MPPT ALGORITHMS IN PHOTOVOLTAICS AND STUDY OF INC METHODS BY USING MATLAB

R. Sujatha*, EEE department, Santhiram Engineering College, Nandyal, Kurnool, AP
N. V. S. Prasad*, EEE department, Santhiram Engineering College, Nandyal, Kurnool, AP. Email: prasad.eee@srecnandyal.edu.in

***Abstract*: The rapid increase in the demand for electricity and the recent change in the environmental conditions such as global warming led to a need for a new source of energy that is cheaper and sustainable with less carbon emissions. Solar energy has offered promising results in the quest of finding the solution to the problem. The harnessing of solar energy using PV modules comes with its own problems that arise from the change in insulation conditions. These changes in insulation conditions severely affect the efficiency and output power of the PV modules. A great deal of research has been done to improve the efficiency of the PV modules. A number of methods of how to track the maximum power point of a PV module have been proposed to solve the problem of efficiency and products using these methods have been manufactured and are now commercially available for consumers.**

As the market is now flooded with varieties of these MPPT that are meant to improve the efficiency of PV modules under various insulation conditions it is not known how many of these can really deliver on their promise under a variety of field conditions.

In this paper the control mechanism of Maximum power point tracking using DC-DC converters is presented. First the photovoltaic module is analyzed using SIMULINK software. The main aim of the project is to track the maximum available power from the solar PV module respective irradiation conditions using different MPPT algorithms to improve the efficiency of the solar panel. The DC-DC converter is to be used along with a Maximum Power Point Tracking control mechanism. The MPPT is responsible for extracting the maximum possible power from the photovoltaic and feed it to the load via the DC-DC converter which steps up/down the voltage to required magnitude.

1. INTRODUCTION

Photovoltaic technology is used to produce electricity in areas where power lines do not reach. In developing countries, it is improving living conditions in rural areas especially in healthcare, education, and agriculture. In the industrialized countries, they have been used extensively and integrated with the utility grid. Photovoltaic arrays are usually mounted in a fixed position and tilted toward the south to optimize the noontime and daily energy production.

The rapid increase in the demand for electricity and the recent change in the environmental conditions such as global warming led to a need for a new source of energy that is cheaper and sustainable with less carbon emissions.

Solar energy has offered promising results in the quest of finding the solution to the problem. The harnessing of solar energy using PV modules comes with its own problems that arise from the change in insulation conditions. These changes in insulation conditions severely affect the efficiency and output power of the PV modules. A great deal of research has been done to improve the efficiency of the PV modules.

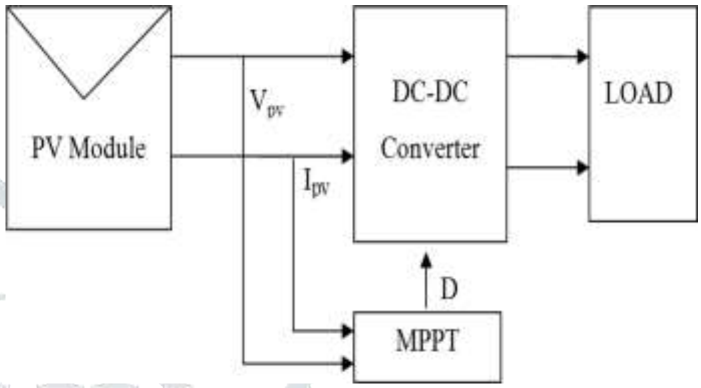


Figure 1.1 Block diagram of PV Module with MPPT

A number of methods of how to track the maximum power point of a PV module have been proposed to solve the problem of efficiency and products using these methods have been manufactured and are now commercially available for consumers. As the market is now flooded with varieties of these MPPT that are meant to improve the efficiency of PV modules under various insulation conditions it is not known how many of these can really deliver on their promise under a variety of field conditions.

Various Solar photovoltaic system applications are as follows,

- Stand alone systems such as solar battery charger.
- Solar vehicles.
- Building systems.
- Solar power plants.
- Decentralized grid connected systems.
- Street lightening.
- Rural electrification where the load sharing is much more.

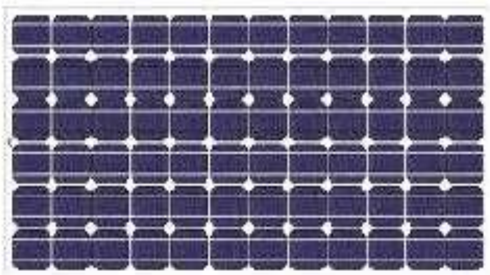
The frequency of the PWM signal is the same as the triangle voltage; hence by controlling the frequency of the triangle voltage the PWM frequency is controlled. The PWM control method is the most common way of controlling a DC-DC converter. However, it is necessary to mention that in modern power electronics the PWM control voltage is usually generated by a microprocessor. And in the implementation part of this thesis, a micro controller has been used to generate a PWM signal.

Basic converter configurations are as mentioned below,

1. Buck Converter (StepDown)
2. Boost Converter (Step Up)
3. Buck Boost Converter (Step Down / StepUp)

2. MODELLING OF SOLAR CELL

A solar cell converts the sunlight into electricity is determined the parameters of solar cells. There are several parameters of solar cells that determine the effectiveness of sunlight to electricity conversion. The list of solar cell parameters is following:



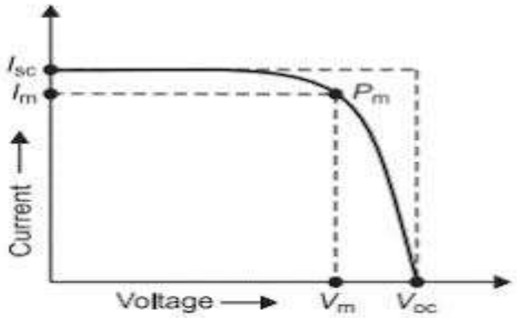


Fig: 2.1.2 I-V Characterstics

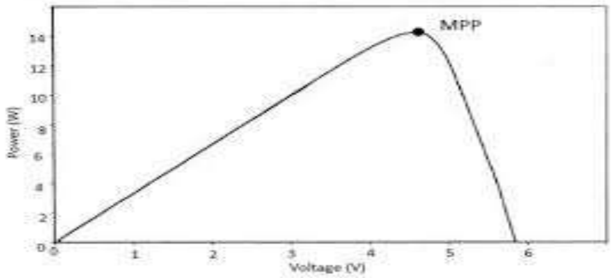


Figure 2.1.3 P-V characteristics of a solar panel

2.1 Effect of Irradiance:

In terms of PV modules, irradiance describes the amount of solar energy that is absorbed by the array over its area. Irradiance is expressed typically in watts per square meter (W/m2). With low irradiance Voc or voltage is not affected much but current will be affected badly. The change in output current is due to the reduced flux of the photons that move within a cell.

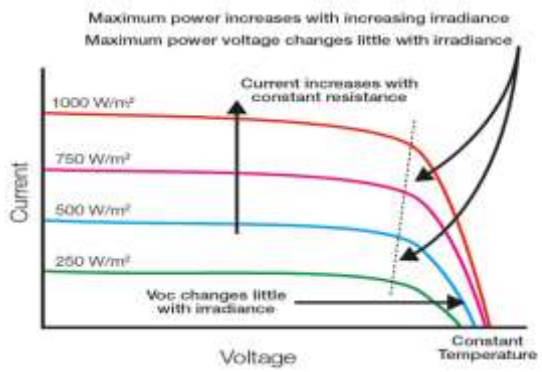


Figure 2.1 I-V characteristics of different irradiation levels

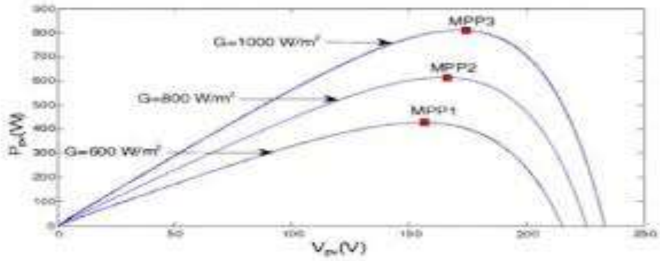


Figure 2.1.4 P-V characteristics of different irradiation levels

2.2 Effect of Temperature:

With rise in the temperature the Short circuit current Isc or current is not affected much but Voc or voltage gets affected badly. The temperature of a PV module also affects its efficiency. In general, a crystalline silicon PV module's efficiency will be reduced about 0.5 percent for every degree C increase in temperature. PV modules are usually rated at module temperatures of 25°C (77°F) and seem to run about 20°Cover the airtemperature.

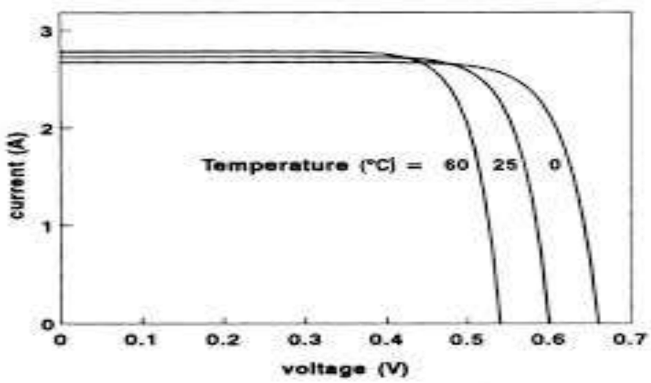


Figure 2.2.1 I-V characteristics of different temperatures

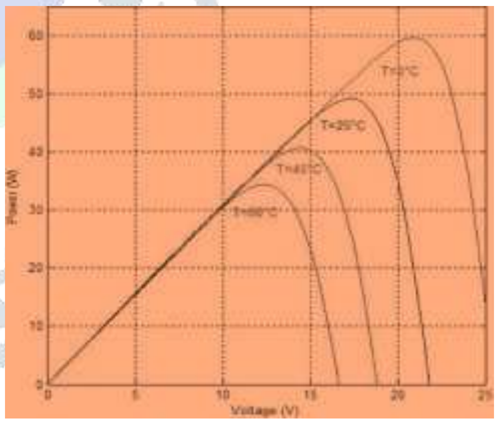


Figure 2.3.2 P-V characteristics of different temperatures

3. MAXIMUM POWER POINT TRACKING

Solar panel converts 30-40% of energy incident on it to electrical energy. A Maximum Power Point Tracking algorithm is necessary to increase the efficiency of the solar panel. An ideal Solar cell works as a constant current source, but practically it follows peculiar I-V characteristics as shown in Figure 3-3. Hence to extract the maximum power from solar cell or module arrangement is necessary. Maximum Power Point Tracking is done to extract the maximum power from solar cell or module by operating it at maximum power point of its I-V characteristics.DC-DC converters are used for extracting the maximum power of the solar cell or module. Converter uses the fact that by varying the duty ratio D, Rini.e input impedance of converter can be changed. Rin is equal to Rpvi.e impedance of the solar PV module.

Also by using principle of "IMPEDANCE MATCHING" when Rin becomes equal to RL i.e Load resistance, maximum power will be transferred from panel.

Many MPPT algorithms are developed for extracting maximum power from the solar module, some of them are,

- Perturb and Observe method or Hill Climbingmethod,
- Incremental Conductancemethod,
- Constant Voltagemethod,
- Modified Hill Climbingmethod,
- System Oscillationmethod,

3.1 Incremental Conductance Method:

In the incremental conductance method, the MPP is tracked by matching the PV array impedance with the effective impedance of the converter reflected across the array terminals. The latter is tuned by suitably increasing or decreasing the value of the duty cycle. Referring to figure 4-3, the algorithm can be explained as follows.

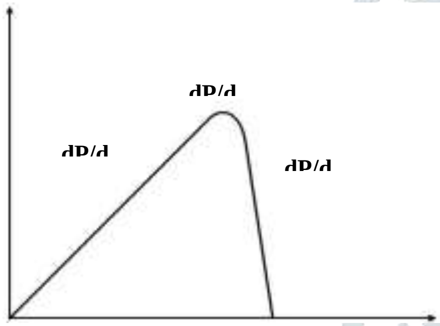


Fig 3..1 Incremental Conductance method of MPPT

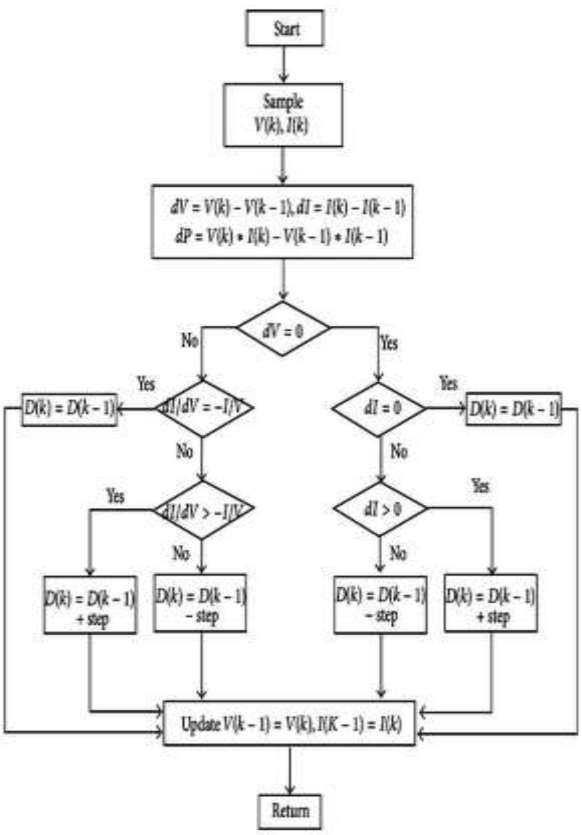


Fig:3.1.2 flowchart of Incremental Conductance

IV. RESULTS AND DISCUSSION

4.1. PV Model withoutMPPT:

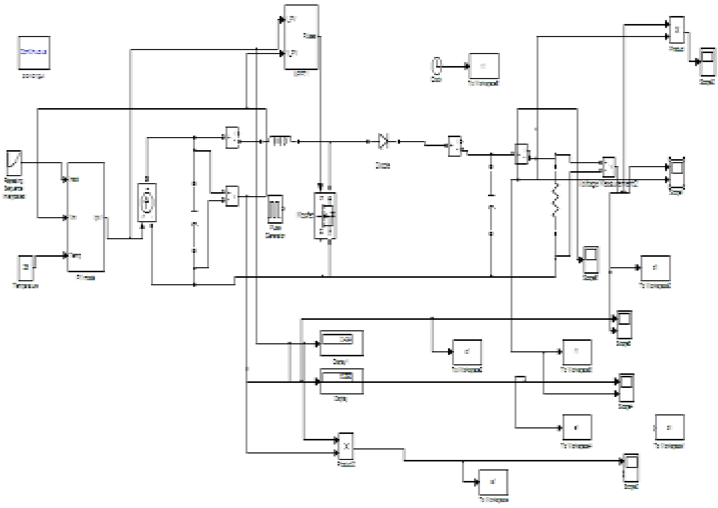


Fig: 4.1.1 Simulation model for boost converter in MPPT(P&O)

Ware made 10W panel is taken as the reference module for simulation and name-plate details are mentioned in

Rated power	10W
Voltage at maximum power(V_{mp})	17V
Current at maximum power(I_{mp})	0.59A
Open circuit voltage(V_{oc})	21V
Short circuit current(I_{scr})	0.61A
Current temp.coefficient	4.4mA/ºC
Voltage temp.coefficient	-0.123V/ºC
Number of cells in series N_s	36

Table 5.1 Electrical Characteristics data of Waaree 10W panel

The electrical specifications are under test conditions of irradiance of 1000W/m2, spectrum of 1.5 air mass and cell temperature of25ºC.

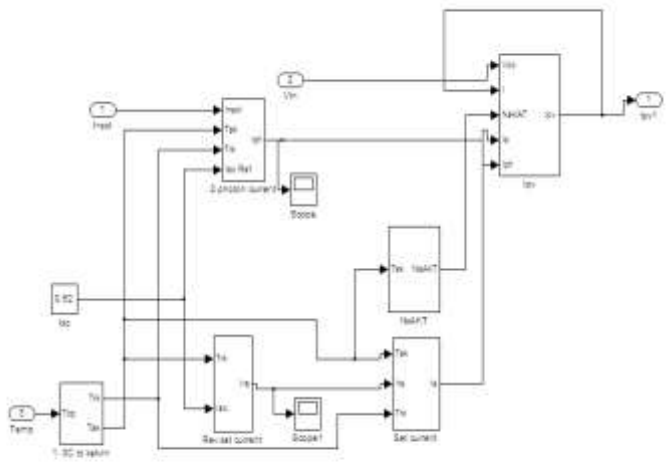


Figure 4.1.2.Subsytem of PV model

The above PV model was directly connected to the load.
Fig shows the maximum power changing when changing the load at Variable irradiance level.

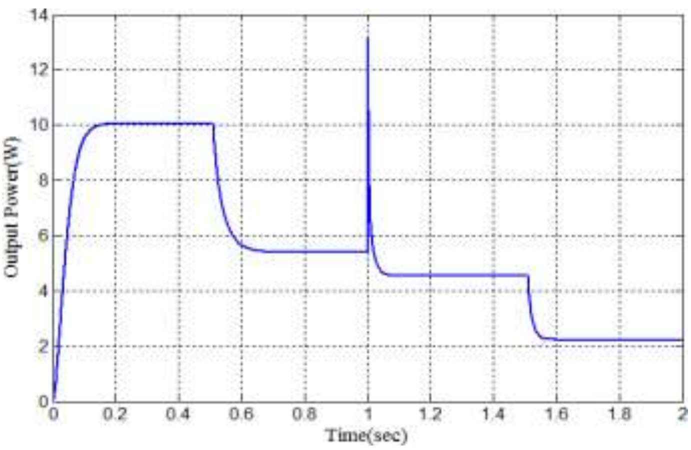


Figure 4.1.3. Output Power with load change

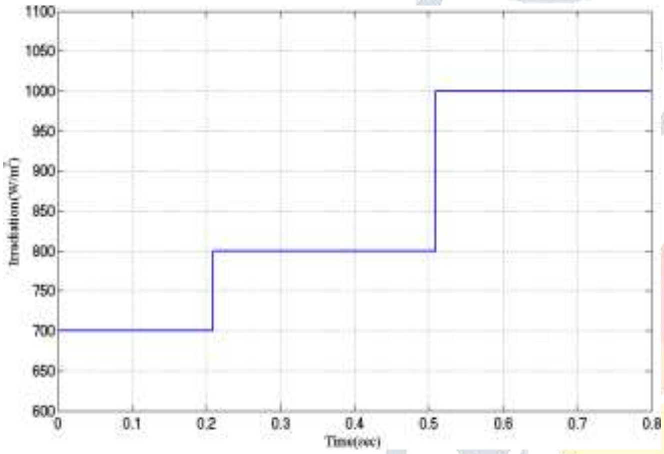


Fig: 4.1.4 Irradiation Level (W/m²)

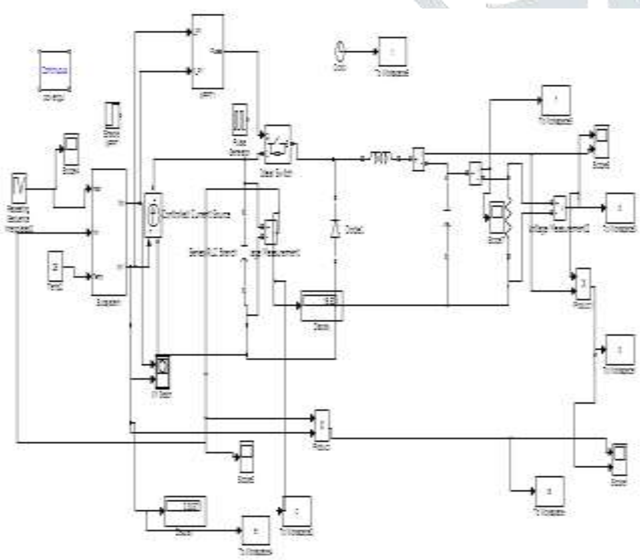


Fig:4.1.5 Simulation model for buck converter in MPPT(P&O)

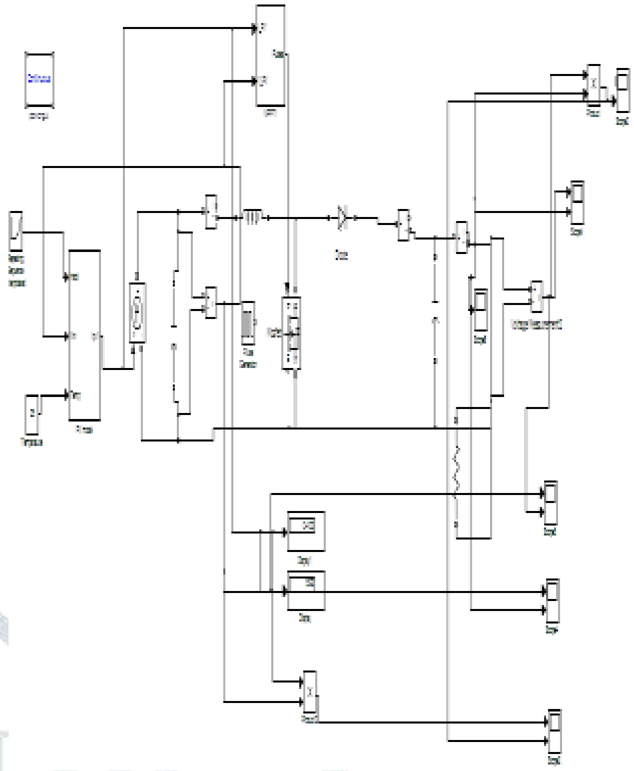


Fig:4.1.6 Simulation model for boost converter in MPPT(INC)

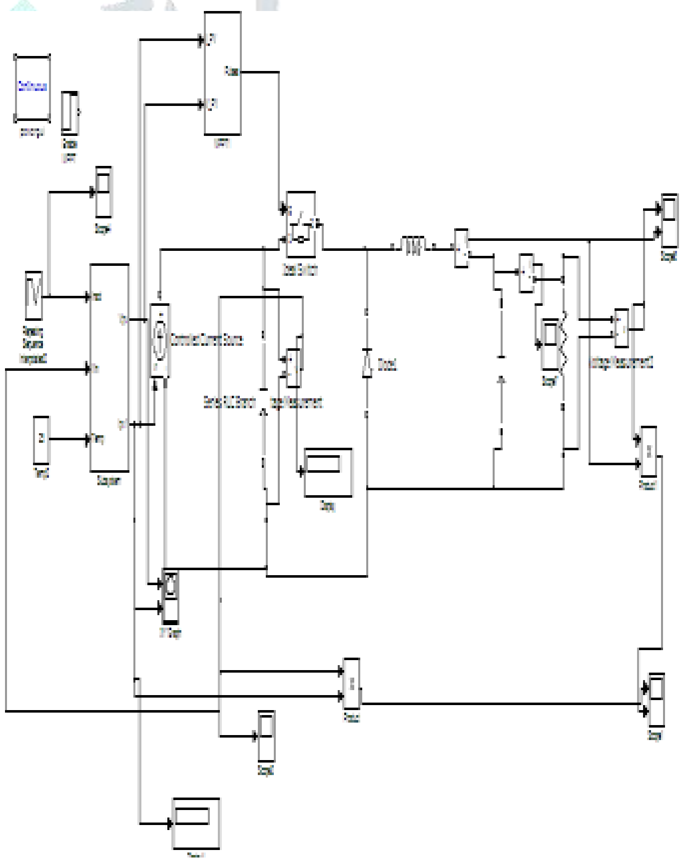


Fig:4.1.7. Simulation model for buck converter in MPPT(INC)

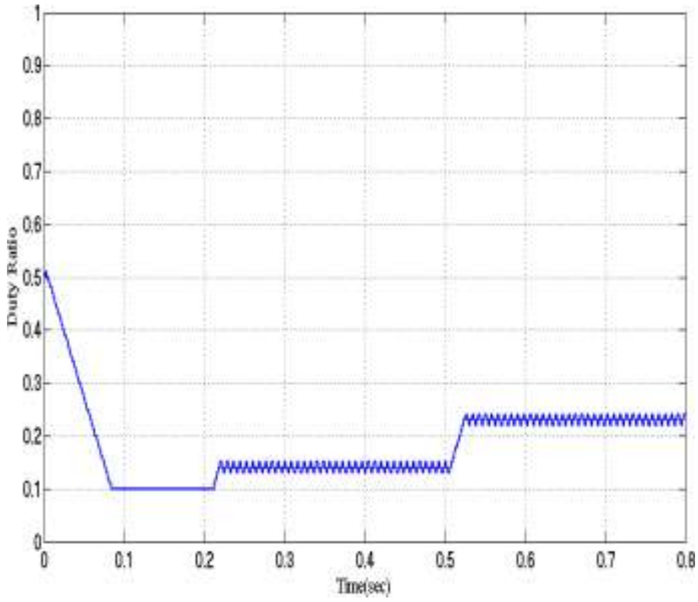


Fig:4.1.8.Duty ratio of Boost converter (P&O Method)

4.2.Output Results of the Boost converter:

Here simulated the Boost converter with the PV model shown in figure 5.4

Voc=21, Vmp=17, Isc=0.62, Imp=0.59, Pin=10W

R_L = 50

L= 1.5Mf

C= 15µF

Switching Frequency= **40 kHz**

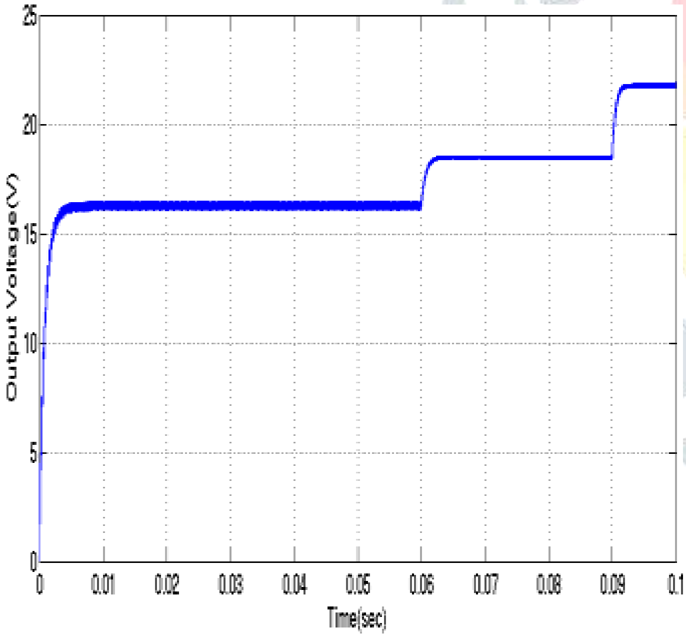


Fig: 4.2.1.Boost Converter Output Voltage (Inc method)

4.3. Output Results of the Buckconverter:

Here simulated the Buck converter with the PV model shown in figure 5.4 Voc=21, Vmp=17, Isc=0.62, Imp=0.59, Pin=10W 10 L= 25mF

R=10

L=25mF

C= 1.25µF

Switching Frequency= **10 kHz**

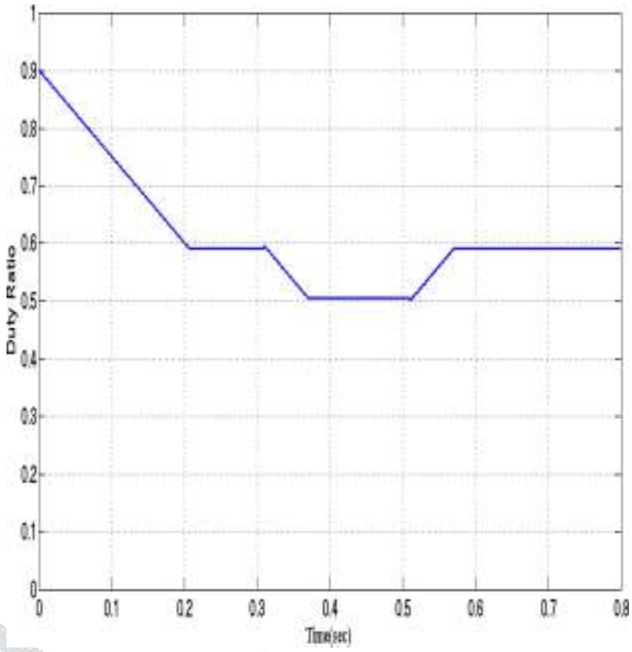


Fig: 4.3.1. Duty Ratio of Buck Converter (Inc method)

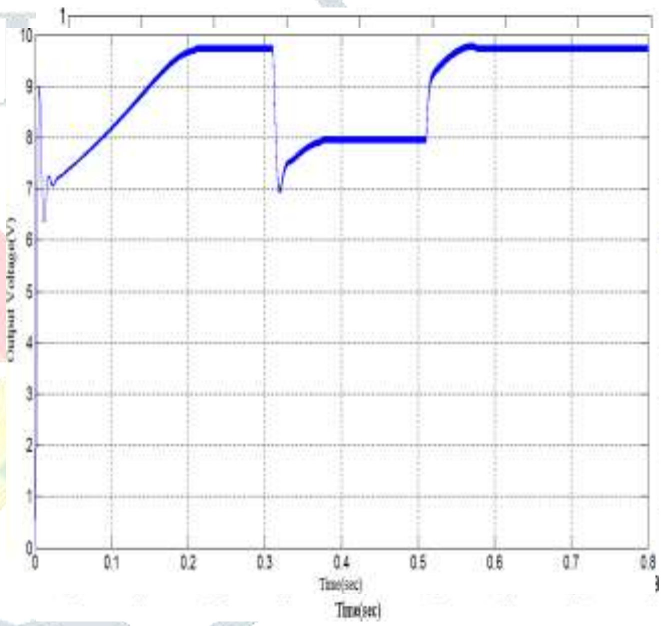


Figure 4.3.2. Buck Converter Output Voltage (Inc method)'

Table 4.2.1 Efficiency of Boost Converter (Inc method)

IRRADIATION (W/m^2)	PANEL POWER(W)	LOAD(Ω)	DUTY RATIO	OUTPUT POWER(W)	EFFICIENCY (%)
700	6.2	50	0.12	5.8	93.5
800	7.5	50	0.15	6.9	92
1000	9.8	50	0.25	9.2	93.38

Table 4.3.1 Efficiency of Buck Converter (Inc method)

IRRADIATION (W/m^2)	PANEL POWER (W)	LOAD (Ω)	DUTY RATIO	OUTPUT POWER (W)	EFFICIENCY (%)
1000	9.81	10	0.59	9.65	98.2
700	6.66	10	0.52	6.53	98

4.4 Comparison of MPPT algorithms:

By observing the tables Buck converter is more efficient than Boost Converter. Incremental conductance method tracks the maximum power very efficiently but perturb and observe method oscillates at the maximum power.

MPPT METHOD	BUCK CONVERTER	BOOST CONVERTER
P&O	97%	96%
INC	98%	93%

Table 4.4.1.Comparison of MPPT algorithms

V. RESULTS:

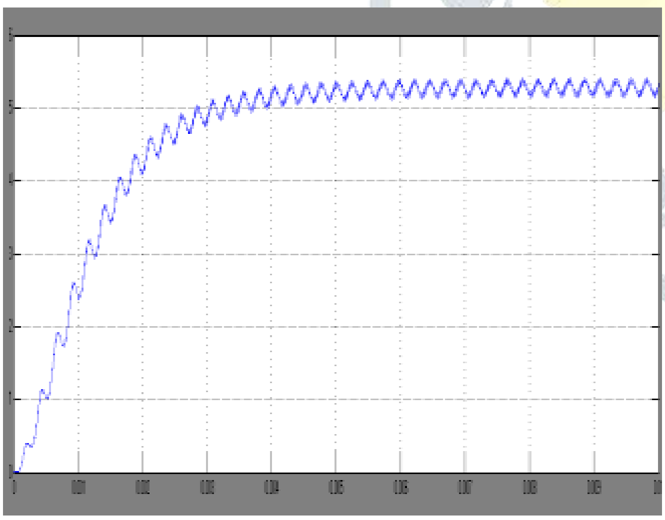


Fig:5.1 V-I characterstics of a boost converter (INC)

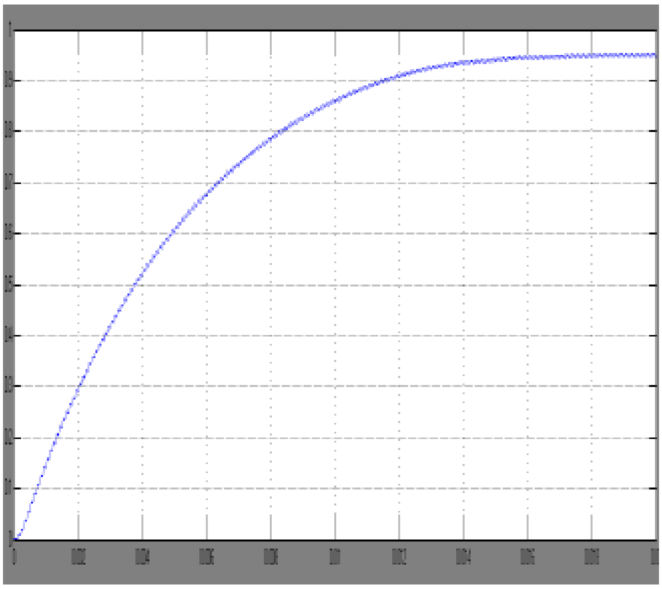


Fig:5.2 V-I characterstics of a buck converter (INC)

VI. CONCLUSION

The most conventional MPPT's for photovoltaic's are studied and simulated using MATLAB/SIMULINK. In this project the main concentration is about comparison of two most usual (perturb & observe and incremental conductance) methods. These methods are done by using DC-DC converters. One simple solar panel that has standard value of insolation and temperature has been included in the simulation circuit. It is interesting to point out that the differences in performances among the analyzed MPPTs are very slight, and these algorithms must be evaluated according to each situation. The similarity of the two algorithms will be investigated deeply in a future work, since the recent results suggest that the two algorithms aresimilar.

REFERENCES

1. Chetan Singh Solanki, "Solar Photovoltaic's Fundamentals, technologies and Applications",Secondedition,publishedbyAsokeK.Ghosh,2011,PHILearning Private Limited, New Delhi.
2. TrishanEsram, Patrick L. Chapman "Comparison of Photovoltaic Array Maximum Power Point Tracking Techniques," IEEE Transaction on Energy Conservation, VOL. 22, NO. 2, June2007.
3. Power Electronics, Converters, Applications and Design, Book by Mohan, Undeland, Riobbins.
4. SørenBækhøjKjær, "Evaluation of the "Hill Climbing" and the "Incremental Conductance" Maximum Power Point Trackers for Photovoltaic Power Systems" ," IEEE Transaction on Energy Conservation, VOL. 27, NO. 4, DECEMBER2012
5. KinalKachhiya, MakarandLokhande, Mukesh Patel "MATLAB/Simulink Model of Solar PV Module and MPPT Algorithm" National Conference on Recent Trends in Engineering & Technology in 13-14 May2011.
6. EftichiosKoutroulis, Kostas Kalaitzakis,"Development of a Microcontroller-Based, Photovoltaic Maximum Power Point Tracking Control System"IEEE Transactions On Power Electronics, Vol. 16, No. 1, January2001.
7. Kun Ding, XinGaoBian, HaiHao Liu, and Tao Peng "A MATLAB-Simulink-Based PV Module Model and Its Application Under Conditions of Non uniform Irradiance" , IEEE Transaction on Energy Conservation, vol. 27, no. 4, December2012

8. M.Lokanadham, K.VijayaBhaskar "Incremental Conductance Based Maximum Power Point Tracking (MPPT) for Photovoltaic System" International Journal of Engineering Research and Applications (IJERA) Vol. 2, Issue 2, Mar-Apr2012.
9. Swati Singh, Lini Mathew, Shimi S.L., "Design and Simulation of Intelligent Control MPPT Technique for PV Module Using MATLAB/ SIMSCAPE" International Journal of Advanced Research in Electrical, Electronics andInstrumentation Engineering, Vol. 2, Issue 9, September 2013.