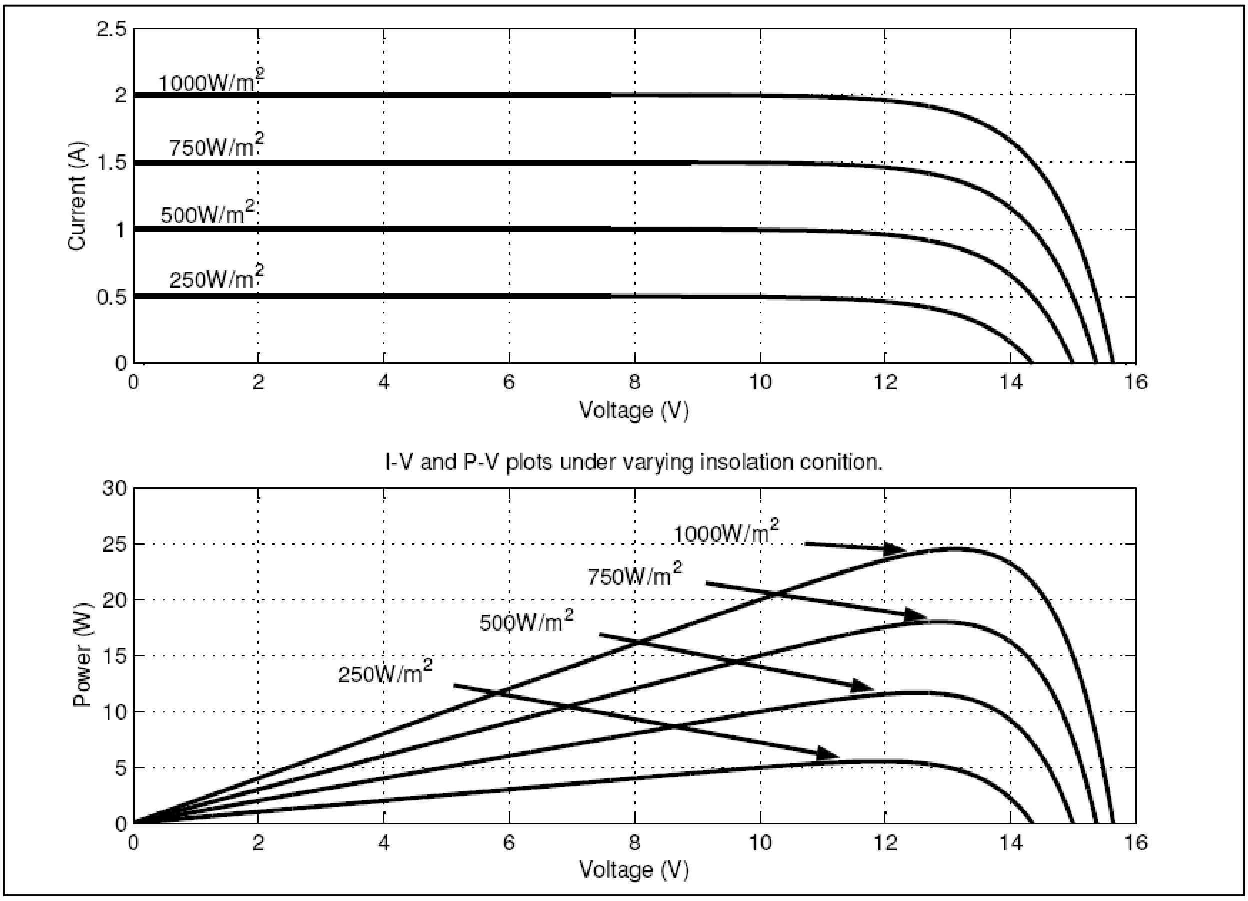


Fig.2 Changes in the characteristics of the solar pv module due to change in insolation level

As seen in the PV(power vs. voltage) curve of the module there is a single maxima of power. That is there exists a peak power corresponding to a particular voltage and current. We know that the efficiency of the solar PV module is low about 13%. Since the module efficiency is low it is desirable to operate the module at the peak power point so that the maximum power can be delivered to the load under varying temperature and insolation conditions. Hence maximization of power improves the utilization of the solar PV module. A maximum power point tracker (MPPT) is used for extracting the maximum power from the solar pv module and transferring that power to the load. A dc/dc converter(step up/step down) serves the purpose of transferring maximum power from the solar PV module to the load. A dc/dc converter acts as an interface between the

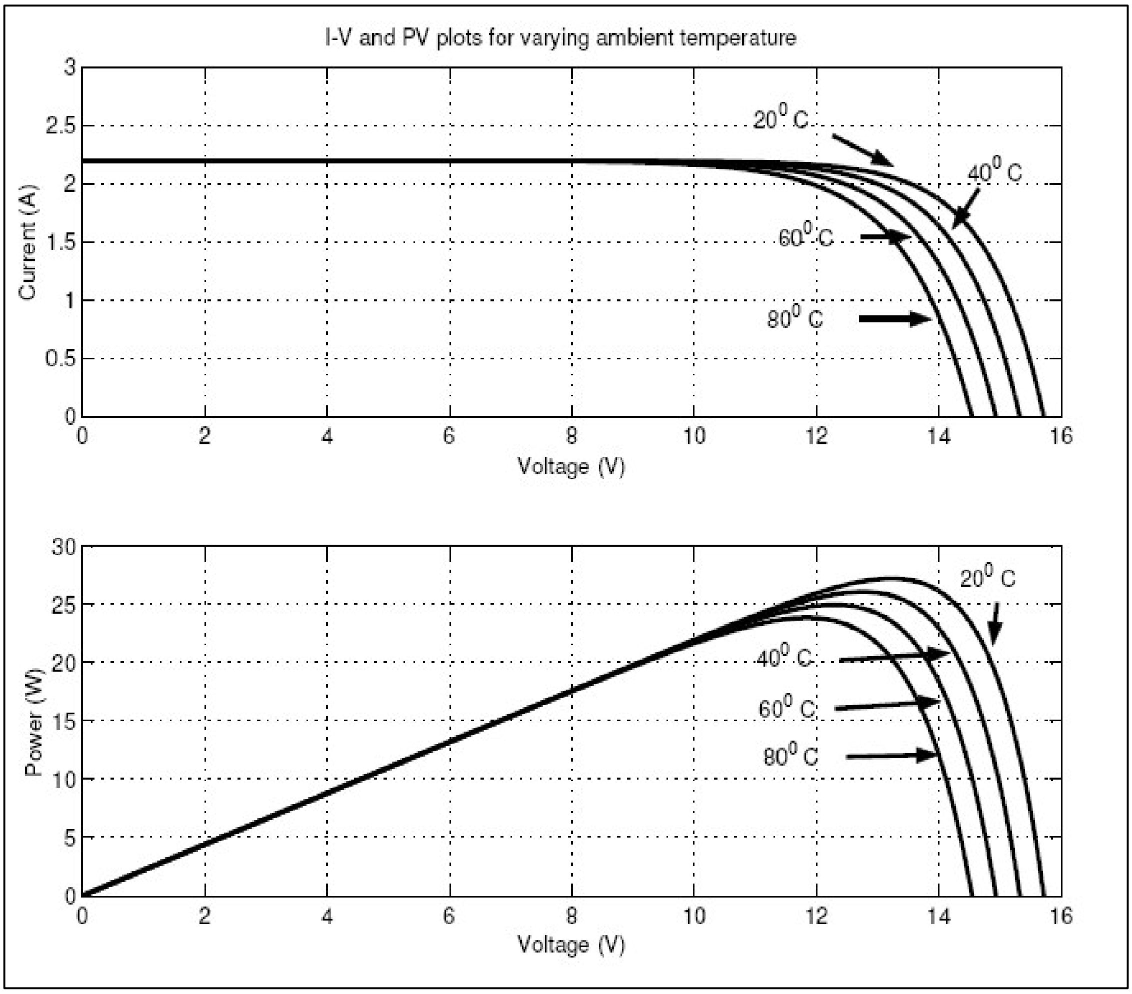


Fig.3 Change in the module characteristics due to the change in temperature

load and the module fig.4. By changing the duty cycle the load impedance as seen by the source is varied and matched at the point of the peak power with the source so as to transfer the maximum power.

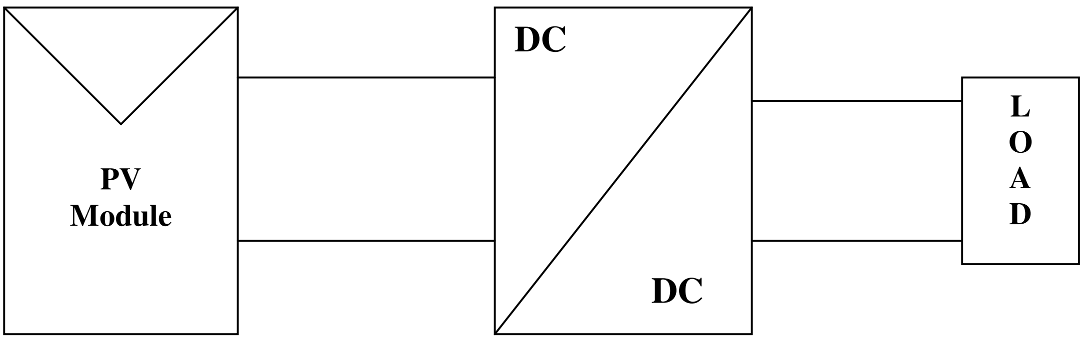


Fig.4 Block diagram of a typical MPPT system

1.3 How maximum power point is obtained.

As discuss in previous chapter the maximum power point is obtained by introducing a dc/dc converter in between the load and the solar PV module. The duty cycle of the converter is changed till the peak power point is obtained.

Considering a step down converter is used

$V_o = D * V_i$……………………………………………………………………...(1)

(Vo is output voltage and Vi is input voltage)

solving for the Impedance transfer ratio

$R_o = D^2 * R_i$..(2)

(Ro is output impedance and Ri is input impedance as seen by the source.)

$R_i = R_o / D^2$……………………………………………………………………...(3)

Thus out output resistance R_o remains constant and by changing the duty cycle the input resistance R_i seen by the source changes. So the resistance corresponding to the peak power point is obtained by changing the duty cycle. As shown in the fig.5.

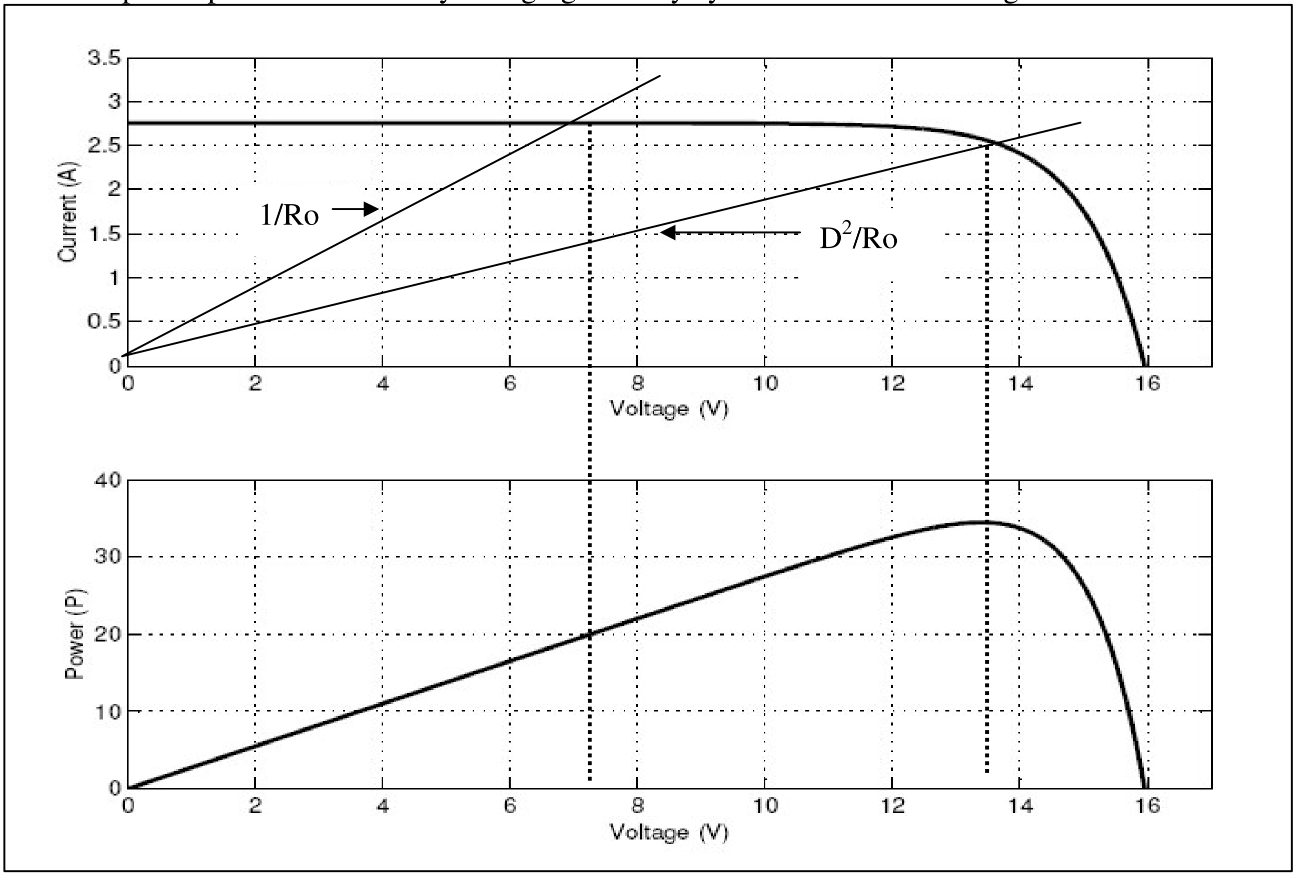


Fig.5 DC/DC converter helps in tracking the peak power point.

1.4 Methods of Peak Power Tracking.

The peak power is reached with the help of a dc/dc converter by adjusting its duty cycle such that the resistance corresponding to the peak power is obtained. Now question arises how to vary the duty cycle and in which direction so that peak power is reached. Whether manual tracking or automatic tracking? Manual tracking is not possible so automatic tracking is preferred to manual tracking. An automatic tracking can be perfromed by utilizing various algorithms.

a. **Perturb and observe [1],[2],[5].**
b. **Incremental Conductance [3],[7].**
c. **Parasitic Capacitance [7].**
d. **Voltage Based Peak Power Tracking [7].**
e. **Current Based peak power Tracking [7]**.

The algorithms are implemented in a microcontroller or a personal computer to implement maximum power tracking. The algorithm changes the duty cycle of the of the dc/dc converter to maximize the power output of the module and make it operate at the peak power point of the module. Various algorithms are explained in detailed in the chapter 2.

1.5 Applications of Maximum Power Point Trackers.

MPPT systems are used mainly in systems where source of power is nonlinear. Such as the solar pv modules or the wind generator systems. MPPT systems are generally used in solar PV applications such as battery chargers and grid connected stand alone PV systems

a] Battery charging – Charging of battery (lead acid/NiCad) which is used for the storage of electrical energy. This energy if it comes from the solar PV systems then fast charging of the battery can be done with the help of the MPPT charge controller.

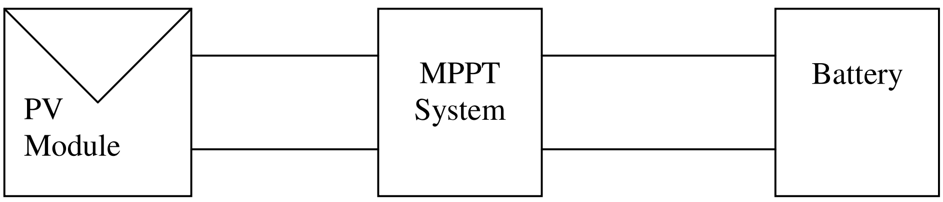


Fig.6.Battery charging application of MPPT

b] Grid connected and standalone PV systems- In grid connected or stand alone PV systems. The solar arrays supply power to the grid or to the local load. A dc/dc converter is used as the array voltage is dc and as grid voltage is ac an dc/ac converter must be used.

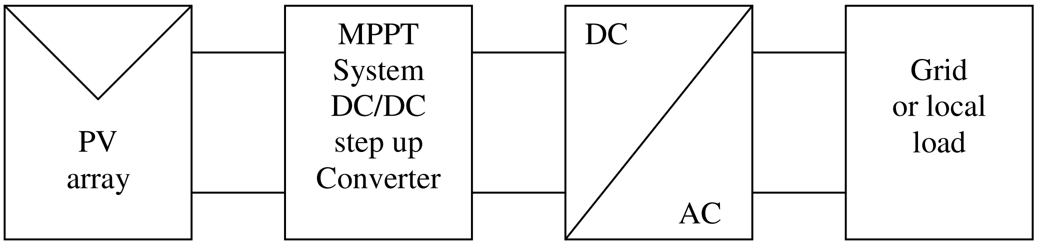


Fig.7.Grid connected application using MPPT

Before a dc/ac converter a dc/dc converter (normally step up) is used which serves the purpose of the maximum power point tracking as explained earlier. Due to maximum power tracking always the peak power is transferred to the grid or the local load.

c] Water pumping applications- Solar pv arrays can be used to run dc motors which drive the pump for supplying the water in the fields. By using the maximum power point tracker the power to the motor can be increased and so the output flow rate of the pump will also increase.

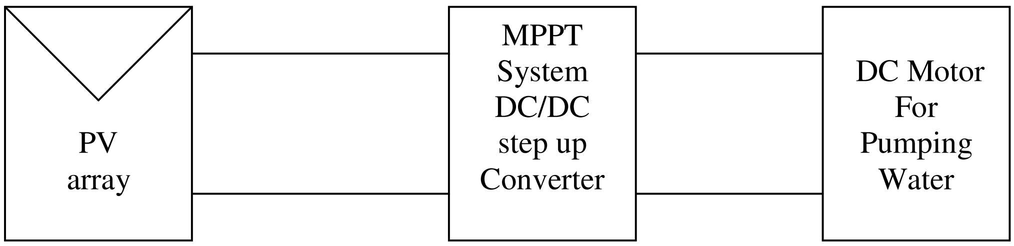


Fig.8. Pumping application of the MPPT.

CHAPTER 2.

Literature Review.

The following literature survey for the current report consists of various papers published in the IEEE conferences and the journals.

1]. Implementation of a DSP-Controlled Photovoltaic System with Peak Power Tracking .[1]

Chihchiang Hua, Jongrong Lin, and Chihming Shen:-

The authors discuss a improved MPPT algorithm based on perturb and observe. The algorithm uses the power as the control variable based on the perturbation and observation method. The algorithm requires two sensors. A better response for the system under rapid atmospheric condition variations is obtained by increasing the execution speed. A TI320C25 DSP is used to implement the proposed MPPT controller. The simulation of the MPPT algorithm is carried out and verified with the practical results. Modelling of the step down converter used for the peak power tracking is carried out. PI controller design and its response for the MPPT system is also discussed. The controller and the MPPT algorithm are implemented through the Personal Computer utilizing a DSP processor TI320C25 of Texas Instruments.

2]. Control of DC/DC Converters for Solar Energy System with Maximum Power Tracking. [2].

Chihchiang Hua and Chihming Shen.

The object of this paper is to analyze and design DC/DC converters of different types in a solar energy system to investigate the perfromance of the converters. A simple method which combines a discrete time control and a PI compensator is used to track the Maximum power points (MPP's) of the solar array. The system is kept to operate close to the MPPT's, thus the maximum possible power transfer from the solar array is achieved. The implementation of the proposed converter system was based on a digital signal processor (DSP). Experimental tests where carried out for buck, boost and buck-boost converters using a simple maximum power point tracking (MPPT) algorithm. The efficiencies for the system with different converters are compared. The paper is use full in evaluating the response of step up, step down converter for the MPPT system. Paper proposes that the Step down converter is the best option for the use in the MPPT system as it give higher efficiency.

3].Maximum photovoltaic power tracking: an algorithm for rapidly changing atmospheric conditions.[3]

K.H. Hussein, I. Muta, I. Hoshino &, M. Osakada.

The authors have developed a new MPPT algorithm based on the fact that the MPOP(maximum peak operating point) of a PV generator can be tracked accurately by comparing the incremental and instantaneous conductance's of the PV array. The work was carried out by both simulation and experiment, with results showing that the developed incremental conductance(IntCond) algorithm has successfully tracked the MPOP, even in cases of rapidly changing atmospheric conditions, and has higher efficiency than ordinary algorithms in terms of total PV energy transferred to the load. The detailed algorithm is explained in the chapter 3.

4].High Efficiency Maximum Power Tracker for Solar Arrays in a Solar Powhered Race Vehicle.,[4]

Charles.R.Sullivan and M.J Powers.

A robust oscillation method is used for implementing the maximum power point tracking for the solar arrays. The method uses only one variable that is load current for detecting the maximum power. This method is suitable for the battery charging application where MPPT is to be implemented. The algorithm is implemented through a simple circuit. The paper gives detailed discussion about design of a step up converter. Used for the MPPT.

5]. Microcomputer Control of a Residential Photovoltaic Power Condictioning System. [5].

B.K. Bose, P.M. Szczesny and R.L. Steigerwald,

The authors discuss a control system of a residential photovoltaic system. The paper explains a perturb and observe algorithm and how can it be implemented using a microprocessor. This paper is one of the basic papers which explains the Perturb and observe algorithm. Also controller design using PI scheme is obtained.

6]. An Improved Perturbation and Observe Maximum Power Point Tracking Algorithm for PV Arrays. [6].

Xuejun Liu and A.C.Lopes,

The corresponding authors have proposed a new kind of maximum power point tracking algorithm based on perturb and observe algorithm. The algorithm is fast acting and eliminates the need of a large capacitor which is normally used in perturb and observe algorithm to eliminate the ripple in the module voltage. The module voltage and current that are taken for processing are not averaged but are instantaneous this speed ups the process of peak power tracking. Also the paper implements the new algorithm on the real time platfrom. The software used was dSPACE^{R}.

7]. Comparative Study of Maximum Power Point Tracking Algorithms Using an Experimental, Programmable, Maximum Power Point Tracking Test Bed.,[7]

D. P. Hohm, M. E. Ropp.

The authors have compares all the different kinds of algorithm that are used for the maximum power point tracking. This helps in proper selection of the algorithm. Preliminary results indicate that perturb and observe compares favorably with incremental conductance and constant voltage. Although incremental conductance is able to provide marginally better perfromance in case of rapidly varying atmospheric conditions , 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.

8].Theoretical and Experimental Analyses of Photovoltaic Systems With Voltage- and Current-Based Maximum Power-Point Tracking

Mohammad A. S. Masoum, Hooman Dehbonei, and Ewald F. Fuchs.

Detailed theoretical and experimental analyses of two simple, fast and reliable maximum power-point tracking (MPPT) techniques for photovoltaic (PV) systems are presented. Voltage-based (VMPPT) and the Current-based (CMPPT) approaches. A microprocessor-controlled tracker capable of online voltage and current measurements and programmed with VMPPT and CMPPT algorithms is constructed. The load of the solar system is either a water pump or resistance. The paper has given a simulink model of the Dc/Dc converter and a solar PV module.

The literature review consists of vast survey of papers from the various conferences. The literatures give sufficient idea about the basics of the MPPT algorithm and how the MPP tracking is takes place. Details of various algorithms that are used for the MPPT technique are discussed in the paper [7]. Also dc/dc converter design and various control aspects for the dc/dc converter are discussed. Which type of dc/dc converter can give maximum efficiency and which is the best choice for a given algorithm is discussed in the paper [2]. As discussed in [2] a dc/dc step down converter gives higher efficiency than the step up converter Some papers also give idea about real time interfacing of the Personal computer with the control hardware.[1],[6]. A improved P&O algorithm is proposed in the [1]. This algorithm is selected for the present thesis work and verified some changes are brought out in the algorithm and is implemented in using a real time interface through dSPACE^{R}.

CHAPTER 3.

Algorithms to track the Maximum Power Point.

As explained earlier in chapter 1.4. Different algorithms help to track the peak power point of the solar pv module automatically. The various algorithms used are.

a. **Perturb and observe.**
b. **Incremental Conductance.**
c. **Parasitic Capacitance.**
d. **Voltage Based Peak Power Tracking.**
e. **Current Based peak power Tracking**.

3.1 Perturb and observe [1],[2],[5]:- In this algorithm a slight perturbation is introduce system. Due to this perturbation the power of the module changes. If the power increases due to the perturbation then the perturbation is continued in that direction. After the peak power is reached the power at the next instant decreases and hence after that the perturbation reverses.

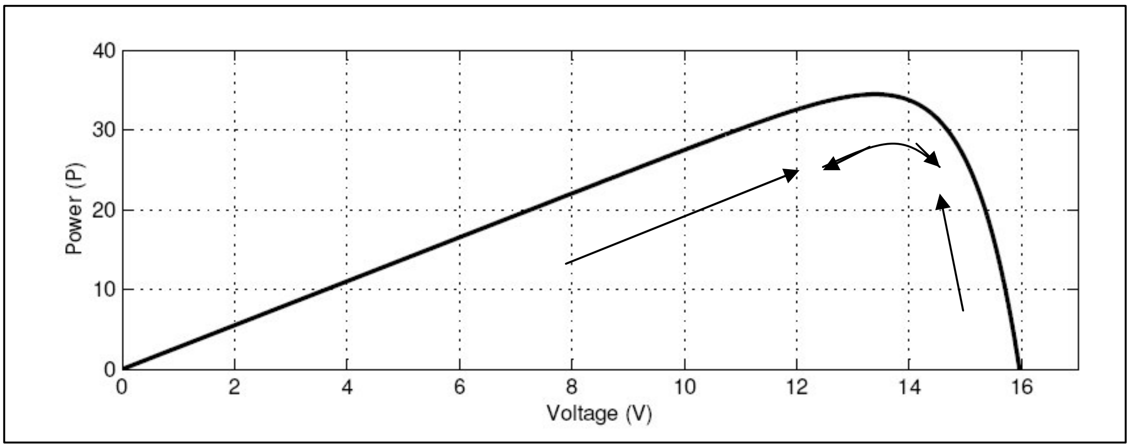


Fig.9. Perturb and observe algorithm

When the steady state is reached the algorithm oscillates around the peak point. In order to keep the power variation small the perturbation size is kept very small. The algorithm is developed in such a manner that it sets a reference voltage of the module corresponding to the peak voltage of the module. A PI controller then acts moving the operating point of the module to that particular voltage level. It is observed that there some power loss due to this perturbation also the fails to track the power under fast varying atmospheric conditions. But still this algorithm is very popular and simple.

3.2] Incremental conductance,[3],[7]:- The disadvantage of the perturb and observe method to track the peak power under fast varying atmospheric condition is overcome by Incremental conductance method. The algorithm makes use of the equation

$$P=V*I \quad (4)$$

(where P= module power,V=module voltage, I=module current);

diff with respect to dV

$$dP/dV=I+V*dI/dV \quad (5)$$

Depending on this equation the algorithm works.

at peak power point

$$dP/dV=0 \quad (6)$$

$$dI/dV=-I/V \quad (7)$$

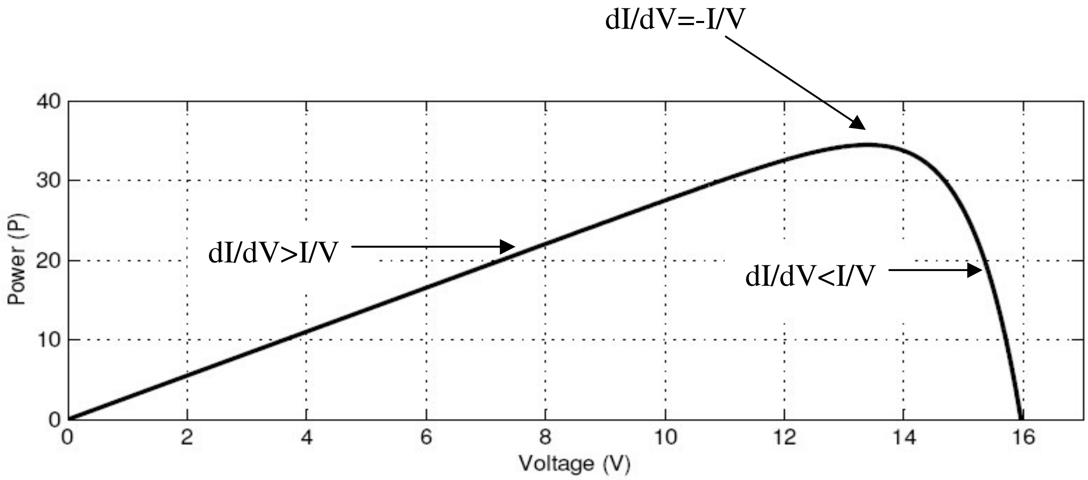


Fig.10.Incremental conductance method.

If the operating point is to the right of the Power curve then we have

$$dP/dV<0 \quad (8)$$

$$dI/dV<I/V \quad (9)$$

If operating point is to the left of the power curve then we have

$$dP/dV>0 \quad (10)$$

$$dI/dV>I/V \quad (11)$$

Using equations 7, 9& 10 the algorithm works.

The incremental conductance can determine that the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between dl/dV and –I/V This relationship is derived from the fact that dP/dV is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP. This algorithm has advantages over perturb and observe in that it can determine when the MPPT has reached the MPP, where perturb and observe oscillates around the MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than perturb and observe. One disadvantage of this algorithm is the increased complexity when compared to perturb and observe.

3.3] Parasitic capacitances,[7]:- The parasitic capacitance method is a refinement of the incremental conductance method that takes into account the parasitic capacitances of the solar cells in the PV array **.** Parasitic capacitance uses the switching ripple of the MPPT to perturb the array. To account for the parasitic capacitance, the average ripple in the array power and voltage, generated by the switching frequency, are measured using a series of filters and multipliers and then used to calculate the array conductance**.** The incremental conductance algorithm is then used to determine the direction to move the operating point of the MPPT. One disadvantage of this algorithm is that the parasitic capacitance in each module is very small, and will only come into play in large PV arrays where several module strings are connected in parallel. Also, the DC-DC converter has a sizable input capacitor used filter out small ripple in the array power. This capacitor may mask the overall effects of the parasitic capacitance of the PV array.

3.4] Voltage control maximum point tracker [8]:- It is assumed that a maximum power point of a particular solar PV module lies at about 0.75 times the open circuit voltage of the module. So by measuring the open circuit voltage a reference voltage can be generated and feed forward voltage control scheme can be implemented to bring the solar pv module voltage to the point of maximum power. One problem of this technique is the open circuit voltage of the module varies with the temperature. So as the temperature increases the module open circuit voltage changes and we have to measure the open circuit voltage of the module very often. Hence the load must be disconnected from the module to measure open circuit voltage. Due to which the power during that instant will not be utilize.

3.5] Current control maximum power point tracker [8]:- The peak power of the module lies at the point which is at about 0.9 times the short circuit current of the module. In order to measure this point the module or array is short-circuited. And then by using the current mode control the module current is adjusted to the value which is approx 0.9 times the short circuit current. The problem with this method is that a high power resistor is required which can sustain the short-circuit current. The module has to be short circuited to measure the short circuit current as it goes on varying with the changes in insolation level.

CHAPTER 4.

Simulation of MPPT in Matlab^R/Simulink^R.

4.1] Modeling of the solar pv module in Matlab[R]/Simulink[R] :-

A solar PV module is developed in simulink. This module is used as a source for the maximum power point tracker system. The module makes use of the equations of a typical solar cell. The typical model of a solar cell is shown in fig.11

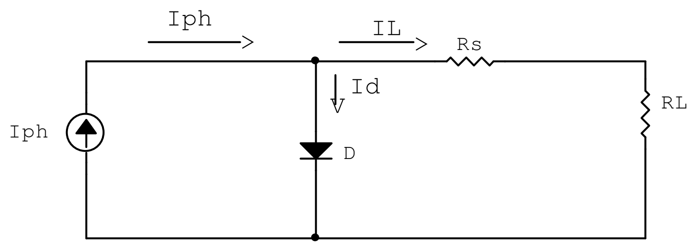


Fig.11. Solar cell Equivalent Model

$I_{ph}=I_L+I_d$……………………………………………………………………………(12)

Where I_{ph}= photon generated current, I_L=Load current, I_d=diode current.

$I_d=I_o\ (e^{(v*q/k*T)}-1)$…………………………………………………………..(13)

Where I_o=reverse saturation current of the diode,

V= forward voltage V, q =charge C, k =Boltzman constant, T= temperature K.

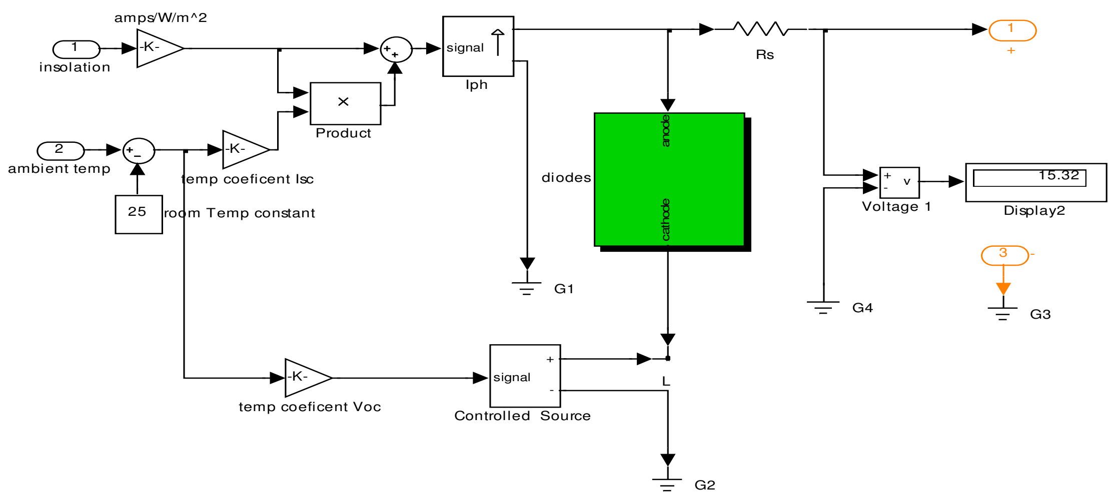


Fig.12 Simulink model of the solar PV module.

As seen in the figure .12 the model takes in to consideration the variation of temperature and insolation. The insolation change affects the photon generated current and has very little effect on the open circuit voltage. Where as the temperature variation affects the open circuit voltage and the short circuit current varies very marginally. Iph blocks takes photo generated current. These current changes with the insolation.

$I_{ph}=G*I_{sc}$…………………………………………………………(14)

where I_{sc} is the short-circuit current of the module at 1000 W/m^2 and

G=present insolation/1000.

Temperature variation affects the open circuit voltage. The open circuit voltage decreases by about 2.3mv/cell/degree rise in temp. And the short circuit current increases by about 1µA/ degree rise in temp. These two effects are taken care of in the simulink model of the solar PV module. The diode block is used from simulink library. With ideal characteristics.In the present work diode block is taken from simulink library. A series resistance is added which has a typical value of 8mΩ

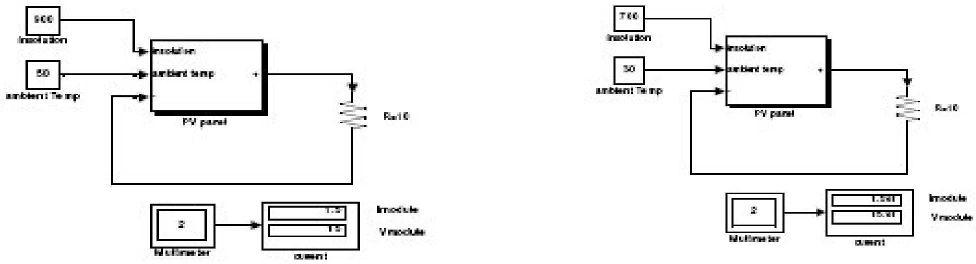


Fig.13.Simulink Model of Solar PV module model with display voltage and current .

The module voltage and current for different temperature and insolation are simulated. The results are shown in the multimeter box.

A characteristic of the solar PV module where plotted for the insolation of 900W/m^2 and temp of about 40degrees.

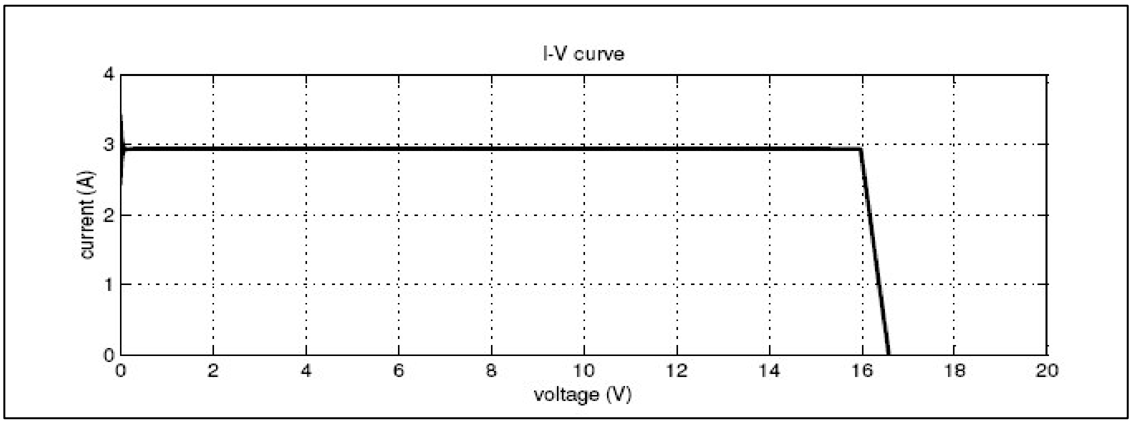


Fig.14. I-V characteristics of solar PV **module**

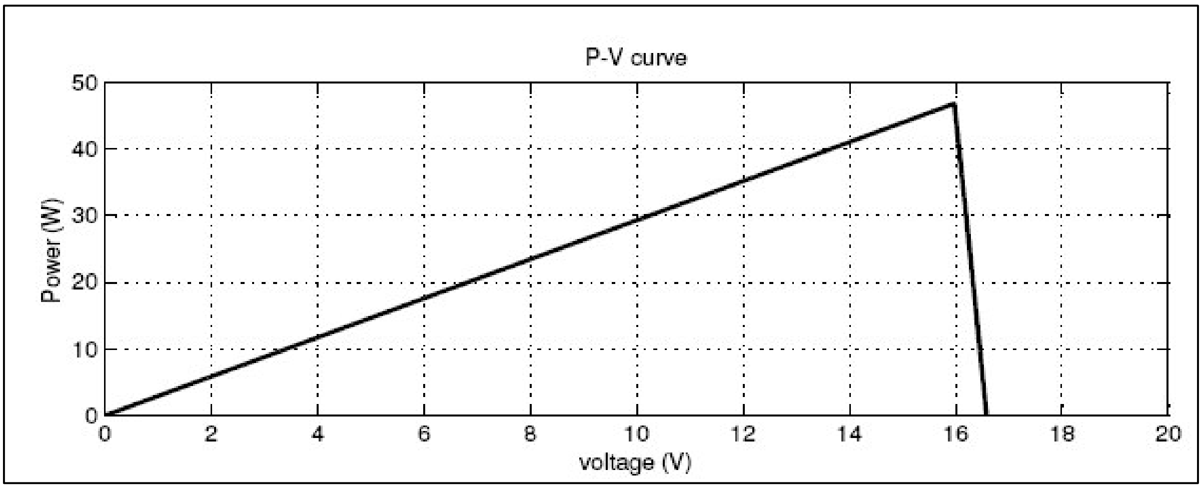


Fig.15 P-V characteristics of solar PV module.

The characteristics curve of the current vs voltage fig.14 and power vs voltage fig.15 are plotted. These characteristics depict typical solar PV module characteristics and also give proper results on the MPPT systems.

4.2] MPPT algorithm used for simulation in Matlab^R/Simulink^R.

As discussed in chapter 2 among different maximum power point algorithms, the perturb and observe algorithm is simple and also gives good results. This algorithm is selected and certain changes are made in the present work . The flow chart of the algorithm is shown in the fig.16. The algorithm reads the value of current and voltage from the solar PV module. Power is calculated from the measured voltage and current. The value of voltage and power at k^{th} instant are stored. Then next values at $(k+1)^{th}$ instant are measured again and power is calculated from the measured values. The power and voltage at $(k+1)^{th}$ instant are subtracted with the values from k^{th} instant. If we observe the power voltage curve of the solar pv module we see that in the right hand side curve where the voltage is almost constant the slope of power voltage is negative (dP/dV<0) where as in the left hand side the slope is positive.(dP/dV>0). The right side curve is for the lower duty cycle(nearer to zero) where as the left side curve is for the higher duty cycle(nearer to unity). Depending on the sign of dP(P(k+1) - P(k)) and dV(V(k+1) -V(k)) after subtraction the algorithm deceides whether to increase the duty cycle or to reduce the duty cycle.

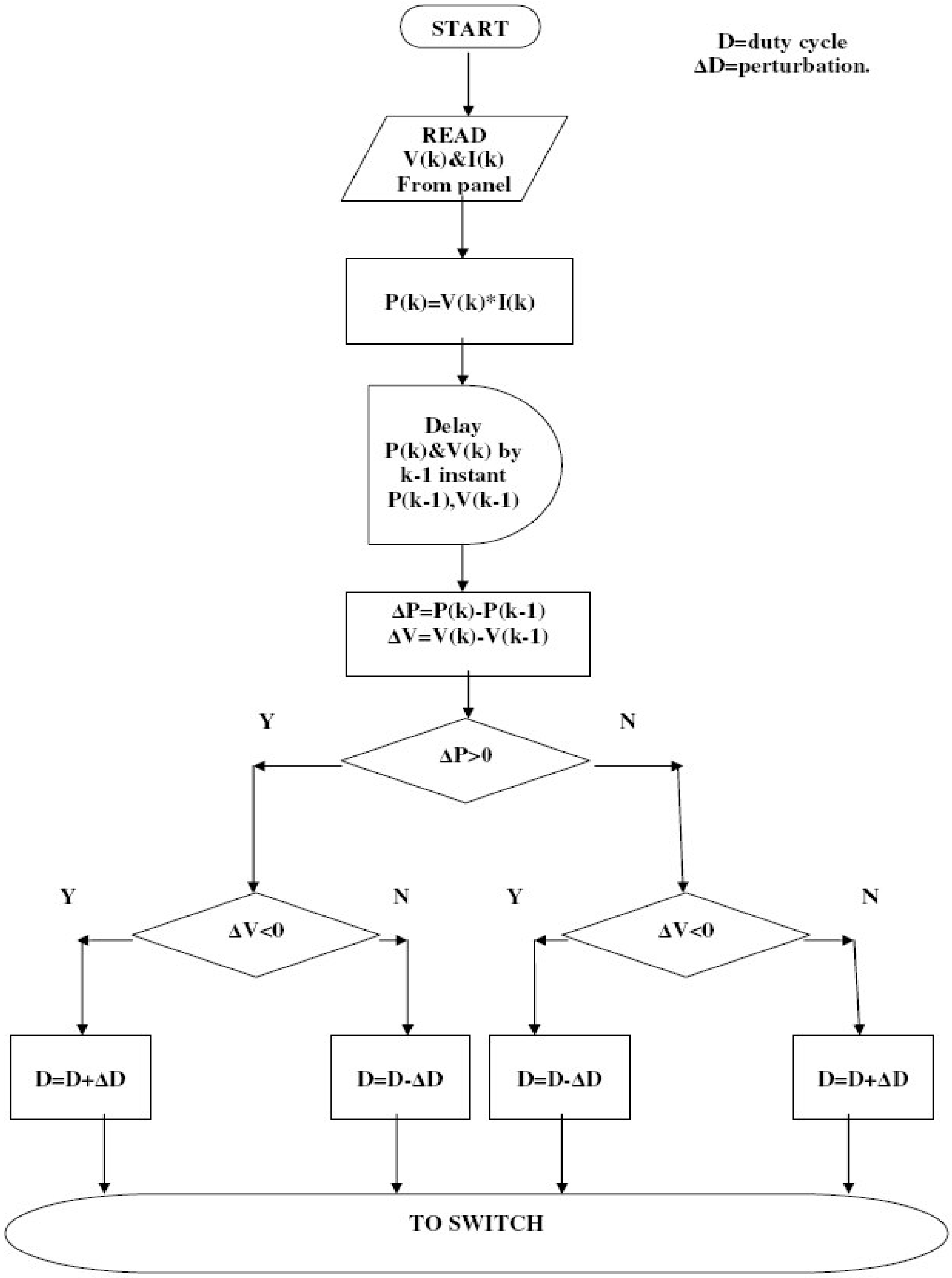


Fig.16. Perturb and observe algorithm

The algorithm is simple and has only one loop. In other perturb and observe algorithms two loops are implemented. One loops sets the Vref corresponding to the peak power point of the module. The outer PI control loop then implements a feed forward control and sets the module operating voltage at the Vref value as specified by the MPPT algorithm. The use of PI controller makes the loop faster as compared to the direct duty cycle control implemented in the present thesis. But still if the sample time is reduced in direct duty cycle control the power tracking can be made faster even in the fast varying climatic conditions.

4.3] DC/DC converter used for the MPPT **system**

A dc/dc converter froms an integral part of any MPPT system. Without dc/dc converter no MPPT system are designed. The dc/dc converter can be either a step down converter fig.17 in which output voltage is less than input voltage or step up converter fig.18 in which the output voltage is higher than the input voltage.

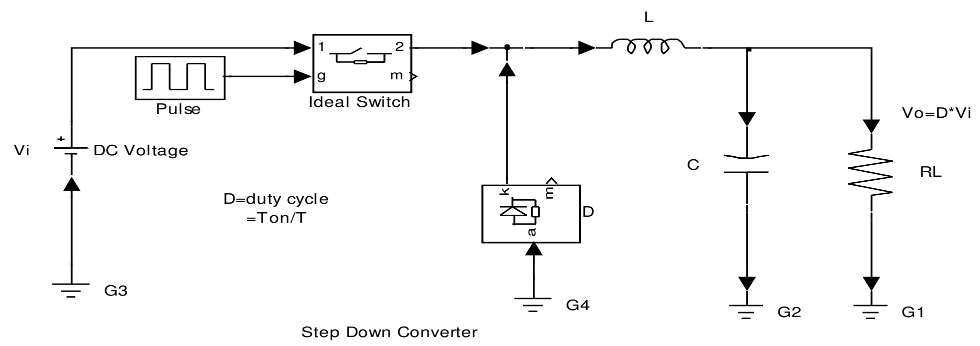
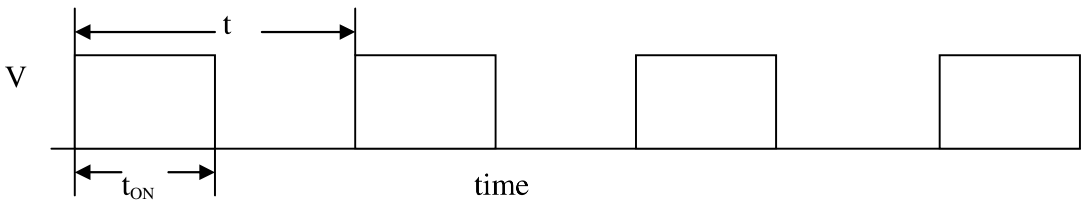


Fig.17.Step down or Buck converter (Vo<Vi)

The step down converter the output voltage (Vo) is less than the input voltage (Vi). The input and output voltage are related with each other by the equation

Vo=D*Vi……………………………………………………………………….(15)

Where D is the duty cycle of the converter that is the ratio of the t_{ON} (time for which the converter remains to the switching time t of the converter).



$D = t_{ON} /t$………………………………………………………………….(16).

Thus by varying the duty cycle the output voltage can be changed also the input current and the output current changes with the change in the duty cycle. Also the impedance seen by the converter input side varies with the duty cycle

$R_i = R_L/D^2$………………………………………………………………(17)

This property of the converter to transfer impedance is utilized in the MPPT.

The step down converter can be used in the cases where the output voltage required is less than the input voltage.

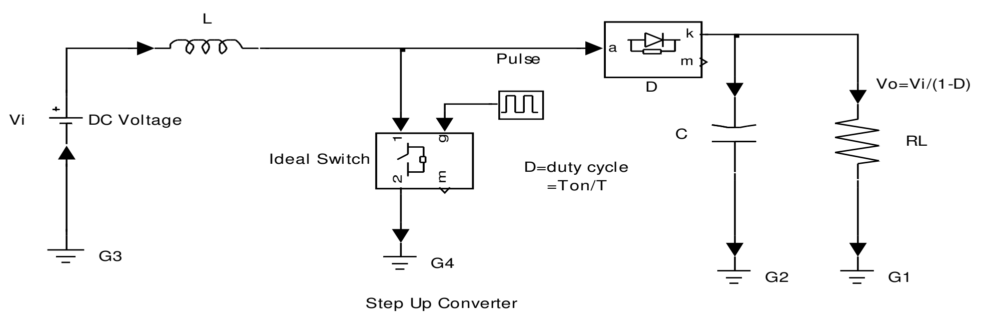


Fig.18. Step Up or Boost converter(Vo>Vi)

The boost converter or the step up converter has the output voltage greater than the input The voltage transformation ratio is

$Vo = Vi/(1-D)$……………………………………………………………(18)

By varying D the output voltage can be changed and it is always more than Vi. The advantage of this converter is that the input and output current both are continuous. Where as in the step down converter the input current is discontinuous. The boost converter can be implemented in the MPPT system where the output voltage of the system is required to be higher than the input voltage. Generally in grid-connected systems where the MPPT system is part a boost converter is utilized which maintains a high voltage even if the array voltage falls. In the present work a step down converter is simulated though a step up converter can also be used as it gives same results as discussed in results chapter.

4.4] Simulation of the MPPT system.

For the simulation of the MPPT system a step down converter model is developed in simulink using power systems block set. The values of the components where carried out from the design procedures given in [10].

At switching frequency 20kHz . the value of the components selected are :

L=330µH.

C=440µF.

R_L=2Ω (60W).

f =20kHz.

The switch used was a ideal switch, with low switching and ON state loss.

The Solar PV module developed was used as the source. The simulink setup is shown in the fig.19.

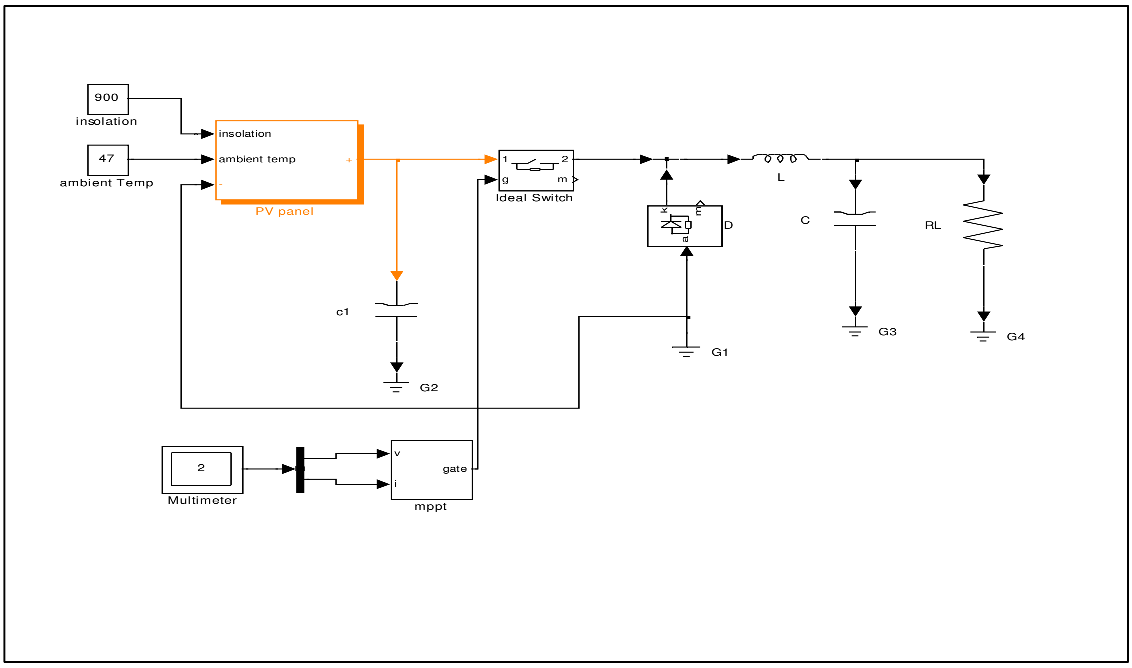


Fig.19 MPPT system simulink setup

The simulink setup of the MPPT system is shown in the fig.19. The MPPT bock takes the module voltage and current through the multimeter. The MPPT block contains the algorithm which was explained in the chapter 3.2. the insolation and the temperature are kept fixed and are not varied. The simulink implementation of the algorithm is shown in fig.20. The logic is developed according to the flow chart. Direct duty cycle control method is implemented. The algorithm outputs a signal which has a value between 1& 0.

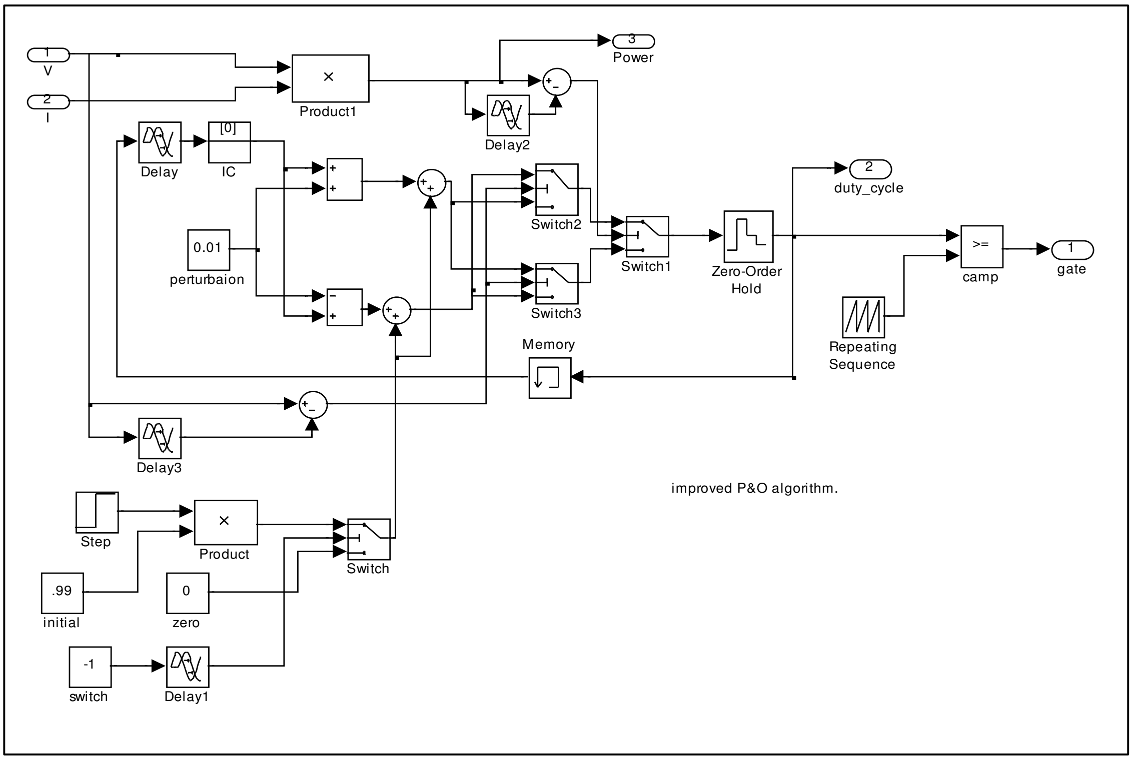


Fig.20 Implementation of algorithm in simulink

this signal is then given to the pwm generator which consists of a saw tooth generator and comparator. The algorithm output signal is compared with the high frequency saw tooth wave from. The output of the comparator is a pulses of high frequency which are used to drive the switch. The algorithm gives duty cycle output. And hence when peak power is reached the algorithm perturbs around the peak power.

4.5] Results of the simulations-

The results for the simulation where carried out for starting from higher duty cycle(left half of the PV curve) that is unity and at some other initial duty cycle value which lies in the right half of the PV curve. The results for both the cases where obtained in simulink. The module parameters where kept constant that is the solar inslation and the temperature where kept constant. The results are shown in the fig. 21 and 22.

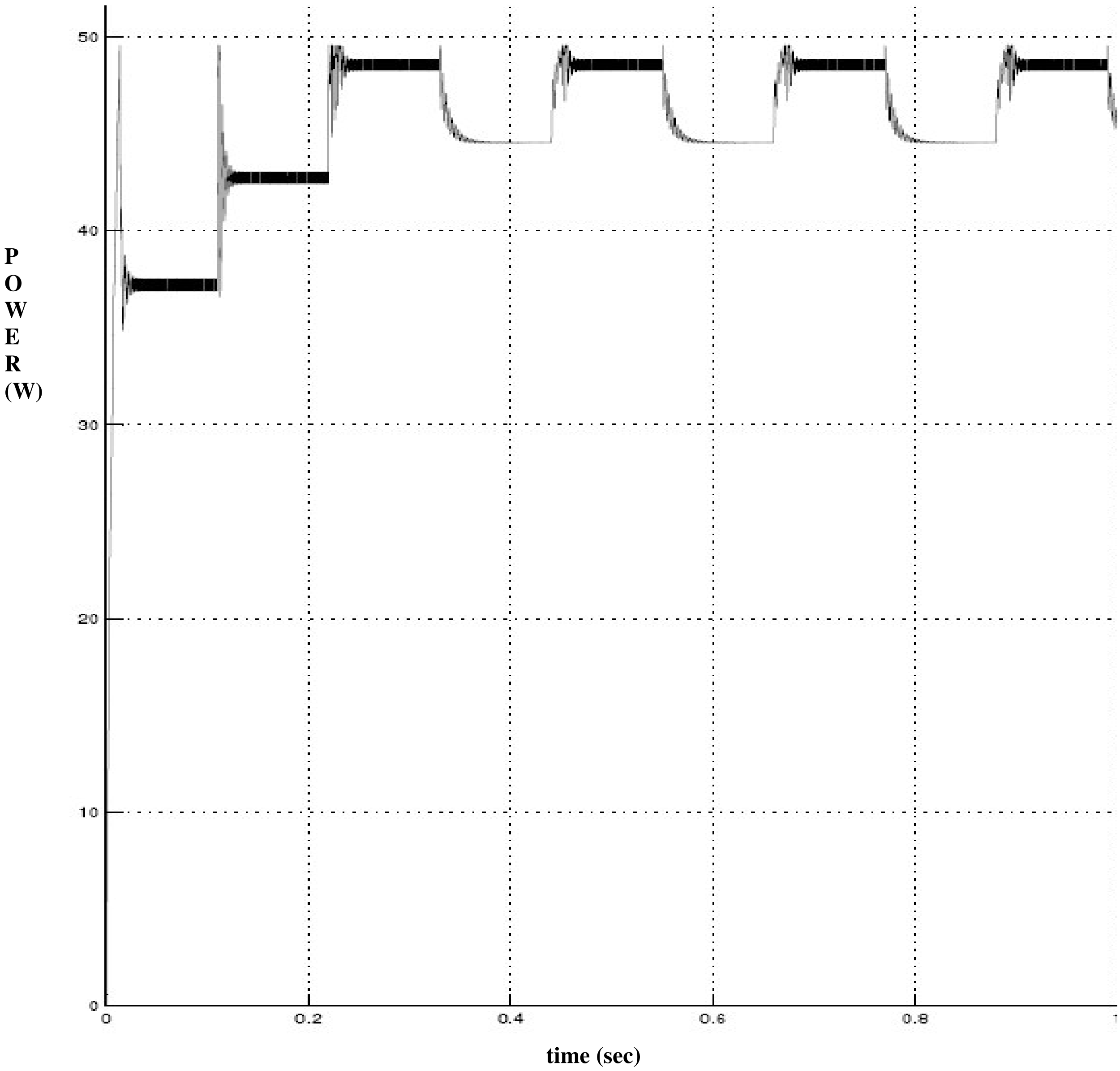


Fig 21 Initial duty ratio 0.65(right half of the PV curve)

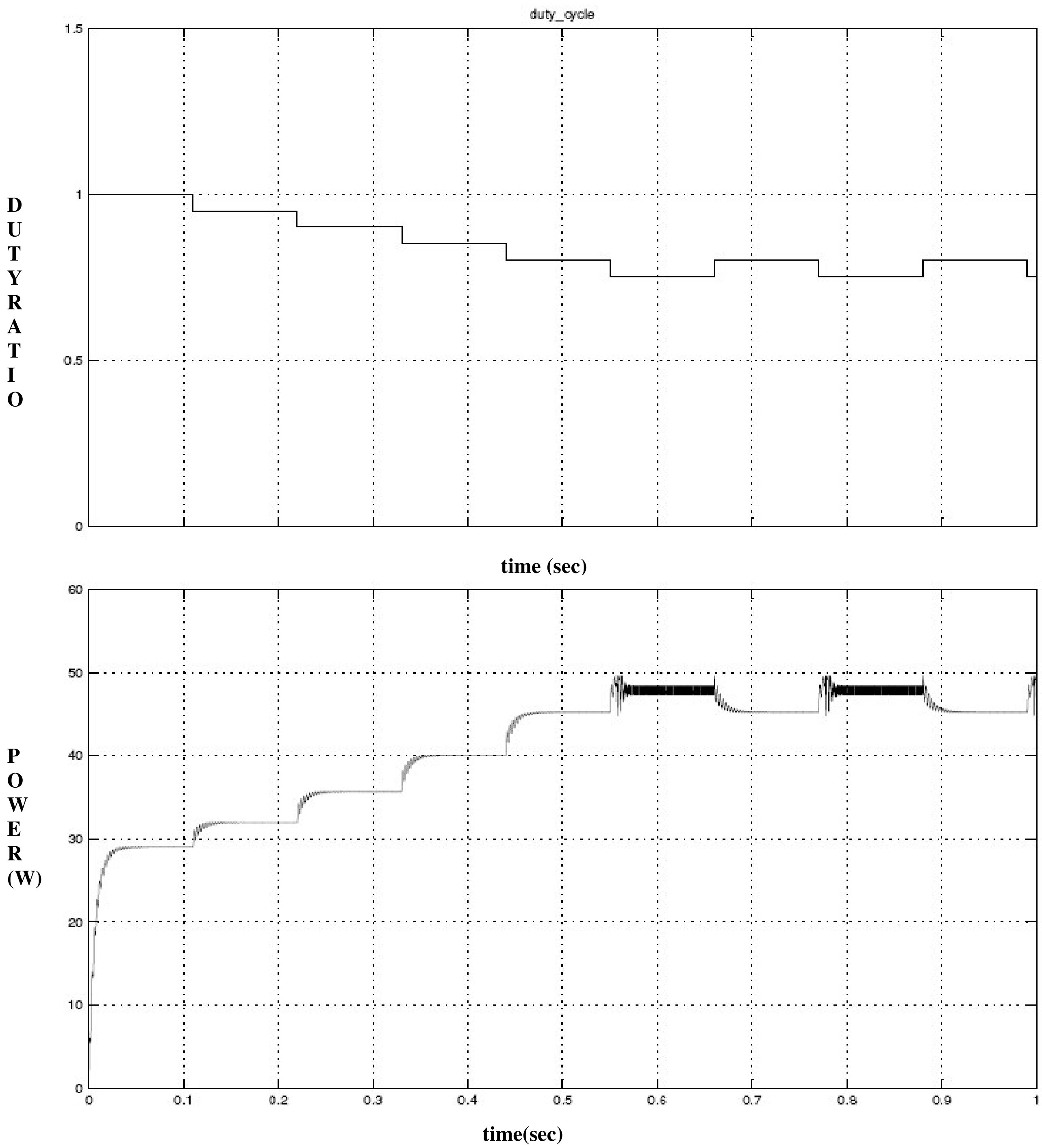


Fig.22 Initial duty ratio equal to unity (left half of the PV curve)

From the results it is inferred that the algorithm tracks the peak power and also from both the directions of the PV curve(right half and the left half). A slow tracking of the peak power is observed.

CHAPTER.5

Introduction to dSPACE^{R}

5.1] Introduction

dSPACE[R] provides complete solutions for electronic control unit (ECU) software development. It is powerful development tools for dedicated services in the field of function prototyping, target implementation, and ECU testing. Real time control systems can be built using dSPACE and the control logic can be implemented. The dSPACE works on Matlab/Simulink platfrom which is a common engineering software and easy to understand. Another feature of the dSPACE is the Control desk which allows the graphical user interface. through the control desk the user can observe the response of the system also he can give command to the system through this interface. Real time interface is needed for the dSPACE to work. Real-time Interface (RTI) is the link between dSPACE's real-time systems and the development software MATLAB/ Simulink from the Math Works. It extends Real-Time Workshop (C-code generation) for the seamless and automatic implementation of our simulink Models on the dSPACE Real-time Hardware. This allows us to concentrate fully on the actual design process and to carry out fast design iterations. To specify a dSPACE I/O board, we can simply pick up the corresponding I/O module graphically from the RTI block library and then attach and parameterize it within simulink.

Advantages of RTI:

- Easy graphical I/O configuration and automatic code generation.
- A periodic event handling support of triggered and enabled subsystems, hardware, and software interrupts.
- Smooth implementation on multiprocessor systems with multiprocessor option.
- Reduces implementation
-

5.2 ROLE OF dSPACE IN DEVELOPING A CONTROLLER*:*

In control engineering hardly any controller is designed without simulation. The typical procedure is to develop a model of the plant and simulate it on a computer. Then a controller is added to the simulation and optimized.

5.2.1 Development Steps:

- **Control design and Simulink simulation:**

  At this stage of development the simulation is perfromed in Simulink. The major feature of this type of simulation is that the computer has as much time as needed to calculate the behavior of the system. Thus, if your model is simple, the results can be calculated quickly. If your model is complex, much more time is needed to carry out the necessary calculations. However, because you do not need to fulfill a strict time requirement for Simulink simulation, you do not need to reduce the complexity of the model.

- **RCP with dSPACE Prototype**

  The whole situation is different once the simulated control system meets your expectations and you want to test the controller on the actual plant. Since the controller might need further modifications, you do not want to produce it in hardware at this stage of development. Therefore, you have to connect the real plant to a controller that is simulated in real time – this technique is called rapid control prototyping (RCP). The major feature of this real-time simulation is that the simulation has to be carried out as quickly as the real system would actually run, thereby allowing you to combine the simulation and the real plant.

- **HIL with dSPACE Simulator**

  When your simulated controller is able to control your real plant, you typically produce the actual controller. For the final tests you usually connect the real controller to a model of the plant, which, of course, has to be simulated in real-time. This way you can ensure that the controller does not contain any errors that could damage the real plant. This technique is called hardware-in-the-loop simulation (HIL). For both RCP and HIL the real-time simulation is rather important. The computing power required by real-time simulation highly depends on the characteristics of the simulated model: If it contains very demanding calculations you have to provide a lot of computing power because the timing cannot be satisfied otherwise. dSPACE systems fulfill this demand for computing power.

- **Automatic code generation**

  Because real-time simulation is such a vital aspect for control engineering, the same is true for the automatic generation of real-time code, which can then be implemented on the hardware. For dSPACE systems, Real-Time Interface (RTI/RTI-MP) carries out this linking function. Together with Real-Time Workshop from The Math Works it automatically generates real-time code from Simulink models and implements this code on dSPACE real-time hardware. Therefore, you save time and effort twice:

  - You do not need to manually convert your Simulink model into another as C.

  - You do not need to be concerned about a real-time program frame and I/O function calls, or about implementing and downloading the code onto your dSPACE hardware.

  RTI carries out these steps for you. You just have to add the required dSPACE blocks (for example, I/O interfaces) to your Simulink model.

5.3 GETTING STARTED WITH dSPACE:

After you install your system, you are ready to implement, download and experiment with your control algorithm.

Development Steps:

The first step is to implement your control algorithm. For this purpose, you can either embed the blocks provided by dSPACE's Real-Time Interface (RTI) in a Simulink model or use RTLib's functions to handcode your application directly in C. Then build your model and download it to your dSPACE real-time hardware.

As soon as the real-time application is running on your hardware, you can use ControlDesk to experiment with it.

5.4] dSPACE PACKAGES:

The packages that comes with this version of dSPACE are as follows:

5.4.1] SOFTWARE:

The dSPACE software comes via CD-ROM. For the license handling, a Key-Disk is also delivered. Base dSPACE software package.

The CD includes the following dSPACE software:

a].Control Desk's Basic Features, a graphical user interface for managing the dSPACE boards. In addition to the functions for registering the hardware and managing applications via the Platfrom Manager, Basic Features provides the functions for managing experiments via the Experiment Manager. The Source Code Editor, which optimizes the treatment of source code in C or Python, is also included.

b].The dSPACE Real-Time Library, the real-time core software with a C programming interface.

c].Optional dSPACE software packages

As an option, dSPACE offers all tools useful for implementing, experimenting and testing control systems. These tools are protected by license.

d].Real-Time Interface (RTI and RTI-MP), the interface between Simulink and the dSPACE hardware. Real-Time Interface can be used to build real-time code, and to download and execute this code on dSPACE hardware. As a further option, you can get additional blocksets, like the RTI CAN Blockset.

e].Control Desk Standard, offering a variety of virtual instruments to build and configure virtual instrument panels via Instrumentation, providing functions to perfrom parameter studies via the Parameter Editor and functions to automate Control Desk's features via Automation.

f].Control Desk Multiprocessor Extension, an extension for dSPACE multiprocessor systems.

g].Control Desk Test Automation, the extension of Control Desk Standard for advanced test automation features.

h].MLIB/MTRACE, the MATLAB–dSPACE Interface Libraries. The functions of these libraries allow direct access to dSPACE real-time hardware from the MATLAB workspace.

5.4.2]. HARDWARE:

The DS1104 R&D Controller Board is a single-board system. The hardware package contains:

- One PCI-slot board with a bracket including a 100-pin I/O connector.
- One adapter cable with two 50-pin female Sub-D connectors. The adapter cable is optional.

a]. DS1104 R & D CONTROLLER BOARD:

The DS1104 R&D Controller Board is a standard board that can be plugged into a PCI slot of a PC.

The DS1104 R&D Controller Board is specifically designed for the development of high-speed multivariable digital controllers and real-time simulations in various fields. It is a complete real-time control system based on a 603 PowerPC floating-point processor running at 250 MHz. For advanced I/O purposes, the board includes a slave-DSP subsystem based on the TMS320F240 DSP microcontroller.

For purposes of rapid control prototyping (RCP), specific interface connectors and connector panels (see below) provide easy access to all input and output signals of the board. Thus, the DS1104 R&D Controller Board is the ideal hardware for the dSPACE Prototyper development system for cost-sensitive RCP applications.

To demonstrate control design and implementation, demo equipment (VCFP Simulator) is available for the DS1104.

b].Adapter cable with Sub-D connectors:

Using the adapter cable you can link your external signals from the 100-pin I/O connector on the board to Sub-D connectors. So you can make a high-density connection between the board and the devices of your application via Sub-D connectors.

c].CP1104:

The CP1104 Connector Panel provides easy-to-use connections between the DS1104 R&D Controller Board and devices to be connected to it. Devices can be individually connected, disconnected or interchanged without soldering via BNC connectors and Sub-D connectors. This simplifies system construction, testing and troubleshooting.

d].CLP1104:

In addition to the CP1104, the CLP1104 Connector/LED Combi Panel provides an array of LEDs indicating the states of the digital

5.5] DS 1104 FEATURES OVERVIEW:

The DS1104 R&D Controller Board is a standard board that can be plugged into a PCI slot of a PC.

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To demonstrate control design and implementation, demo equipment (VCFP Simulator) is available for the DS1104.

5.5.1].The DS1104 R&D Controller Board provides the following features:

1].Master PPC representing the computing power of the board, and featuring several I/O units.

2].Slave DSP featuring further I/O units.

3].Interrupt controller providing various hardware and software interrupts.

4].Memory comprising DRAM and flash memory.

5].Timers providing a sample rate timer, a time base counter, and 4 general-purpose timers.

6].Host interface for setting up the DS1104, downloading programs and transferring runtime data from/ to the host PC.

1.1]Features Provided by the Master PPC:

The DS1104's main processing unit, MPC8240, consists of

A PowerPC 603e microprocessor (master PPC) on which your control models will be implemented

- Running at 250 MHz (CPU clock)
- Containing a 16-KByte L1 data cache
- Containing a 16-KByte L1 instruction cache
- An interrupt controller.
- A synchronous DRAM controller.
- Several timers.

A PCI interface (5 V, 32 bit, 33 MHz)

2.1].Features Provided by the Slave DSP:

- The DS1104's slave DSP subsystem consists of
- A Texas Instruments TMS320F240 DSP, Running at 20 MHz.
- 4Kx16 bit dual-port memory (DPMEM) used for communication with the master PPC.

2.2]I/O features of the slave DSP:

The slave DSP provides the following I/O features of the DS1104:

- Slave DSP Bit I/O Unit

- Slave DSP Timing I/O Unit
- Slave DSP Serial Peripheral Interface (SPI)

Except for the latter, these features can be fully programmed from RTI and RTLib. The Slave DSP Serial Peripheral Interface can be programmed fromRTLib1104.

4.1] Memory Features*:*

The DS1104 is equipped with two memory chapters:

- Global memory, 32 MByte
- Synchronous DRAM (SDRAM) for applications and data.
- Fully cached (L1 cache) Flash memory 8 MByte, divided into 4 blocks of 2 MByte each, 6.5 MByte can be used for a user-specific application, 1.5 MByte are reserved for the boot firmware, 8-bit read / write access by master PPC.
  At least 100,000 erase cycles possible

5.1].Timer Features:

The DS1104 board is equipped with 6 timer devices. The timers are driven by the bus clock, whose frequency is referred to as BCLK.

The timers have the following characteristics:

5.2]Time Base Counter

- Free-running 64-bit up counter driven by BCLK/4
- Measurement of relative and absolute times

5.3]Time-stamping Timers 0 ... 3

- 32-bit down counters driven by BCLK/8
- Selectable period for each timer
- Trigger for periodic tasks
- Generation of a timer interrupt when counter reaches 0, and automatic reload.

5.4]Decrementer

- 32-bit down counter driven by BCLK/4
- Selectable period
- Trigger for periodic tasks
- Generation of a timer interrupt when counter reaches 0, and automatic reload

6.1]Host Interface Features

The DS1104 provides a PCI interface requiring a single 5 V PCI slot.The interface has the following characteristics:

Access from/to the host PC via 33 MHz-PCI interface

The interface serves the board setup, program downloads and runtime data transfers from/to the host PC. Interrupt line

The host interface provides a bi-directional interrupt line: Via this line, the host PC can send interrupt requests to the master PPC and vice versa. Both the host PC and the master PPC can monitor the state of the interrupt line to detect when the corresponding interrupt service is finished.

5.6 IMPLEMENTATION STAGE:

The Real-Time Interface (RTI) board library for the DS1104 R&D Controller Board – the rtilib1104 – provides the RTI blocks that implement the I/O capabilities of the DS1104 in Simulink models. These RTI blocks are designed to specify the hardware setup for real-time applications. Furthermore, the rtilib1104 provides additional RTI blocks, demo models, and useful infromation. RTI Blockset for the Master PPC

5.6.1]. RTI Blockset for the Master PPC :

The following I/O units and the corresponding blocks can be accessed by the RTI block set for the master PPC of the DS1104:

1].ADC Unit

- DS1104ADC_Cx
- DS1104MUX_ADC

2].DAC Unit

- DS1104DAC_Cx

3].Bit I/O Unit

- DS1104BIT_IN_Cx
- DS1104BIT_OUT_Cx

4].Incremental Encoder Interface

- DS1104ENC_SETUP
- DS1104ENC_POS_Cx
- DS1104ENC_SET_POS_Cx
- DS1104ENC_HW_INDEX_Cx
- DS1104ENC_SW_INDEX_Cx

5].Serial Interface

- DS1104SER_SETUP
- DS1104SER_STAT
- DS1104SER_TX
- DS1104SER_RX
- DS1104SER_INT_Ix
- DS1104SER_INT_REC_LEV

6].Interrupts

- DS1104MASTER_HWINT_Ix

7].Synchronizing I/O Unit

- DS1104SYNC_IO_SETUP

5.6.2]. RTI Block set for the Slave DSP

After you click the SLAVE DSP F240 button in the Library: rtilib1104 window, the Library: rtilib1104/DS1104 SLAVE DSP window is displayed. It contains the I/O blocks served by the TI F240 slave DSP.

The following I/O units and the corresponding blocks can be accessed by the RTI block set for the slave DSP of the DS1104:

1. Slave DSP Bit I/O Unit

- DS1104SL_DSP_BIT_IN_Cx
- DS1104SL_DSP_BIT_OUT_Cx

2. Slave DSP Timing I/O Unit

- DS1104SL_DSP_PWM

- DS1104SL_DSP_PWM3
- DS1104SL_DSP_PWMSV
- DS1104SL_DSP_D2F
- DS1104SL_DSP_F2D
- DS1104SL_DSP_PWM2D

3. Slave DSP Interrupts

- DS1104SLAVE_DSPINT_Ix
- DS1104SLAVE_PWMINT

5.7].EXPERIMENTATION AND TESTING USING CONTROLDESK

Control Desk, dSPACE's well-established experiment software, provides all the functions to control, monitor and automate experiments and make the development of controllers more efficient.

5.7.1] REASONS TO USE CONTROLDESK:

1].Control Desk makes our experiments more effective:

1. One integrated tool for all experiment tasks.
2. Real time data acquisition and online parameter tuning.
3. Automation of our complete experiments.

2].Control Desk makes building instrument panels easier than ever*:*

- Comprehensive set of virtual instruments.
- Intuitive and powerful instrument configuration.
- Automated instrument panel setup.

3].Control Desk shortens our development cycles dramatically:

- Perfect connection to Simulink and system build.
- Macro Recorder for automation of most Control Desk features.
- Stimulus editor for graphical test scripting.

4].Control Desk gives us control on our experiment anytime.

5.8] CONTROLDESK PACKAGES:

Since Control Desk is divided into several software packages, you only have to purchase the parts you need to fulfill your modeling tasks. The following packages are available:

- **Control Desk Standard** is the basis of each experiment.
- **Control Desk Multiprocessor Extensions** provides features for dSPACE multiprocessor systems and requires that Control Desk Standard be installed.
- **Control Desk Test Automation** is for advanced test automation tasks and requires that Control Desk Standard is installed.

5.9] FEATURES OF CONTROLDESK STANDARD:

Since Control Desk consists of several packages, you can build a software environment according to your needs. Installing a new Control Desk package adds the new functions and tools to the software environment provided by Control Desk Standard.

Control Desk Standard provides the following features:

1].Basic Features:

1.1].Experiment Manager: Experiment Manager ensures consistent data management to control all of the experiment-relevant data. An experiment can be loaded as a complete set of data in a single operation. The user can define the contents of the experiment. To use Control Desk's experiment features, you first have to create an experiment that will be the basis for all further actions.

1.2].Platfrom Manager: Platfrom Manager lets you register dSPACE real-time boards and configure the registered platfroms (Simulink platfrom and dSPACE real-time boards). In addition, Platfrom Manager allows you to handle applications on a specific platfrom and update the firmware of dSPACE real-time boards.

2].Instrumentation:

Instrumentation offers a variety of virtual instruments to build and configure virtual instrument panels according to your needs. Input instruments let you change parameter values. You can combine any set of instruments to produce a virtual instrument panel that is specific to the application. In addition, Instrumentation provides data acquisition instruments that let you capture data from the model running on either the Simulink or the real-time platfrom.

3].Parameter Editor:

To perfrom parameter studies, ControlDesk provides the Parameter Editor that lets you save, load and modify sets of parameters. Load parameter sets to the platfrom to optimize the behavior of the control model. Parameter sets are also used to initialize the model or resume previous parameter studies.

4].Source Code Editor:

The built-in Source Code Editor of ControlDesk supports C and Python files and any other files in ASCII fromat. The editor is optimized for programming in C or Python.

5].Automation:

5.1].Python Interpreter:

The built-in Python Interpreter is Control Desk's programming interface that allows you to enter Python commands interactively and to run Python scripts for time-consuming tasks such as parameter studies.

5.2].Macro Recorder:

ControlDesk provides the Macro Recorder that allows you to record and replay often-needed tasks. It automatically generates a Python script that can be used as a basis for complex automation scripts .

5.10]. TERMS AND DEFINITIONS:

This topic gives a brief alphabetical description of some basic terms and definitions used by ControlDesk:

1].Application:

The executable file containing the simulation application is called the application. For real-time boards, this is an OBJ, AXP or PPC file, and for Simulink simulations, it is the MDL file.

2].Experiment:

An experiment comprises all files belonging to a ControlDesk session:

- Experiment management data including a description of the experiment, infromation on the version and author, a textual explanation of the experiment, and a descriptive graphic.
- All ControlDesk files related to the experiment: instrument panels, parameter data, automation macros and scripts, simulation results, and external files (comprising model files and documentation, for example). These files can be added or removed to an experiment one by one.

Experiments may be used to load and save data concerning an application and the parameter values with a single mouse click.

3].Layout windows and instrument panels:

Instrumentation provides a set of powerful instruments. They are designed to monitor and/or control variables interactively or display data captures. Instruments can be arranged freely in one or more windows called layout windows. Any set of instruments arranged in a layout window and connected to the corresponding variables is called a virtual instrument panel.

4].Multiple systems:

ControlDesk allows you to handle several platfroms in parallel. Using the Platfrom Manager, it is possible to register several boards and/or modular systems. To set Control Desk's working focus to a system it is sufficient to click the system's icon in the Platfrom Navigator.

5].Multiprocessor systems:

A multiprocessor system consists of several processor boards and I/O boards: for example, a DS1003 and DS1004 connected by a high-speed data link (dual-port memory), or two or more DS1005s connected via the onboard DS910 Gigalink Module. ControlDesk handles a multiprocessor system as a unit and uses system description files to load applications and associate the variables with the boards.

6].Platfrom:

This specifies either a dSPACE real-time board (DSxxxx) or the interface used for Simulink simulations.

7].Reference data:

Reference data is useful for comparing the current data curves of an experiment, for example, with data from older experiments or a curve designed in MATLAB.

8].Simulation:

Real-time simulations run on dSPACE hardware. Using Simulink to perfrom a simulation is referred to as a Simulink simulation.

9].Variables:

The term variable or simulator variable comprises signals and parameters. You can visualize a signal within Simulink as a line between two blocks, or more precisely as the block output the line is connected to. Thus, the value of a signal depends on the simulation and usually changes with each simulation step. Parameters do not depend on the simulation, but may be changed by the user to influence the behavior of the blocks. P, I and D are parameters of a PID controller, for example.

10].Working focus:

Clicking on the icon of a platfrom gives it the working focus of the Platfrom Navigator. This means that actions (for example, Show Properties) are associated with it. However, the assignment of a platfrom to a system description file is not affected by the working focus.

5.11]. EXPERIMENTING ON THE SIMULINK PLATFROM:

With the integrated control of Simulink simulations, you can acquire data and influence and validate your models on the host PC within ControlDesk in an early development phase. Since no real-time hardware is needed for Simulink simulations, experiments can be prepared by different team members, and subsequently run on the real-time hardware.

- **System requirements:** The simulation of large Simulink models on your host PC requires a lot of computation power for both calculation in MATLAB and visualization within ControlDesk.

- **How ControlDesk interacts with Simulink?**
  To enable communication between Simulink and ControlDesk and initialization of model parameters, ControlDesk uses callback routines provided by MATLAB. An External MATLAB Server is set up as the communication interface between ControlDesk and MATLAB/Simulink
- **Handling Simulink simulations**: Handling Simulink simulations from within ControlDesk is similar to working with models in Simulink. You can load a Simulink model or invoke Simulink and create a new model from within ControlDesk via the Platfrom Navigator. To specify simulation parameters, you can use either the Simulation Parameters dialog provided by Simulink or the Simulink Properties dialog provided by ControlDesk.

5.12] HANDLING SIMULINK SIMULATIONS FROM WITHIN CONTROLDESK:

Handling Simulink simulations from within ControlDesk is similar to working with models in Simulink.

- **Create/load model:** The main difference is that regardless of whether you create a model from scratch or use an existing one, ControlDesk automatically perfroms some preparatory steps. These include inserting callback routines, or, if you create a new model, inserting some simple Simulink blocks.
- **Simulation parameters:** To specify simulation parameters, you can use either the Simulation Parameters dialog provided by Simulink or the Simulink Properties dialog provided by ControlDesk. The latter is a subset of Simulink's simulation parameters, containing only dialogs relevant to ControlDesk.
- **Prepare model:** Although you can start a Simulink simulation after you have loaded or created the model, you cannot monitor signals and control parameters in ControlDesk until the corresponding variable description file is loaded and at least one variable is connected to an instrument. To monitor signals, you have to perfrom some preparatory steps.

5.13]. TRANSITION FROM SIMULINK TO REAL-TIME SIMULATIONS:

The transition from Simulink to real-time simulation and vice versa is made in two Steps. First, you have to replace the system description file and then assign it to the desired simulation platfrom of the model.

Replacing system description file:

Replacing the system description file <model> _offline.sdf with its real-time equivalent <model> .sdf perfroms the step from Simulink to real-time simulation. Both system description files refer to a TRC file that provides infromation on the available variables and the hierarchy of the underlying Simulink model or real-time application.

The structure and variable naming of the variable description files is block-based, representing subsystems and blocks as groups containing block-specific attributes. This block-based structure of the variable description files enables system description files to be replaced for easy transition from Simulink to real-time simulation. The difference between the two variable description files lies in the data type used for variables and the availability of certain variables such as the turnaround time, which is needed for real-time applications only.

After you replace the system description file, the handling of the two simulations is absolutely identical. When changing the simulation platfrom, you can reuse your virtual instrumentation layouts, Test Automation scripts and parameter sets, which are largely independent of one another.

Reusing layouts:

By means of virtual instrumentation layouts, ControlDesk lets you monitor and control Simulink and real-time variables available from the corresponding variable description file. When you migrate from Simulink to real-time platfrom, it is important that the variable the data connection is based on is still accessible after you change the simulation platfrom. Then you can reuse your layouts. Reusing parameter sets The Parameter Editor lets you save parameter sets for later use, load predefined parameter sets to the model and tune them. You can exchange parameter sets between different platfroms according to your needs.

5.13]. HOW TO USE CONTROLDESK:

To observe the variables of a running real-time application, you have to create a ControlDesk layout with an instrument such as a plotter, and connect the instrument to the variables to be observed. For detailed instructions, see below.

To observe the system behavior

1.Start ControlDesk.

2.If Control Desk's Platfrom Navigator displays more than one dSPACE board in your system, it may be necessary to specify the DS1104 as the working board: In the Platfrom Navigator, you can recognize the working board by its bold print. If the DS1104 is not the current working board, choose Platfrom – Set Working Board to call up the Set Working Board dialog.

3.Use the Platfrom Navigator to load the SDF file `smd_1104_hc.sdf` from the directory `%DSPACE_ROOT%\Demos\DS1104\GettingStarted\HandCode`.

- The hierarchical structure of the model and its variables are displayed in the Variable Browser, a tab of the Tool Window.

4.In the Variable Browser, click the trace group Model to display the variables (a, v, x, f) of that block in the Show list on the right.

5.To display the behavior of the system, choose New – Layout from the File menu. Two new windows will appear: The Layout window and the Instrument Selector (on the right side in the illustration below).

6.Do the following to build an instrument panel within the layout window:

- In the Instrument Selector, click the instrument group containing the desired instrument (for example, Data Acquisition).
- In the Instrument Selector, click the icon of the instrument (for example, a Plotter).
- In the layout window, draw a rectangle using the mouse.
- The new instrument is opened in the layout window, and an icon for the instrument is added to the Instrumentation Navigator. The red frame of the instrument indicates that there is no valid data connection yet.
- In the Variable Browser, choose a signal, and drag & drop it onto the instrument (for example x). The red frame disappears when the connection is built.

7.Select the instrument, and choose Properties from the context menu to display or change the properties of the instrument.

8.From the menu bar, choose Instrumentation – Animation mode to start the animation. In the following example there is one plotter to display the signal x.

9.To add new instruments to the layout or to change the properties of existing instruments, choose Instrumentation – Edit Mode.

10. From the menu bar, choose File – Save to save the new layout.

Data connections describe the connection between variables of the real-time application and a ControlDesk instrument. To save data connections, you should create an experiment and add the layout to it.

5.14]. HOW TO CREATE A NEW EXPERIMENT:

When creating a new experiment, you have to specify the experiment name and the working root directory. The working root directory is the folder to which ControlDesk saves the experiment file (CDX), which contains all the infromation related to the experiment, for example, the references to the files administered by the experiment. In this folder it is possible to create subfolders to sort the files.

In addition, it is possible to enter the name of the author responsible for the experiment, a description of the experiment (for infromation only) and an experiment graphic.

Additionally, you have to specify the scene, which contains the objects to be animated. After loading the scene a series of observers can automatically be created.

To create a new experiment

- From the menu bar, choose File – New Experiment to open the New Experiment dialog.
- In the New Experiment dialog, enter the data for the new experiment.
- In the New Experiment dialog, click Create Subdirectories if you want to generate subfolders (for example, for certain file types) within the working root directory.
- In the Create Subdirectories dialog, click the Create new folder icon and enter the name of the new folder. Once you have created all the subfolders you need, click Done.

- Click OK to save the new experiment.

The new experiment is created and the experiment file is saved.

5.15]. HANDLING VARIABLES:

Instrument panels are used for visualizing the signals and controlling the parameters of real-time applications and Simulink simulations.

1. Creating SDF, TRC and MAP files:

These simulator variables are defined in two application-specific files – variable description files (SDF, TRC) and MAP files – that have to be loaded in ControlDesk to build data connections from instrument panels to the variables.

- **SDF files:** The system description file (SDF) provides infromation on whether one (single processor) or more (multiprocessor) processors are used. The corresponding TRC file of a real-time application or Simulink simulation is automatically loaded, but not displayed, with the system description file.
- **TRC files:** The structure of the TRC file and variable naming is block-based, representing subsystems and blocks as groups containing block-specific attributes The TRC file of a real-time application or Simulink simulation specifies the variables and blocks that are defined in the related Simulink or hand coded model. If you want to use your own TRC files, you have to give each one the same name as the corresponding application. It is used by the corresponding system description file.
- **MAP files:** The MAP file maps symbolic names to physical addresses. The way these files are generated depends on the methods used for implementation.

2. Variable Browser:

ControlDesk provides the Variable Browser to display the simulator variables and connect them to the instruments of an instrument panel.

3. Modifying the model:

If the TRC file has been rebuilt (for example, by RTI), it can be reloaded to display the current variables. When you start the Animation mode, ControlDesk checks if the object file has an earlier date than the corresponding system description file and reloads the system description file automatically to update a model.

5.16].CREATING A NEW INSTRUMENT PANEL

Creating a new instrument panel requires the following steps:

- Create a new layout.
- Insert instruments.
- Save the new instrument panel.

Arranging instruments

You can arrange the instruments (multi-selection is available):

- Select instruments.
- Align instruments.
- Group instruments.
- Change instruments properties.

5.17]. SAVING AND LOADING INSTRUMENT PANELS:

ControlDesk allows you to save and load an instrument panel as an independent object, as well as a part of an experiment.

- **File handling**

  If you save an instrument panel as an independent object the data connections between variables and instruments are also saved (only if no experiment is opened.

- **Importing/exporting data connections**

  You can export and import data connections between variables and instruments. Data connections are exported to connection files (CON), and can be imported from a connection file to an instrument panel.

5.18]. CREATING DATA CONNECTIONS:

The next step in building an instrument panel is to establish data connections between the different elements in it. Data connections are used to send and receive data or control layouts.

- **Applying events**

  To trigger the data transfer or execution of an action, you can use events. These can be standard system events such as system polling or specific instrument events such as Write Data

- **Building data connections**

  All data connections can be built with drag & drop operations from the source to the target of the connection. You have two possibilities:

  - A drag & drop operation with the left mouse button offers standard data connections. You can connect variables and instruments or layouts and instruments.
  - A drag & drop operation with the right mouse button displays a context menu that provides functions to build standard and user-defined data connections with a Connection Wizard.

- **Connection Wizard**

You can use the Connection Wizard to build user-defined data connections. The Wizard provides a guided tour on building the data connections

- **Highlighting variables**

To display, which variables are in use, you can highlight the variables in in the Variable Browser.

- **Verifying data connections**

  You can verify the connections that are already established for the current experiment

  You can also build connections between layouts and instruments. These instruments are not used to transfer data but to control the display of layouts.

- **Table Editor connections**

  The Table Editor instrument is used to display the values of a connected look-up table, matrix, or vector. You can build standard or user-defined data connections to the Table Editor instrument.

5.19]. INSTRUMENTATION TOOLS

ControlDesk provides powerful tools to create instrument panels.

- **Instrumentation Navigator**

  The Instrumentation Navigator gives an overview of all open instrument panels and their instruments. The Instrumentation menu is used to set the operation mode (Edit, Test, or Animation) of the instrument panel.

- **Layout windows**

Layout windows are the areas of ControlDesk where instrument panels are built:

- **Instrument Selector**

  The Instrument Selector grants access to all available instruments. ControlDesk Standard offers a set of instruments – Animated Needle, InvisibleSwitch, Message, MultiStateLED, Slider, Bar, CheckButton, PushButton, RadioButton, Frame, Knob, Gauge, Display, StaticText, NumericInput, Plotter, Logic analyzer, XYPlot, Template, Capture Settings. The illustration shows where the instrumentation tools are located in ControlDesk:

5.19.1]INSTRUMENTATION NAVIGATOR:

The Instrumentation Navigator displays the hierarchy of all open instrument panels and their instruments

- **Instrumentation commands**

  Many instrumentation commands are available via the Instrumentation and Lay outing toolbars.

  The Instrumentation toolbar is available to set the mode of the instrument panels. To switch the operation mode you can also use the Instrumentation toolbar, which is available when Instrumentation is selected in the View – Toolbars menu.

- **Edit mode**

  The Edit mode allows you to create and modify instrument panels.

- **Test mode**

  The Test mode allows you to test the user interface of instrument panels. In this mode, it is possible to operate input instruments (for example, a slider) and modify data connections, but there is no data transfer to the real-time or Simulink platfrom.

- **Animation mode**

  The Animation mode puts the instrument panel into operation: It is possible to change parameters using input instruments, and observe output signals. Data transfer from and to the hardware or Simulink is active. To choose the Animation mode for real-time applications, the application has to be running on the corresponding platfrom. Using Simulink simulations you first have to choose the Animation mode and then to start the simulation).

5.19.2]. INSTRUMENT SELECTOR:

The Instrument Selector grants access to all the available instruments. The illustration shows the Instrument Selector with its context menu.

You can use the Small Icons and Large Icons commands of the context menu to modify the appearance of the instrument icons in the Instrument Selector

Instruments

ControlDesk Standard offers a basic set of instruments divided into the following groups:

- Virtual instruments
- Data acquisition instruments
- Custom instruments

(i) Virtual instruments

Virtual instruments (single-shot instruments) are used to display values of connected variables or to enter values to the simulation platfrom:

Icon	Instrument	Purpose
	Animated Needle	To display the value of a connected numeric variable by a needle deflection.
	Bar	To display the value of a variable by a bar deflection.
	Check Button	To display whether the value of a connected variable or instrument matches predefined values or to write a predefined value to a connected variable or instrument.

	Display	To display numerical values with a predefined fromat.
	Frame	To arrange instruments on the layout.
	Gauge	To display the value of a connected numeric variable by a needle deflection on a circular scale.
	Invisible Switch	To simulate the different buttons (On/Off button, Push button, Check button) with a transparent background.
	Knob	To set the value of the connected numeric variable or display the value of the connected variable on a circular scale.
	Message	To display messages that are related to values of the connected numeric variable.
	MultiStateLED	To display an LED or image that is related to values of the connected numeric variable.
	Numeric Input	To enter or display a value that is transferred to a connected variable or instrument.
	OnOffButton	To set the value of the connected numeric variable or activate/close an event-based layout.
	Pushbutton	To write a predefined value to a connected variable or instrument and/or start an action, for example to call up a layout.
	Radio Button	To set an option and transfer a specified value to the simulation platfrom or display the state of a variable.
	Selection Box	To select a text that is connected to a value and to write the value to the respective variable or display the state of a variable.
	Slider	To enter values of a connected variable to the simulation platfrom or display the values of the variable.
	Static Text	To display explanations or inscriptions on the layout.

	Table Editor	To display and change values of a connected table variable in a chart and a grid view.

(ii) Data acquisition instruments
Data acquisition instruments (time trace instruments) are used to capture data from the simulation platfrom:

Icon	Instrument	Purpose
	Capture Settings	To control/observe the properties of data captures.
	Logic Analyzer	To display bit patterns of captured integer variables.
	Plotter	To display the values of several variables related to different y-axes.
	Template	To combine the functions of the LogicAnalyzer, Plotter and XYPlot instruments.
	XYPlot	To display variables as functions of other variables.

(iii) Custom instruments
Using the dSPACE instrument definitions, you can specify your own instruments or grouped instruments and save them in the Customer library.

5.20]. HOW TO SET THE OPERATION MODE:

To switch between the operation modes

- From the menu bar, choose Instrumentation – Animation Mode to switch to the Animation mode, or choose Instrumentation – Test Mode to switch to the Test mode.

Test Mode:

The Test mode allows you to check the user interface of instrument panels. In this mode it is possible to operate input instruments (for example, a slider) and to modify data connections, but there is no data transfer from or to the simulation platfrom. The red frame indicating invalid data connections vanishes and all auxiliary layout functions are switched off in Test mode. Thus, the look-and-feel of the final instrument panel can be checked even without the platfrom installed.

Animation Mode:

Switching to the Animation mode puts instrument panels into operation. Data connections are activated and data is transferred from/to the simulation platfrom. The Animation mode allows you to

- Change parameter values interactively with input instruments (such as sliders)
- Change data connections
- Observe signals with data acquisition instruments (such as plotters)
- Capture data and save the results to disk.

Conditions:

The following conditions must be fulfilled to start the Animation mode:

- Instrument panel(s) are loaded.
- System description file(s) are loaded.
- Data connections are defined.
- Matching object file(s)/model are loaded.

These types of infromation must match each other. It is possible to either load all infromation sets manually or to use Control Desk's Experiment Manager functions to load all infromation as a whole entity. The experiment management supervises file consistency, whereas the manual procedure does not.

4.21]. LIMITATIONS OF CONTROLDESK:

For technical reasons, there are a few limitations that apply to the current version of ControlDesk. These are listed according to the ControlDesk elements:

- General Limitations
- Limitations of the Experiment Manager
- Limitations of the Platfrom Manager
- Limitations of ControlDesk Instrumentation
- Limitations of the Parameter Editor
- Limitations for Mask and Workspace Parameters
- Limitations for Simulink Simulations
- Limitations of the Operator Mode

5.21.1].GENERAL LIMITATIONS:

The following general limitations apply to this version of ControlDesk.

1].Data types

The following data types are not yet supported by this version of ControlDesk:

a. 64-bit integers (supported by Alpha processors only). ControlDesk handles these data types only as 32-bit integers.

b. 8- and 16-bit integers (Alpha and PowerPC processors). ControlDesk handles these data types only as 32-bit integers.

2].Value ranges

ControlDesk and its virtual instruments are certified within a numerical value range from $-1.0 \cdot 10^{300}$ ... $1.0 \cdot 10^{300}$. If data on the platfrom exceeds this range, the results are not predictable.

3].Communication timeout

Communication timeouts may occur between ControlDesk and the particular server when you execute processes that take a long time to complete. This type of timeout can occur, for example, when you build the variable description file for a large ControlDesk-controlled Simulink simulation.

4].Redundant host services

If platfroms of different types such as a DS1102 (DSP Board), DS1103 (PPC Board) or Simulink are registered and you load a variable description file that is not suitable for the current working board, it might happen that a second, identical host service is created. This error occurs if you connect a variable with a new data acquisition instrument after you have carried out the Assign Platfrom command for the respective platfrom. Since the redundant host service is not desired, do not save the experiment.

If you connect a simulator variable with an existing data acquisition instrument, an error message opens that infroms you that the data connection could not be built. Confirm the message and carry out the Assign Platfrom command for the appropriate platfrom once again.

5.21.2].LIMITATIONS OF CONTROLDESK INSTRUMENTATION:

For this version of ControlDesk, the following limitations apply to ControlDesk Instrumentation:

1].Docking/floating layouts

Layouts are MDI windows by default. Do not change the window state to "Docked" or "Floating". This may cause ControlDesk to crash.

2].Layout names

Layout names are limited to 31 characters.

When you save an experiment or a layout and the following error message occurs, check the name(s) of the layout document(s):

3].New layout fromat with ControlDesk Vs. 2.0

Layouts generated with ControlDesk version 1.2.1 or lower must be converted to the new layout fromat. Conversion is perfromed automatically the first time you load them in ControlDesk version 2.0 or higher. For this purpose, they must not be write-protected. Ensure that the write protection is removed beforehand. Otherwise, you cannot load them.

Under ControlDesk version 1.2.1 or lower, all instruments where handled as windows. Since ControlDesk version 2.0, under Microsoft Windows NT, Windows 2000 and Windows XP, most of the instruments are non-window instruments, except for Numeric Input, Table Editor and the Data Acquisition instruments. For technical reasons, window instruments are always in front of the non-window instruments. If you want to convert older layouts, check whether or not the non-window instruments will be covered by Numeric Input, Table Editor or Data Acquisition instruments and rearrange the layout if required.

4].Instrument properties

The following restrictions concern instrument properties :

Instruments can only be displayed in the windowless mode for the operating systems Windows NT, Windows 2000 and Windows XP.

- The Transparency property of instruments is only available for the operating systems Windows NT, Windows 2000 and Windows XP.

- The slash character "/" is not allowed in instrument names. You can assign individual names by the Extended Properties page of the instrument properties. Using the slash in instrument names will affect the data connections.
- Do not use special characters in the instrument name. The approved characters are letters, numbers and the underscore sign.
- A change of the font settings in a property dialog of any instrument cannot be undone with Cancel.
- On the StaticText page of the StaticText Control Properties dialog, all dialog elements of the page are deleted if you press the `Esc` key and the edit field has the input focus. Close the dialog and open it again.
- In LogicAnalyser, Plotter, TableEditor and XYPLot instruments, you can load pictures of the fromats BMP and DIP only.
- Some properties of the Data Acquisition instruments are administered in lists (via an index), for example, the signals of a Plotter instrument. If you change the settings of these properties, you cannot undo the changes with Cancel.

5].Table Editor

The following restrictions concern the TableEditor instrument:

The number of elements in vectors or matrices is limited to a maximum of 10000For the TableEditor instrument, the Macro Recorder features are not available. You cannot record values and play them again..

6].Loading SDF, TRC, or A2L files

In Animation mode, you cannot load variable description files or A2L files.

7].Python scripts

If you use older Python scripts (up to ControlDesk version 1.2.1), the execution of the Preset () method has no effect. .

8].Time-stamping

Time-stamping is only available for the DS1005, DS1103, DS1104 and DS1401 boards. For more infromation, refer to the corresponding RTLib Reference.

9].COCKPIT layouts

COCKPIT layouts (CCS files) are obsolete and direct migration to ControlDesk version 2.1 is not supported. To reuse old COCKPIT layouts, convert them with older ControlDesk versions or contact dSPACE Support to perfrom this for you.

CHAPTER 6

Experimental setup for MPPT.

Implementation of the hardware for the MPPT system is done using realtime control. A personal computer (PC) is used for implementing the real time control.

6.1] System components .

The hardware setup of the MPPT consists of a

- Solar PV module
- Dc/Dc converter(step up and step down).
- A load (resistive load)
- Personal computer(installed with dSPACE hardware)

The control of the converter(fig.23) is through the PC with add on dsp card (ds1104) which works on the Matlab^R/Simulink^R platfrom.

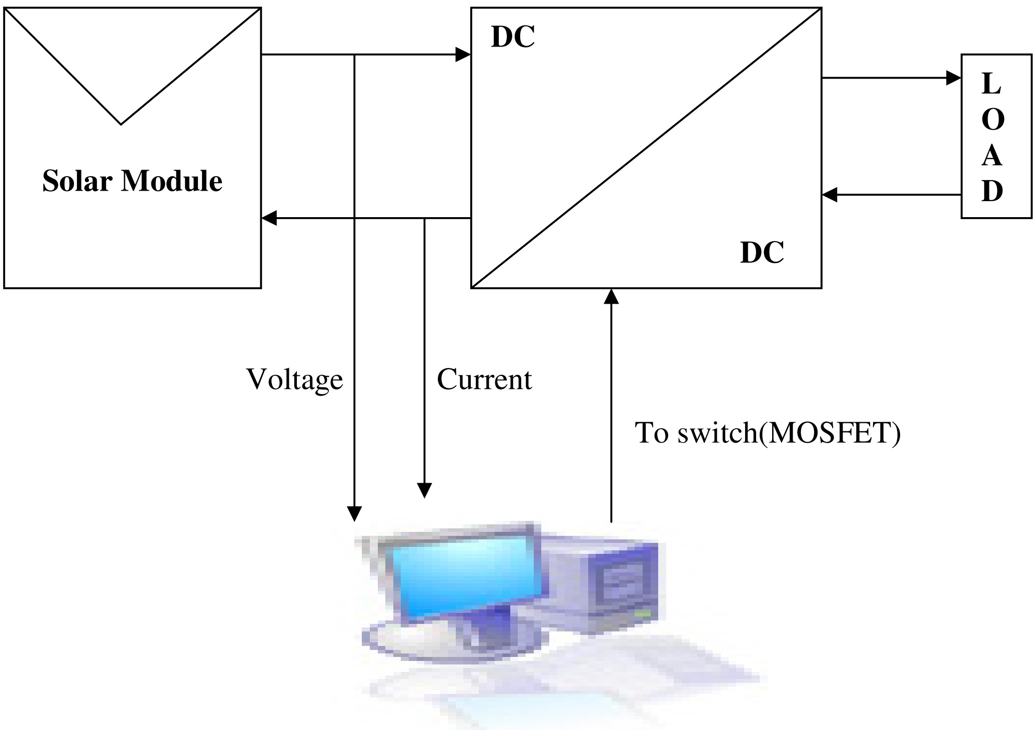


Fig 23 Hardware setup.

1].Solar PV module:-

Solar PV module used is a 38W module having 17.7Vp and 2.2Ap at 25degree Celsius and and 1000W/m^2.The module make is of M/s TATA BP solar INDIA. The module is multicrystalline having 36 cells. The module is shown in the fig.24.

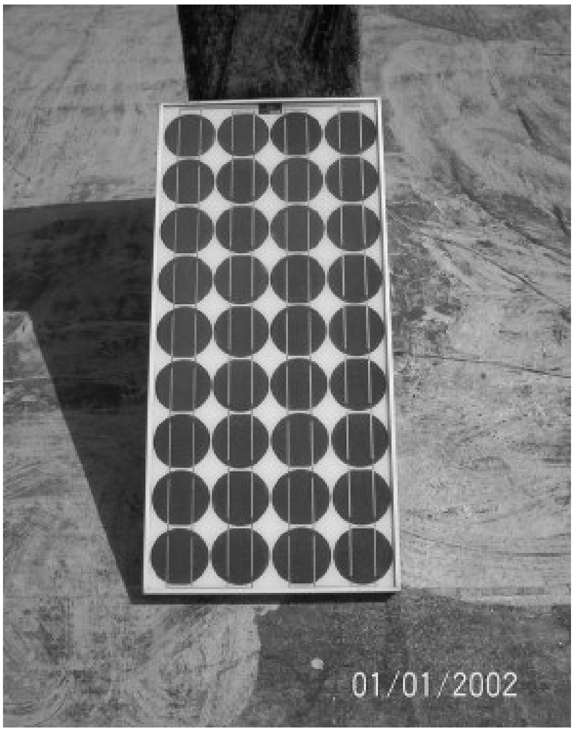


Fig.24 Solar PV module.

The module voltage and current where measured and signals are fed to PC the fig.23.

2].Dc/Dc converter:-

The dc/dc converter is the main component of the MPPT system it acts as an interface between the module and the load. The experimentation is carried out using the step up and step down converters. The detailes of the converters are explain in the chapter 3.3. The converters are controlled through the PC. A driver IC 74HC14 is used to drive the MOSFET. In step down mode there was problem of grounding the driver IC as the control signal need to be applied between the gate of the MOSFET and the source. For reliable operation a Moset of rating 100V and 25A was selected. IRF540. The other components of the dc/dc converter inductor and capacitor where selected according to the thumb rule.

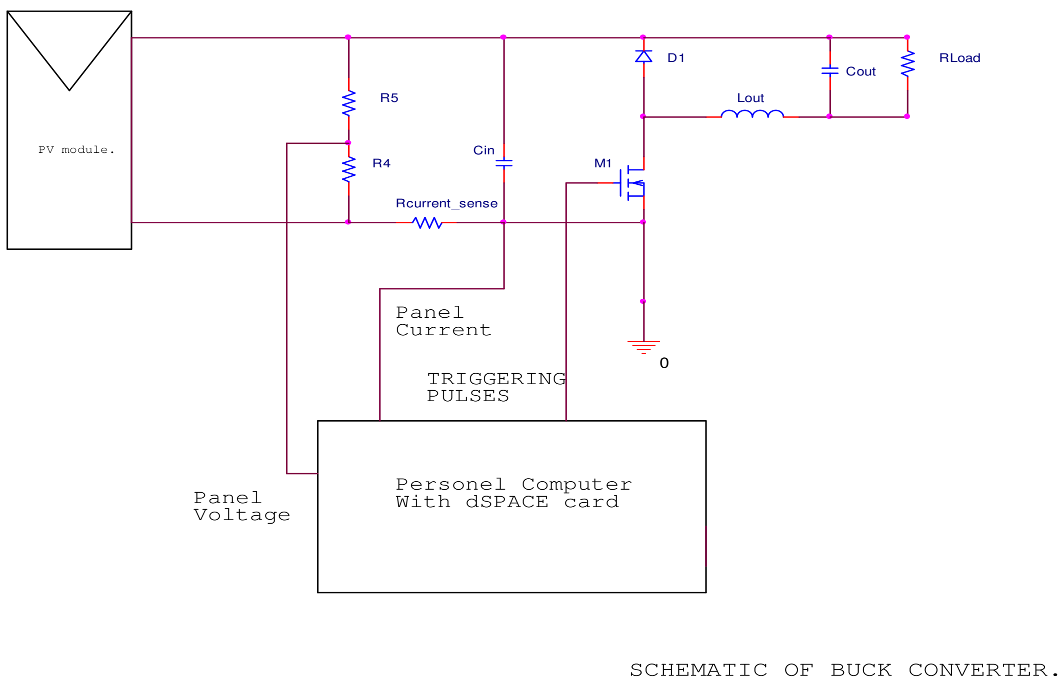


Fig.25.Schematic of the hardware setup.

2.1].Inductor selection- The inductor is responsible for reducing the output current ripple. larger the value of the inductor smaller the value of the ripple.

$\Delta I = Vi*D/f*L$……………………………………………………………(19)

$L = Vi*D/f*\Delta I$……………………………………………………………(20)

By using this fromula the inductor value was selected.

L=330µH.

f=100kHz

Vi=12V

ΔI=0.5A

D=0.1&0.9.

The inductor designed had air cored and was wound on a rectangular bobbin of area 4cm x 3cm. With a 20guage enameled copper wire.

2.2]. Capacitor selection:- Larger the value of the capacitor smaller is the voltage variation at the output. Also keeping in mind the switching frequency and the ESR (equivalent series resistance loss in the capacitor) the 470µF/200V rating capacitor was selected.

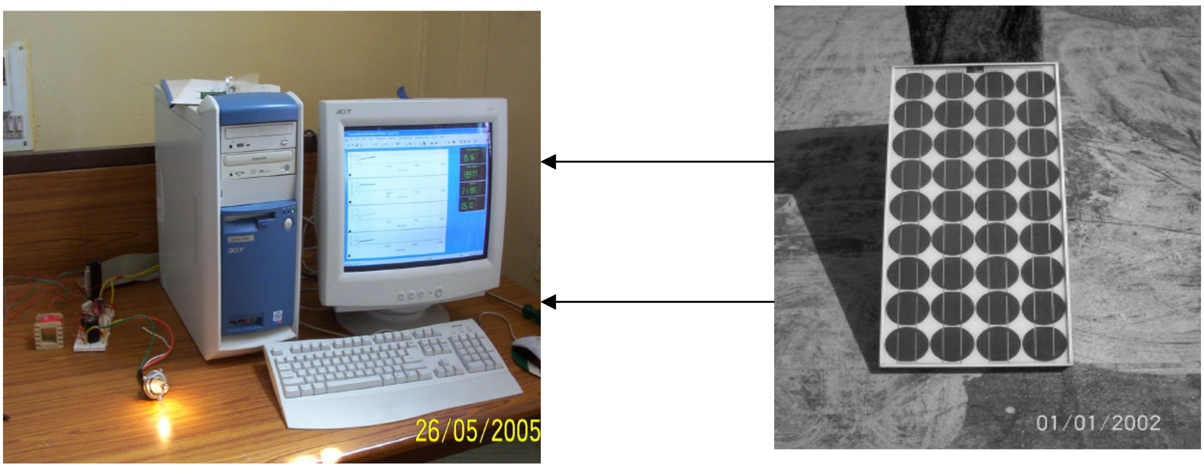
The system switching frequency was reduced to 20 kHz and performance of the system was noted. Even for 20 kHz the system was giving satisfactory performance with the designed parameters so the switching frequency was reduced to 20 kHz. By reducing the switching frequency the switching power loss in the switch (MOSFET was also reduced) this ensured longer period of operation of the switch.

3].Personal computer with the dSPACE^{R} add on card installed.

Personal computer is used for control of the MPPT system. The algorithm selected is implemented in the Matlab/ Simulink.The algorithm developed in the Matlab/Simulink is downloaded in the dsp card memory. The card acquires the necessary data from the solar PV module (panel voltage and current) and sends the control signals to the algorithm developed in Matlab/Simulink in PC which works on the signals and gives necessary PWM signals to drive the MOSFET. The algorithm working is explained in the chapter 3.2.

4]. Load

Load used is a purely a resistive load. A resistance capable of sustaining power of about 30W is utilize. Also a halogen bulb of rating 90W(having a resistance of 1Ω) is used.



Experimental setup

6.2]. Algorithm implementation in the dSPACE^{R}

On the Matlab Simulink platfrom dSPACE works so Simulink model of the algorithm for simulation of the MPPT system is implemented in dSPACE^{R} . Simulink model in dSPACE^{R}. is shown in the fig.26.

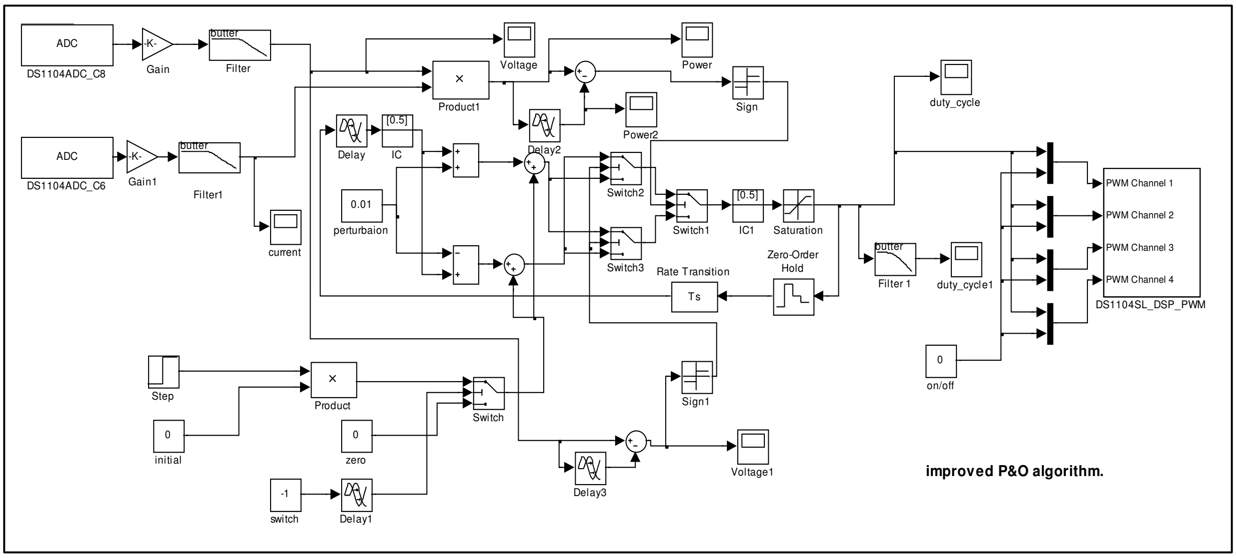


Fig.26 Simulink Model implemented in the dSPACE^{R}

The algorithm is explained in the chapter4. The voltage and current signals from the Solar PV module are fed to Analog to Digital Converter (ADC) of the Add on card of the PC. The filters are used for removing any high frequency noise or any switching noise that appear in the signals. The algorithm gives a signal between range 0 to 1.These values are in the from of a constant step size that is defined by the perturbation block. In our case we have considered the perturbation of 0.1%. A PWM block is used for generating the PWM switching signals which are given to the MOSFET through a IC 74HC14 . The PWM block is implemented through a DSP processor on the Add on card. The PWM block generates signals which can produce signals upto 1GHz frequency. In our case we have considered the switching frequency to be 20 kHz.

CHAPTER 7

Results.

7 . Results.

Chapter discusses the results obtained from the experimental setup of the MPPT setup. Results of the MPPT setup where obtained using Control Desk^R a graphical user interface provided in dSPACE. The data was captured for the period of 8hrs. From morning 8:30am to evening 4:30pm. The results where recorded for following different conditions

1]. The results where recorded on control desk when the load was driven through the MPPT converter and when the solar PV module was directly connected to the load.

2]. The step up and step down converter were used as an interface between the load ond the solar PV module.

3].The algorithm efficiency was calculated by manually varying the duty cycle till peak power is tracked. These readings of manual peak power tracking obtained where verified with the automatic teacker. And efficiency of the MPPT algorithm was calculated. The efficiency of the algorithm was found to be 95% .

4]. Test were carried out on 30W (5Ω) resistor and a 90W halogen bulb. The readings where obtained and displayed and recorded on the Control Desk^R and also Ms Excel.

5].The testing of the dSPACE^R card and the results are discussed in detail in the preceding section.

Testing of the dSPACE^R card.

The dSPACE Add on card which is installed on a PC is tested for its working by simple sending and receiving data from the external circuit to the PC and back to the external circuit from the PC. This is accomplished by using Analog to Digital Converter (ADC). The analog signal is converter into digital form and fed to the PC. To send data from PC to the experimental module the digital signal is converted into analog signal by Digital to Analog Converter (DAC). Simulink models are used for receiving and sending signals to and from PC.

The procedure used in the experiments is as follows. At first a simulink model of the control logic is developed ADCs and DACs are connected to the model as shown in the Fig. 27 & 28.

Receiving data

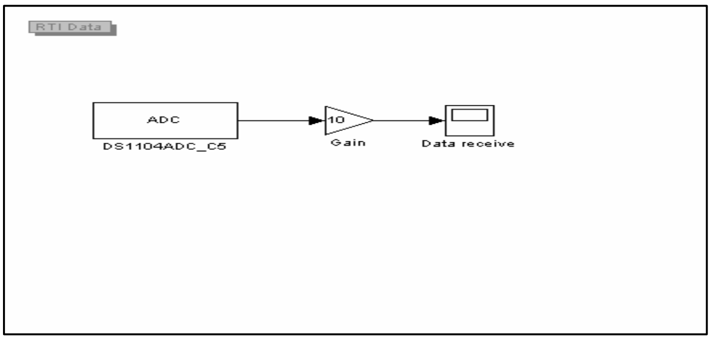


Fig.27. Simulink model for receiving data

Small models are developed such as receiving and sending the data. These models are useful for future applications requiring data acquisition systems. The Fig.25 shows the simulink model, which is used for the acquiring the data from the field and then displaying the data on the monitor. The data acquired is used for further processing. An ADC block is used for acquiring the data from the field an internal gain for amplifying the data and display is used to observe the signal on PC.

Sending data

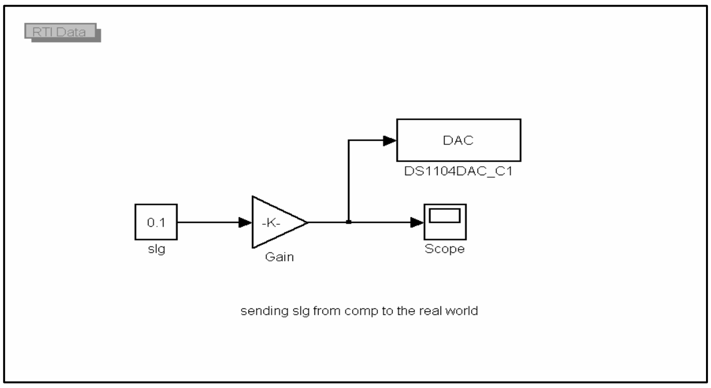


Fig.28. Simulink model for sending data.

The next experiment shows how data is sent from the computer to the field. This signal can be a dc signal or a pulse or any low level ac signal. A signal is generated and amplified and then connected to a DAC through which the interfacing of the signal with the field device is done. As seen in the Simulink[R] model a signal is send to the display device through a DAC. The signal is observed externally on the multimeter or a volt meter.

1].Module power with and with out MPPT system.

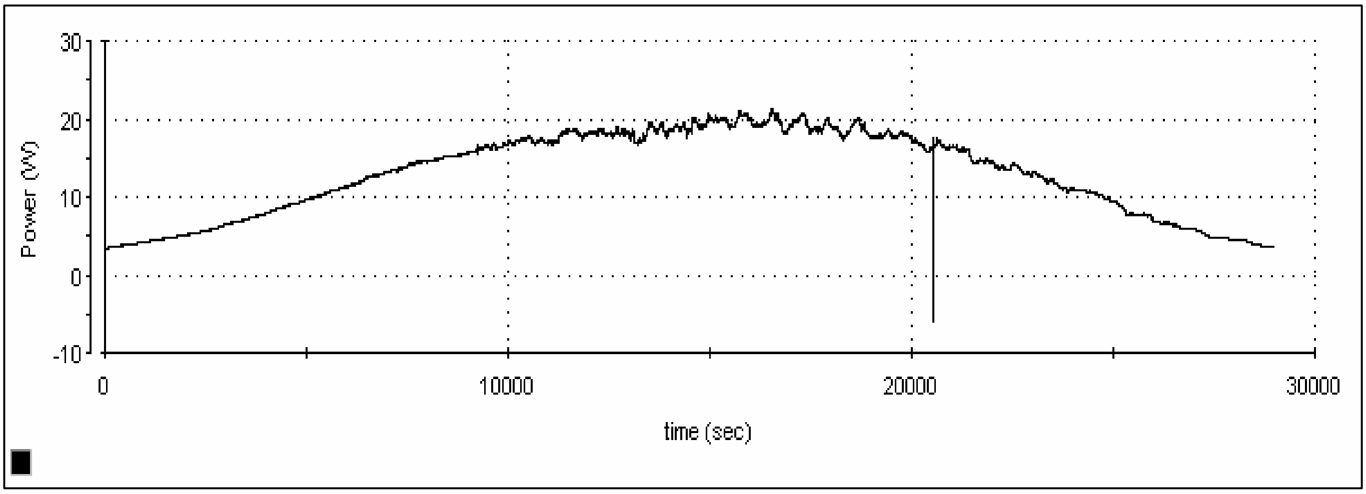


Fig.29.Module power with out MPPT system

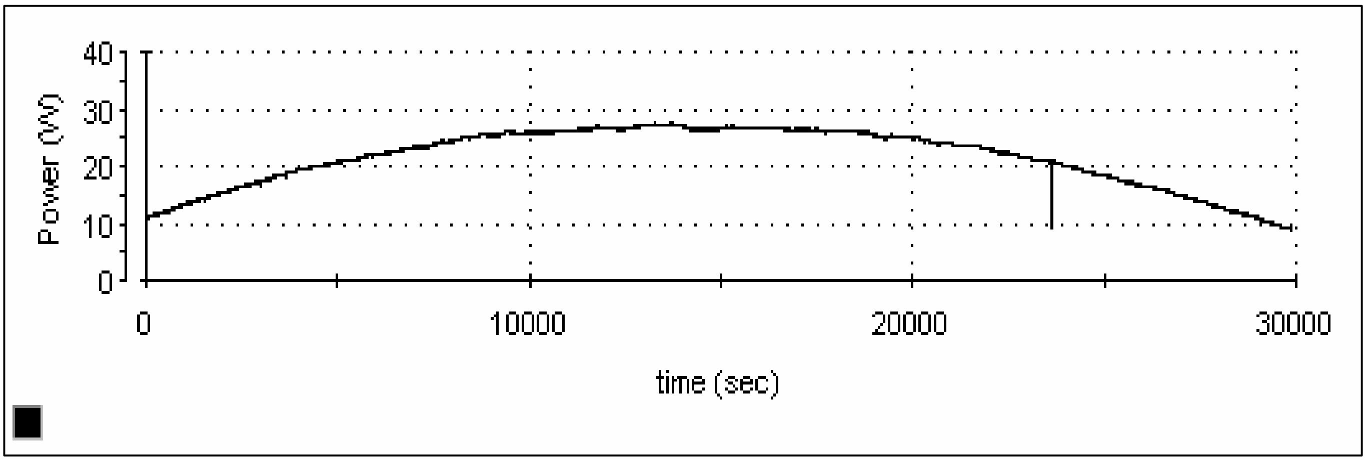


Fig.30.Module power with MPPT system

Fig.29 and 30 shows the module power without and with MPPT system. It is observed from the fig.27 that with out the MPPT system the module power is about 20W. These readings where taken for the period of 8hrs (8:30am to 4:30pm). The module power increases with the increase in solar insolation from morning till (10000sec) noon time(12:00) noon. then the module power remains constant (10000sec to 20000 sec) After noon the module power decreases till evening. But it never reaches the peak power. When the MPPT system is connected we have increase in the module power. It is observed that the module power is almost doubled for that particular insolation level. Again the same pattern is followed the module power increases till noon and then decreases after noon. But with MPPT system the module power is increased by 50%. This proves the usefulness of the MPPT system.

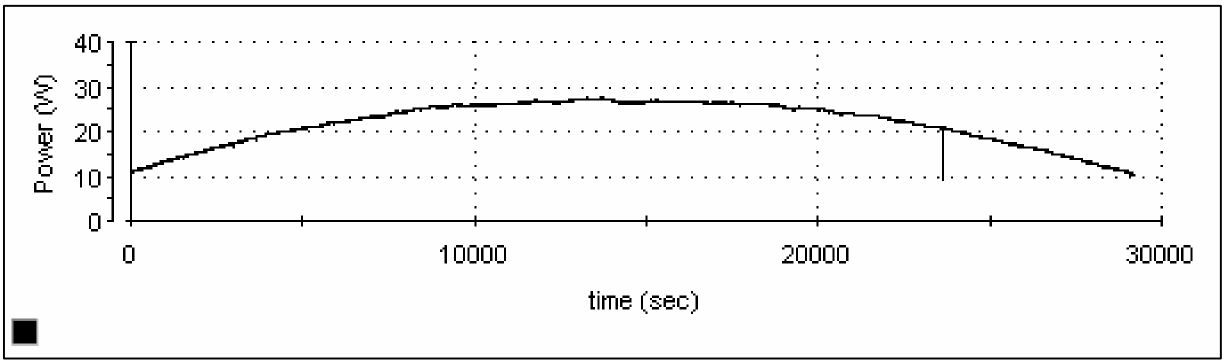


Fig.31.Module power With MPPT system

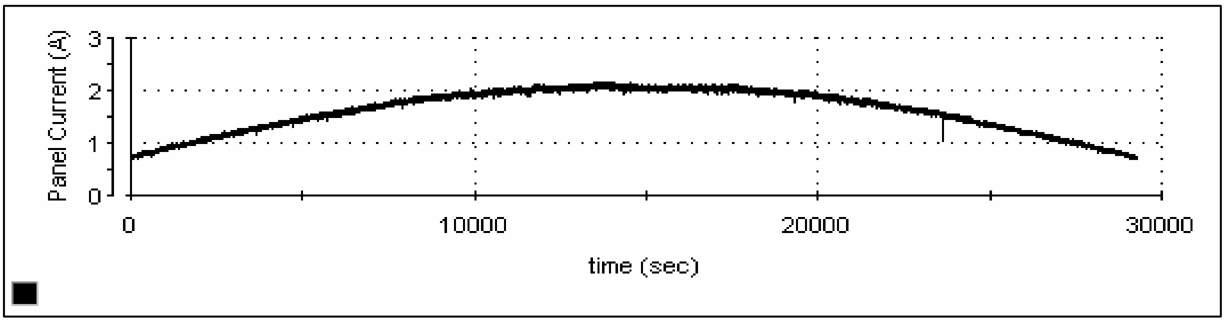


Fig.32.Module Current with MPPT system

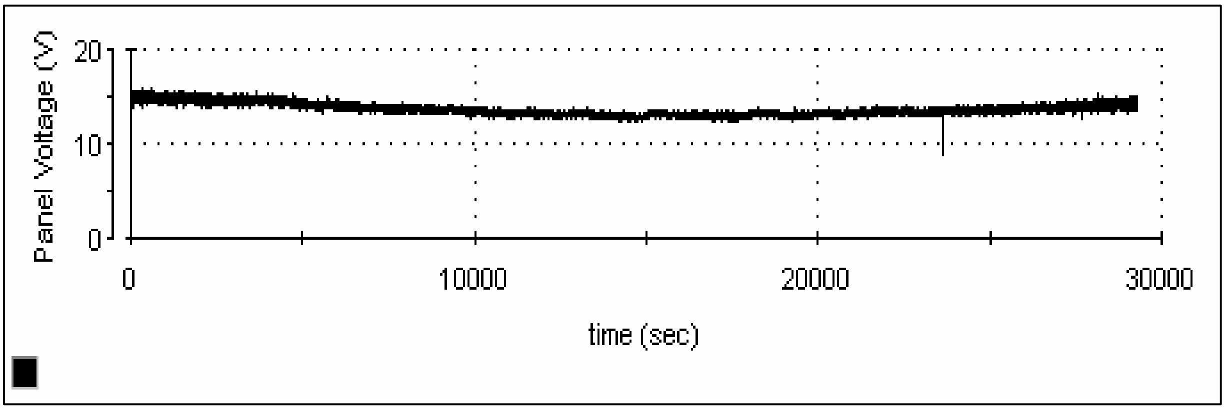


Fig.33.Module Voltage with MPPT system

The figures.31,32&33 show the Module Power ,Current and Voltage when MPPT system is connected to the solar PV module. The results where plotted for the period of 8hrs(8:30am to 4:30pm). The maximum power (29W)that is obtained by the system is at noon time. As observed in the voltage and current profile of the module the voltage decreases as the power output increases but current increases. The variation in voltage is also due to the change in the input resistance due to the change in duty cycle as explained in the chapter 1.3 and the temperature of the module.

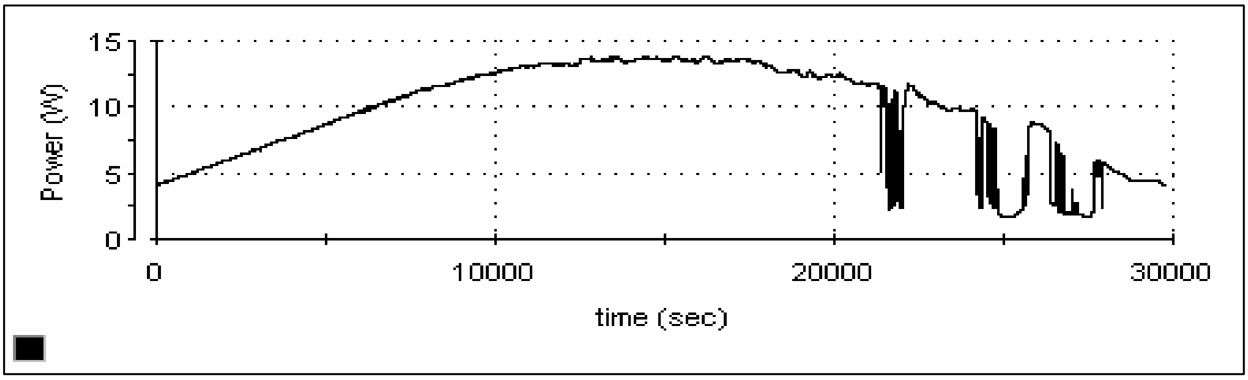


Fig.34 Module power with out MPPT system

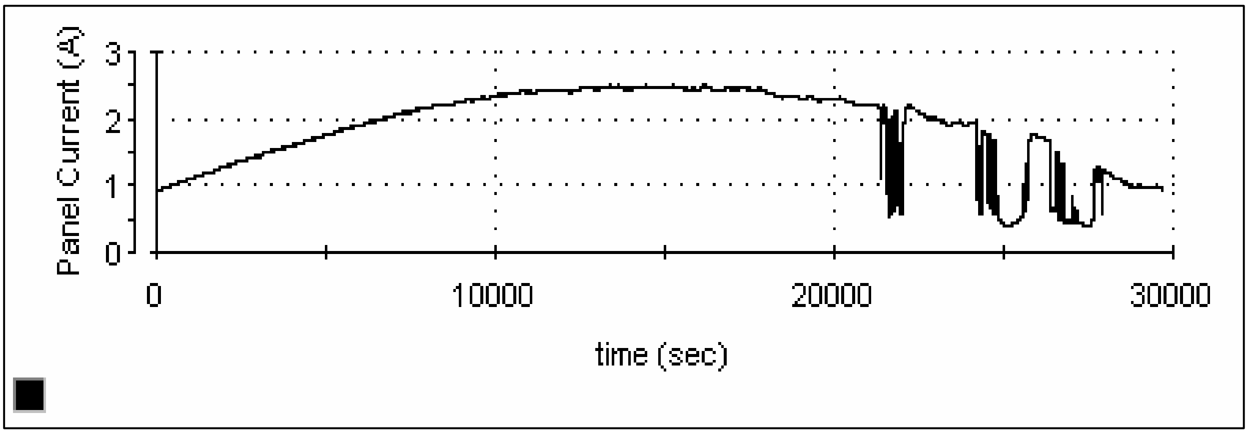


Fig.35.Module power without MPPT systems.

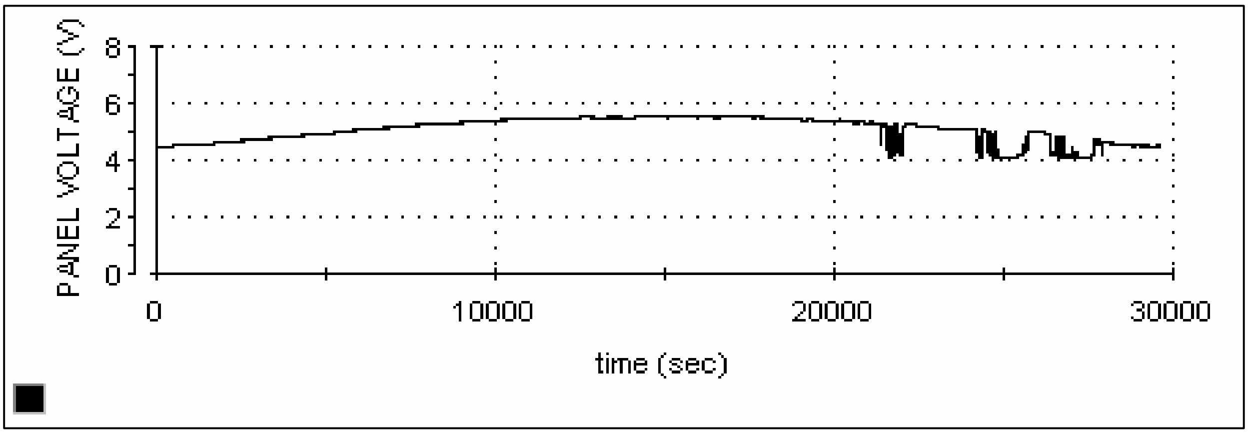


Fig.36.Module Voltage without MPPT system

The module is directly connected to the load with out MPPT controller. The observations are shown in the fig.34,35&36. The plot of module power, current and voltage are plotted. The module power obtained in this case is very low as compared to the module power in the case of MPPT system. The module voltage is also very low as the load is in direct in contact with the module. The module current is more in the noon time that it was observed in the case of MPPT system. The disturbance in the wave from time 20000 sec is due to the cloudy sky.

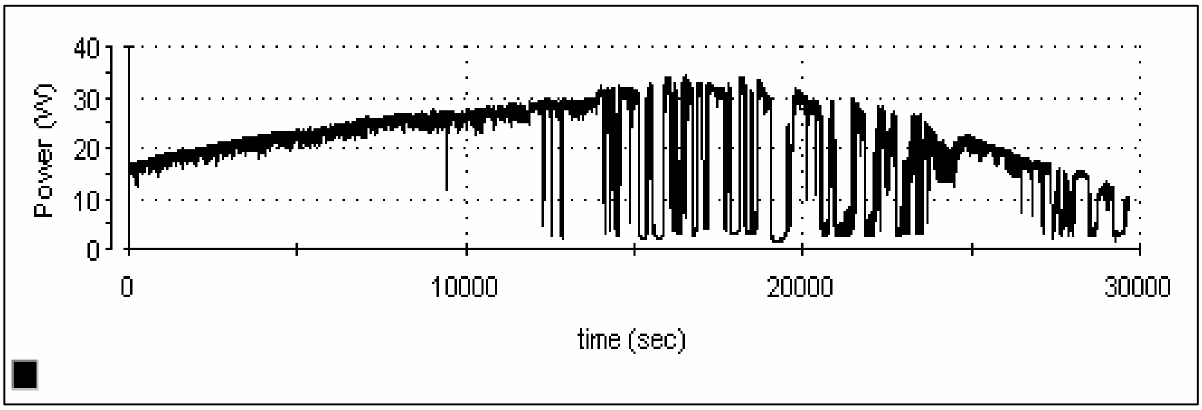


Fig.37 Module Power when clouds are present in the sky.

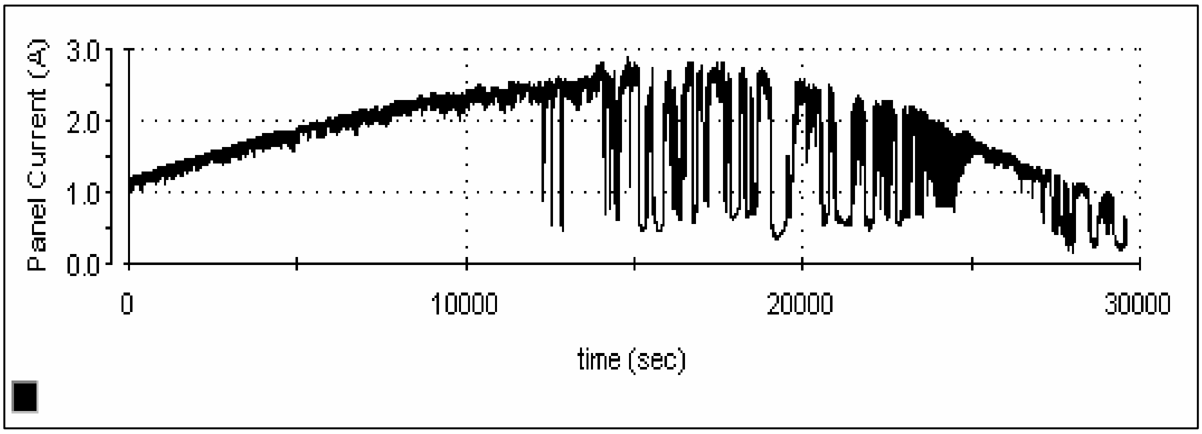


Fig.38.Module current when the clouds are present in the sky.

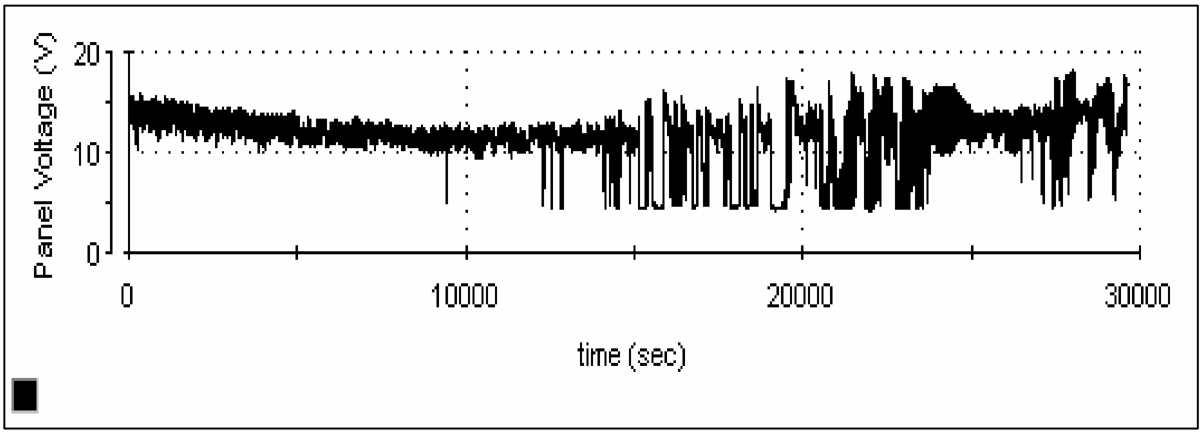


Fig.39.Module voltage when clouds are present in the sky.

The figures 37, 38&39 shows the module power, current and voltage when the cloud cover is present in the sky. The cloud appeared during the afternoon time(12000 sec). As can be observed in the figures that till about half time the sky is clear and there is no disturbances in the power output. But when the clouds appear the solar insolation begin to change and the peak power is adjusted by the algorithm according to the new solar insolation level.

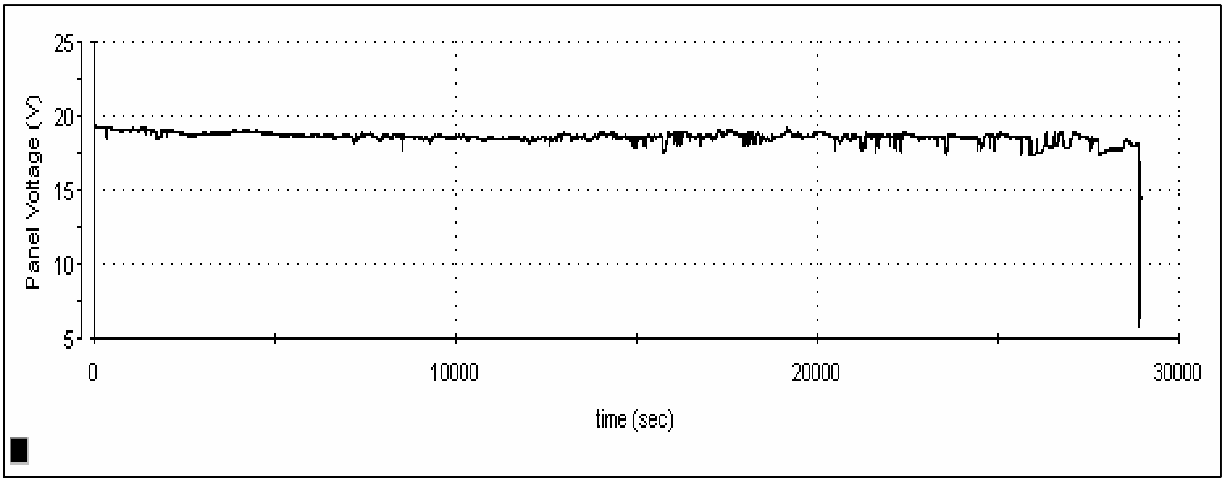


Fig.40.Open circuit voltage of the solar PV module.

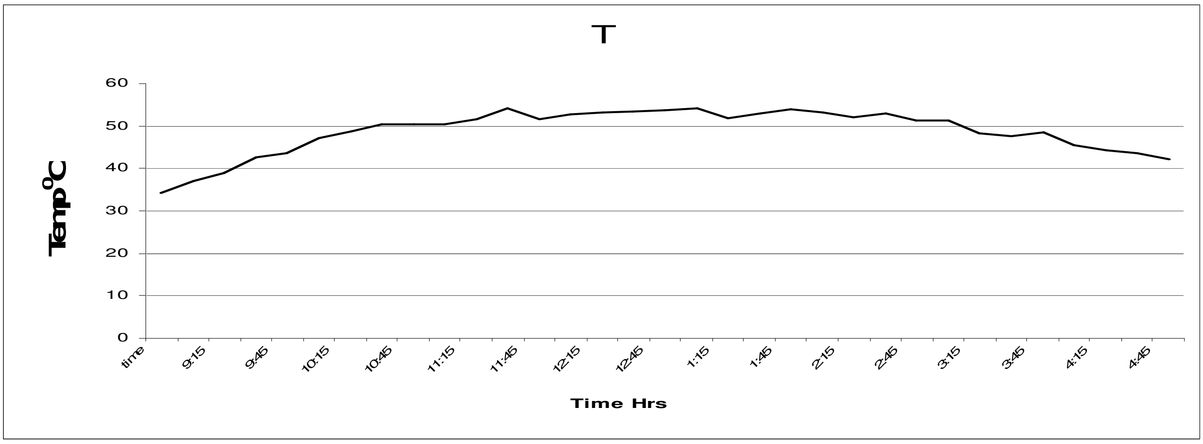


Fig.41.Temperature variation of the module.

The figure.40&41 show the variation of the open circuit voltage with respect to the temperature change throught the day. It is found that the open circuit voltage decrease by about 2.3mV/C^o rise in temp of each cell. Also the power output of the module changes with the increase in temperature as explained in sec 1.2. Although the short-circuit current of the cell increases with increase in the cell temperature but its effect it nominal as compared to the change in the voltage. So the overall effect of the increase in the module temperature is to decrease the power(peak power) of the module.

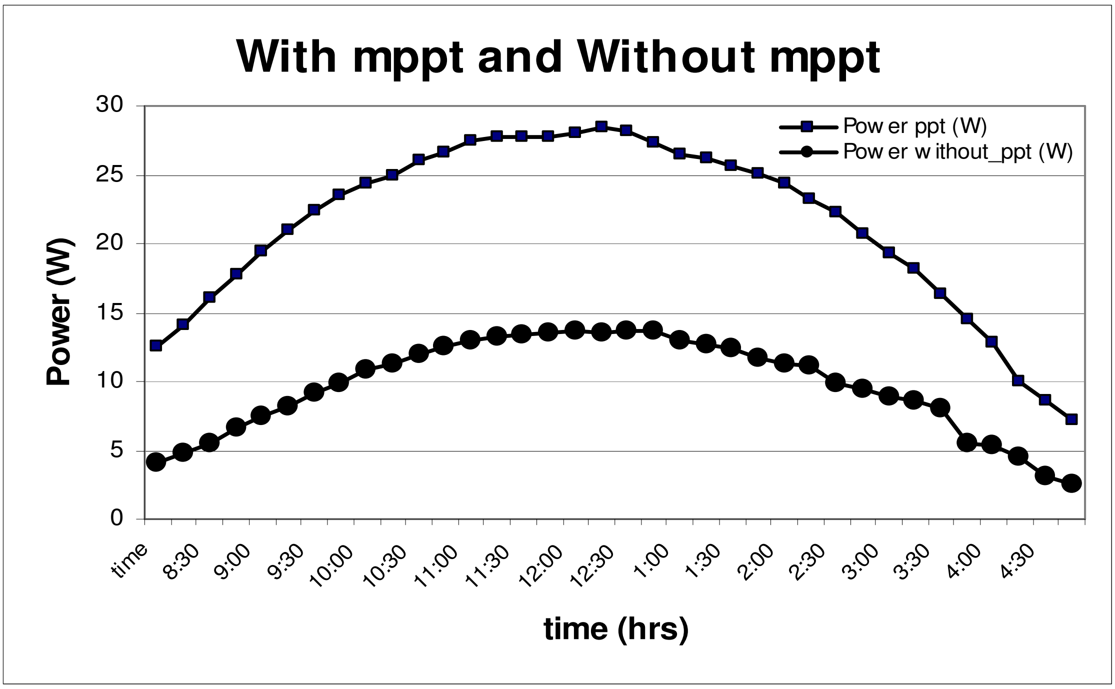


Fig.42.Comparison Module power with and with out MPPT system.

Figure.42 shows the excel plot of the module power with and with out the peak power tracker. The load in this case was considered to be a halogen bulb of resistance 1Ω. The converter used was a step down converter. It is observed from the figure that the peak power obtained with the peak power tracker is more than that it is with out the MPPT system. The readings where taken for a period of 8hrs on different days one reading for the system with peak power tracker and on the other day with the MPPT system. As the load is lΩ. The module power that we get when the pv module is directly connected to the load is less as compared to the earlier experiments.

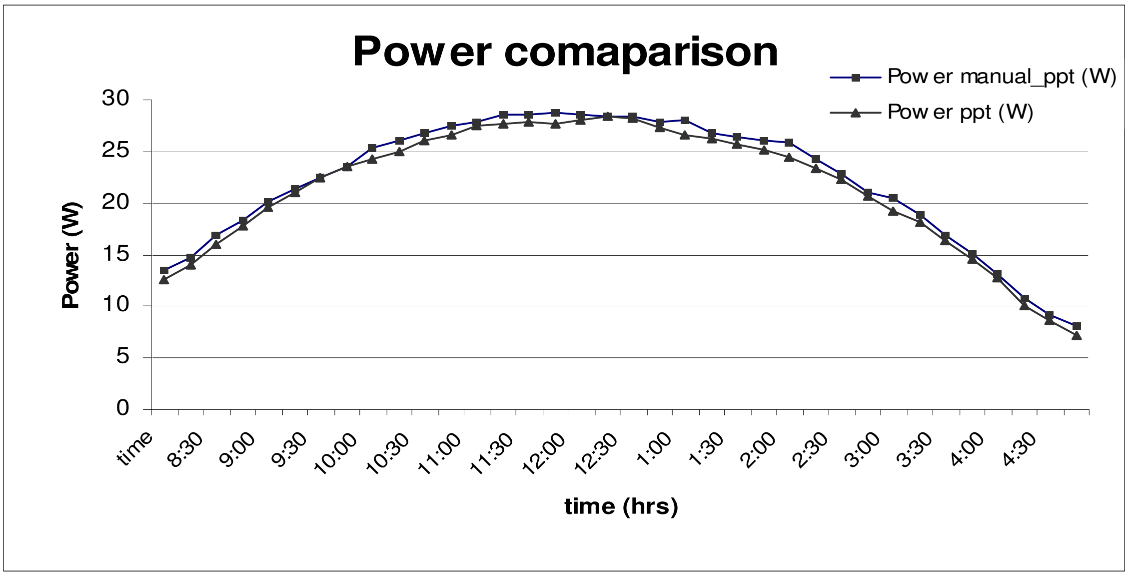


Fig.43.Module Peak power comparison Between manual Peak Power tracking and Automatic Peak Power Tracking.

The figure.43 shows the comparison between the manual peak power tracking and the automatic peak power tracking. The manual tracking is perfromed by manually varying the duty cycle of the dc/dc converter to get the peak power point. The duty cycle of the converter is changed every 15 minutes and the peak power noted. The next day the automatic peak power tracker is implemented and the readings of the module power are noted after the period of 15 minutes. The effeiciency of the algorithm can be calculated by deviding the manual power tracked readings from the automatic power tracked readings. The efficiency of the algorithm was found to be around 95% as shown in fig.44.

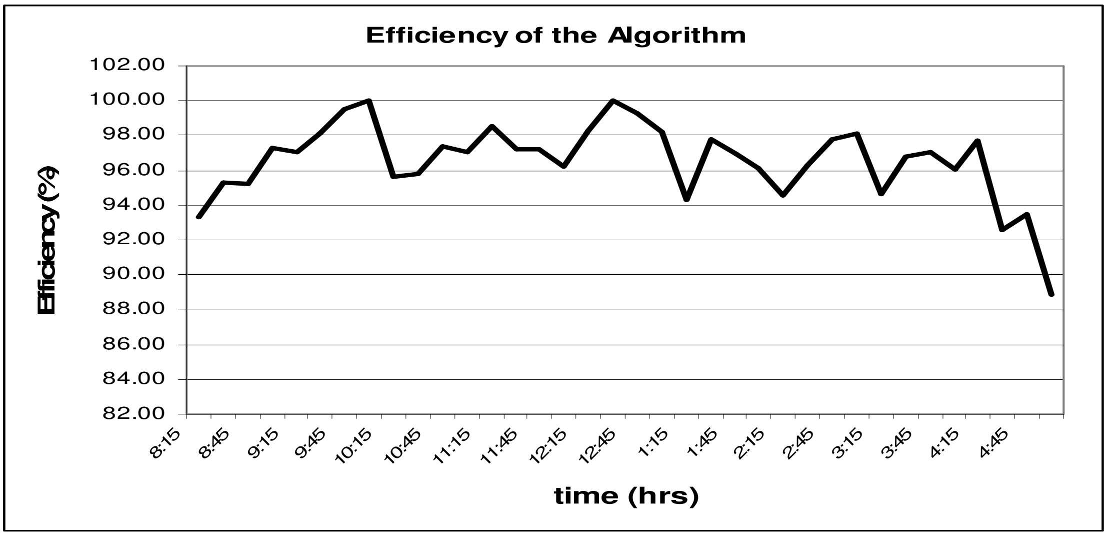


Fig.44 Efficiency of the algorithm

The efficiency curve of the algorithm shows that at the higher insolation level that is at the noon(12:00 noon to 1:45 pm) the efficiency is higher but as the insolation level decreases(2:15pm to 4:30pm) the efficiency also decreases. The decrease in efficiency occurs at the very low insolation level especially at in the evening time(4:00pm to 4:30pm). Overall the performance of the algorithm is satisfactory.

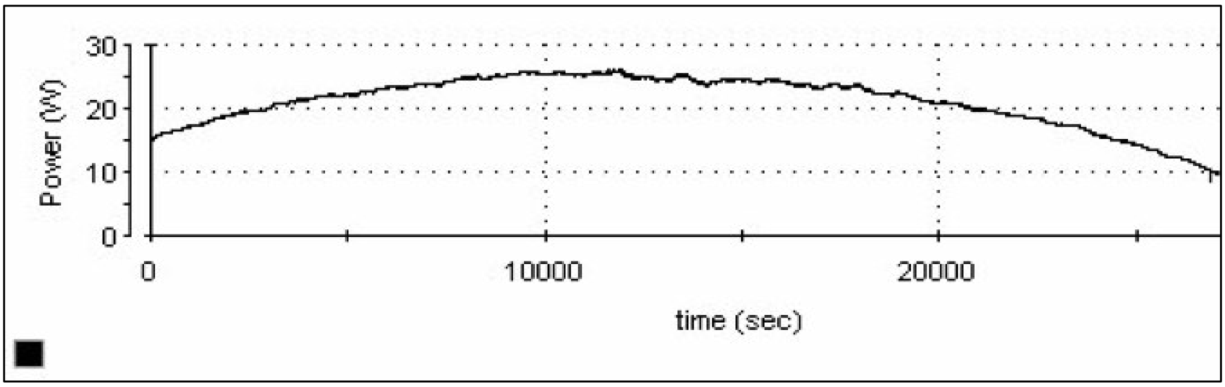


Fig.45.Module Power with MPPT system for Step converter

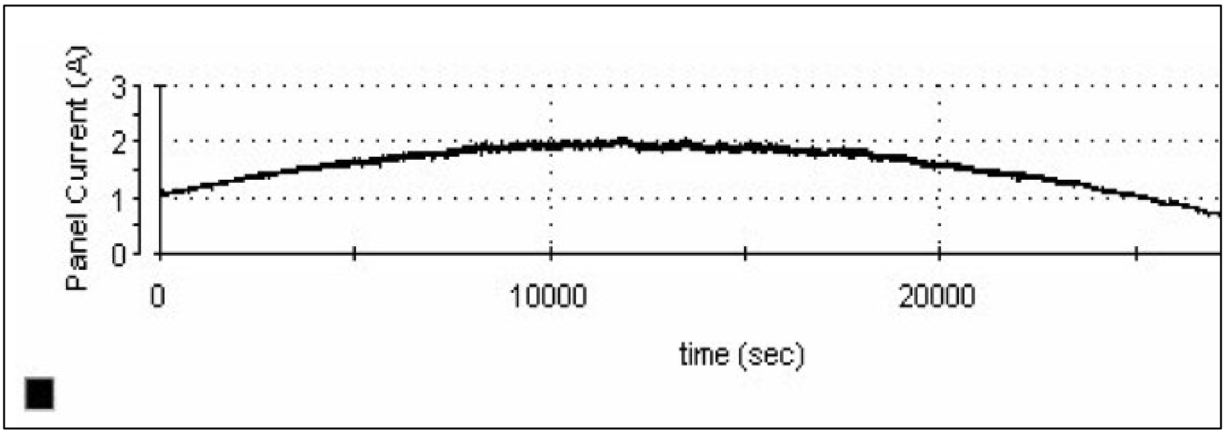


Fig.46 Module current with MPPT system for step up converter

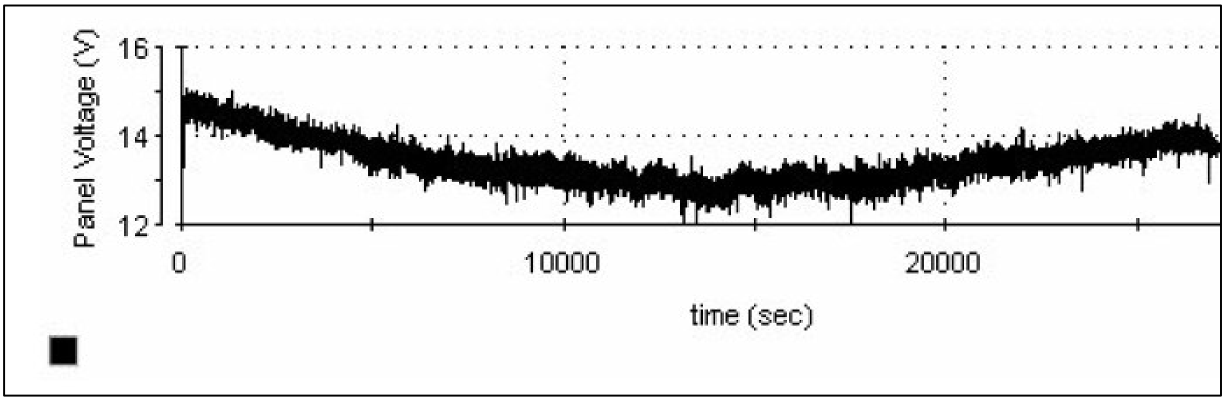


Fig.47.Module Voltage with MPPT system for Step up converter

The MPPT system was checked on the Step up converter. The peak power was obtained by the MPPT system using step up converter configuration. The results of the Module Power,Voltage and Current are obtained. The response matches with that of the step down converter fig.31,32&33. The response is similar but the only difference is obtained in the output voltage of the converter which is more than 15V fig.49 as against the 3V fig.48obtained in the case of the step down converter.. This higher voltage is useful in most of the application related to the solar pv system.

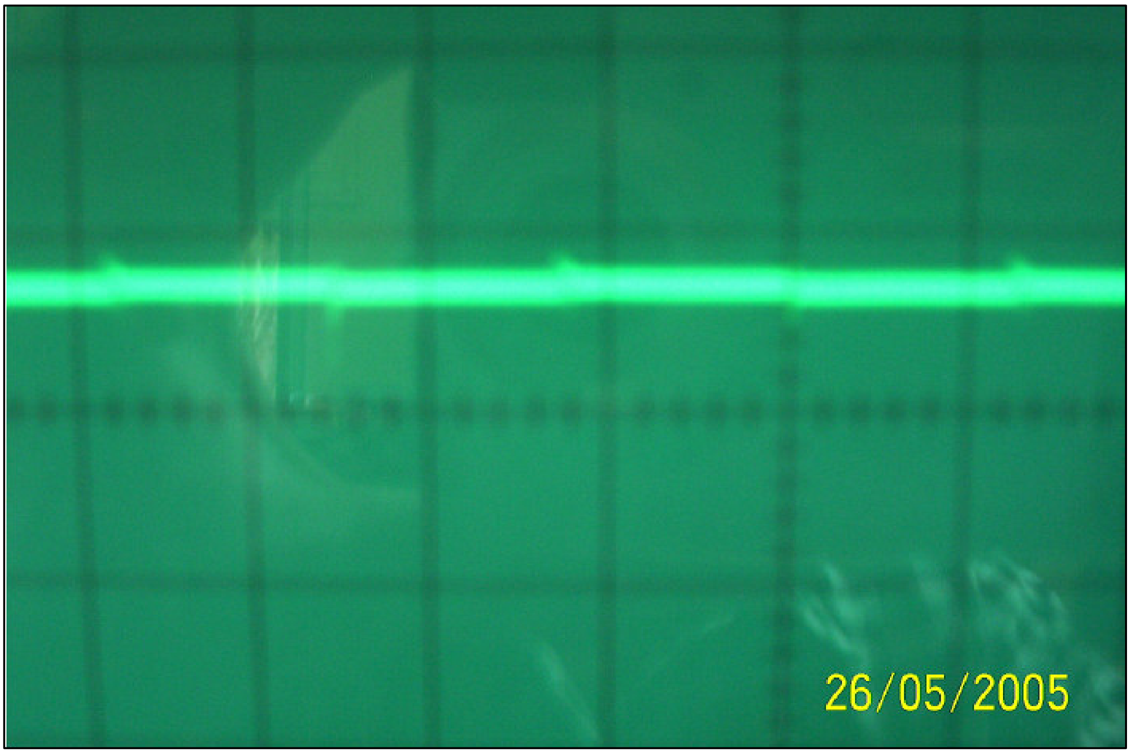


Fig.48 Step down converter output voltage 5V/div.

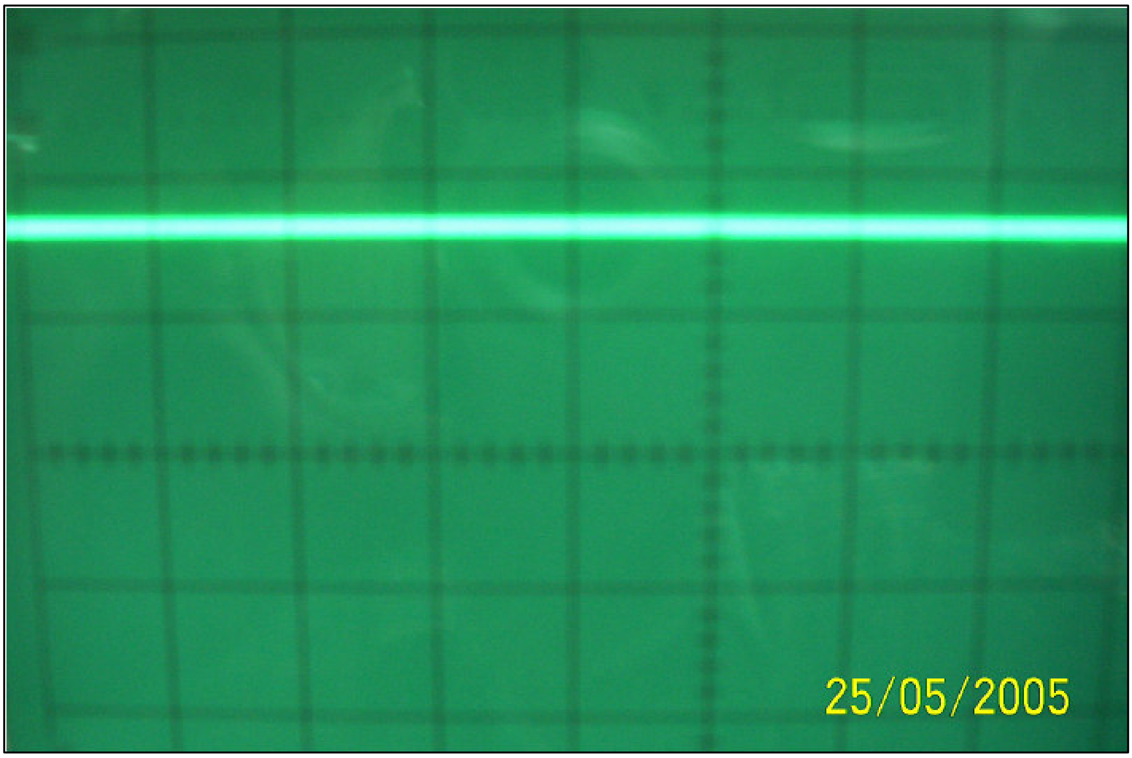


Fig.49 Step up converter output voltage 10V/div

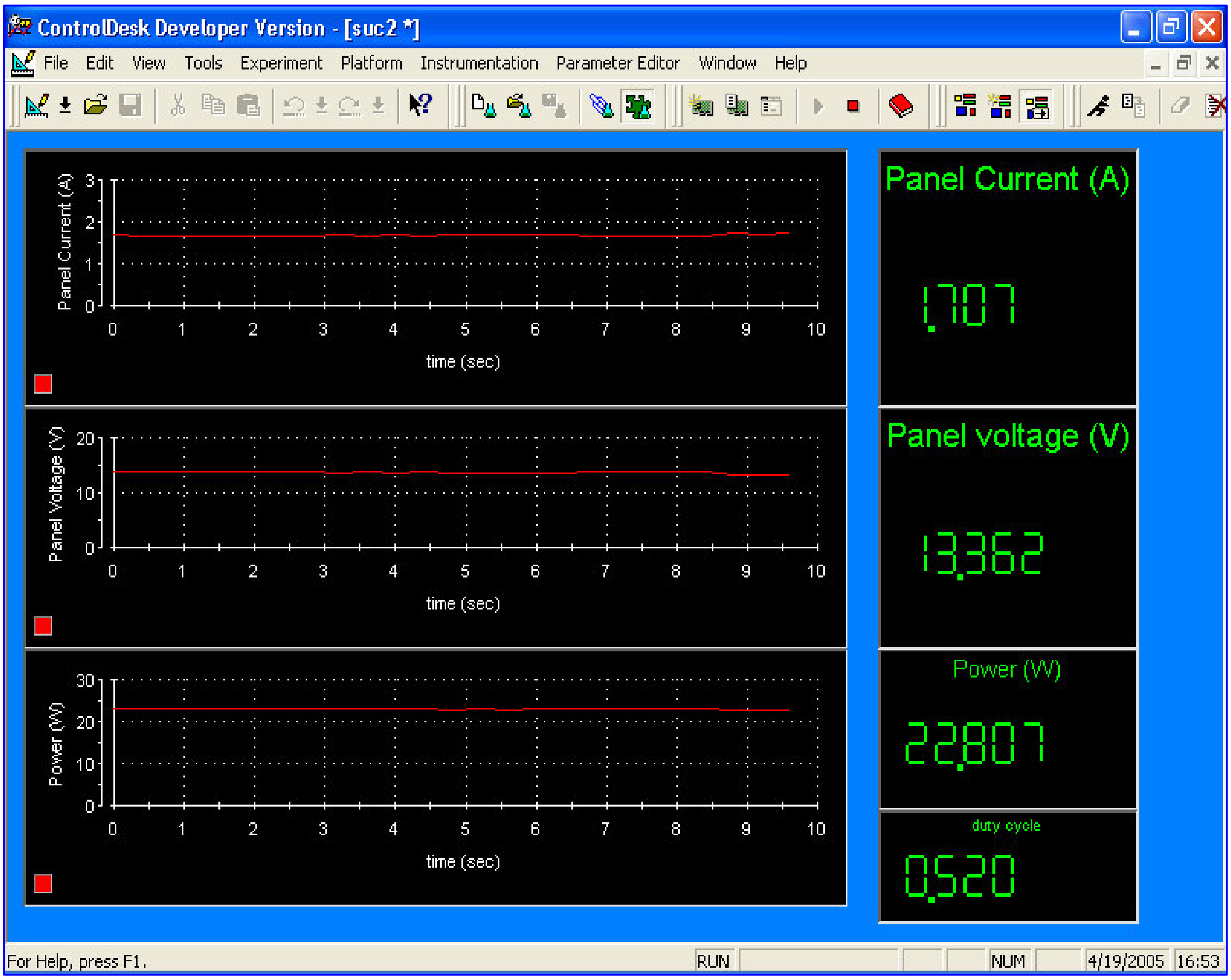


Fig.50.Control Desk screen for display of the Module parameters.

The fig.50 shows the control desk screen which is used for the display of the module parameters. The same tool can be use to plot the module Power,Voltage and Current for a longer duration of time(typically for the whole day).

CHAPTER 8

Conclusions and Future scope.

Conclusions

1].Power output of module improves by about 100%(doubles) with the MPPT system than it was with out the MPPT system. It is observed that the module gives the output peak power of 29W at noon time(12:00 noon). In early morning it gives power of about 10W same power is obtained in the evening. The temperature has effect on the peak power as shown in fig.3 in chapter 1. From the plots fig.44 and 39 it was observed that as the temperature increases the peak power decreases.

2].The power delivered to the load in case of step-down and step up converter is almost same. Only difference that was observed was with the output voltage. In case of steps down converter the output voltage falls to about 3V which is less than what is required for most of the system and in the step up converter the output voltage is always more than 15V fig.46,47 hence higher voltage level is desirable in most of the cases.

3].Temperature of the module is an important parameter. The power output of the module changes by about 0.5% for every degree rise in temperature. So a 38W module gives only a power of about 29W peak at 50^0 C temperature of the solar PV module. Temperature profile of the module for a hole day is shown in fig.39 and it was found that the temperature of the module is 45^0 C (average) for the whole day. Due to the increase in temperature the power output decreases very sharply.

4]. The module placement also plays an important role in power output. Module is kept south facing that is the path of the sun for around the year . Buts its elevation angle must be adjusted every month to get high power output. The axial tracking for the individual module which are not too heavy (10W to 60W) can be obtained automatically. Where as for the panel or arrays the automatic tracking is not feasible due to large torque required to rotate the arrays. So in these cases a manual tracking/automatic tracking can be perfromed by adjusting the array direction for three times a day. i.e. morning, afternoon and evening. This type of tracking can add to the power in the module.

Future scope.

Perturb and observe (P&O) algorithm for peak power tracking is explained in the present project report. Simulink models of algorithms other than P&O as explained in chapter.3 can be developed and tested on the real time platfrom using the dSPACE^{R}.

1]. Development of Microcontroller based dedicated MPPT controller for solar PV module based on the present algorithm. This can be a low cost embedded controller.

2]. Automatic recording and monitoring of the temperature and insolation level on the module to predict the peak power of the module.

3]. Implementing the axial tracking with the electrical (MPPT) tracking on a solar pv module and checking its response on the module power output.

4]. Implementing other algorithms as explained in chapter 3 on the dSPACE and checking their response.

5]. A whole stand alone system including the MPPT system and the inverter system can be developed using the dSPACE.

CHAPTER 9

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