International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 02 Issue: 06 | Sep-2015 www.irjet.net p-ISSN: 2395-0072

Proportional plus Integral (PI) Control for Maximum Power Point Tracking in Photovoltaic Systems

Arun Raj[1], Anu Gopinath[2]

[1] PG scholar, Electrical and Electronics Engineering Department, Mar Baselios College of Engineering, Kerala, India
[2] Assistant Professor, Electrical and Electronics Engineering Department, Mar Baselios College of Engineering, Kerala, India

---***---

Abstract - ***Solar photovoltaic power generation system is one of the burning research fields these days. Nowadays, governments are also making plans towards increasing the amount of power generation from renewable energy sources, as the viability and crisis of conventional energy sources will increase in near future. However, government liberalization and technical developments encourage the use of renewable sources for power generation in terms of distributed generation system. In order to overcome the present energy crisis, one renewable method is to develop an efficient manner by which power is extracted from the incoming sun light radiation called Solar Energy. This paper deals with the design and implementation of a simple and efficient solar photovoltaic power generation system for isolated and small load up to 1 KW. It provides simple basic theoretical studies of solar cell and its modelling techniques using equivalent electric circuits. Solar Photovoltaic (PV) power generation system is comprised several elements like solar panel, DC-DC converter, MPPT circuit, and load. These components are designed in MATLAB software. Proportional plus Integral (PI) is used for tracking maximum power from the photovoltaic panel in the case of varying irradiation.***

Key Words: *Solar Panel, Proportional plus Integral control.*

1. INTRODUCTION

In the field of power sector one of the major concerns in these days is day-by- day increase in power demand. But, the quantity and availability of conventional energy sources are not enough to meet up the current day's power demand. While thinking about the future availability of conventional sources of power generation, it becomes very important that the renewable energy sources must be utilized along with source of conventional energy generation systems to fulfill the requirement of the energy demand.

In order to overcome current day's energy crisis, one renewable method is to extract power from the incoming sun radiation called Solar Energy, which is globally free for everyone.

Solar energy is lavishly available on the earth surface as well as on space, so that we can harvest it and convert that into suitable form of energy and properly utilize it efficiently. Power generation from solar energy can be grid connected or it can be an isolated or standalone power generating system. It depends on the utility, location of load area, availability of power grid nearby it. Thus, where the availability of grids connection is very difficult or costly, the solar energy can supply power to those areas. The most important two advantages of solar power are that its fuel cost is absolutely zero and solar power generation during its operation do not produce any greenhouse gases. Another advantage of using solar power for small power generation is its portability that is we can carry that whenever wherever small power generation is required.

In the last few years the power conversion mechanisms for solar energy has been significantly reduced to compact size. The new researches in the field of power electronics and material science have greatly helped engineers to develop such systems. So that very small but effective and powerful systems that have capability to meet high electric power demand has been developed.

For every country, day by day power density demand is increasing. Solar power generation have also the capability to handle the voltage fluctuation very effectively by setting the system for the use of multiple input and converter units. But in solar power generation system, due to its high installation cost and the low efficiency of the solar cells, this power generating systems can hardly participate in the competitive power markets as a main renewable source of power generation.

Scientists are constantly trying to improve the field of development of solar cells manufacturing technology for increasing efficiency. This will definitely make the solar generation as a habit for use in daily life as a prime renewable source of electrical power on a wider range basis than present day conditions. In solar power generation system the latest power control mechanisms is using the Maximum Power Point Tracking frequently referred as MPPT, to increase the efficiency of operation of power generation from the solar cells. Thus MPPT is most important in the field of renewable sources of energy [1].

Now this area became burning research field these days. A key point of encouragement to the use of solar PV power generation system across the whole world is that governments are giving large investments in renewable and clean energy sources for developing their power sector. This is because every country have limited sources of conventional energy. Even in India, government aims to achieve a generating capability of 20GW from solar energy by year 2020 and 40% of it will be generated by solar PV power generation system according to draft report of JNNSM (Jawaharlal Nehru National Solar Mission) India.

Power generation method using solar photovoltaic module is a foremost effective technique of using the solar energy. In this method solar panel directly convert sunlight irradiation into electricity by the photoelectric effect. It is clean and pollution-free. This is because solar power generation do not releases any greenhouse gases in its operation. It is also easy in structure and free from noise pollution since it does not contain any moving parts. There is no fuel cost required because it uses sun light as a input that is globally free. It also need very little maintenance [1]. Solar power generation have low conversion efficiency and high installation cost therefore our target should be to increase the efficiency for power generation from the system. Researchers are continuously searching to develop better and efficient solar cell materials and to minimize the cost for installation of solar panel.

While thinking of designing this paper one designing software like Matlab, Labview, Multisim, PSpice and Proteus etc is required. MATLAB is used in this paper because it has a special feature that is while executing conditions of programming or circuit functions, we can switch the circuit or change the operating mode of design.

A series of the control algorithms for the MPPT are available at the present time due to the significance of improving the photovoltaic system's performance efficiency. The underlying principle of maximum power point tracking algorithm is that to use the ripple voltage or current component to identify the variation trend of the power output with the knowledge of the current versus voltage and the power output versus the voltage variations of the PV system. Generally, the operating point for different environment conditions varies and the characteristics of the *I-V* and *P-V* are generally illustrated in the way shown in Fig. 1 and Fig. 2 respectively. The corresponding voltage array for the maximum power point is varied, as a result of the variation in the solar insolation and the panel temperatures. By implementing the photovoltaic system with a DC-DC converter integrated with an MPPT controller, the nominal voltage can be modulated so that the maximum power is delivered. To track the maximum power point with dynamic changes, many algorithms deliver appropriate solutions in literature to solve the problem.

Many refined MPPT algorithms have been optimizing the digital realization, implementation complexity and operating cost since 1970s. Among these algorithms, ripple correlation control (RCC) is a better solution to solve the MPPT problem, considering the issue of stability, complexity and expense. Ripple correlation control is utilizing the integration of the correlation between the ripple power component and the ripple current or voltage component in the power electronic systems to obtain the duty cycle of the optimal power output. But it has many disadvantages also.

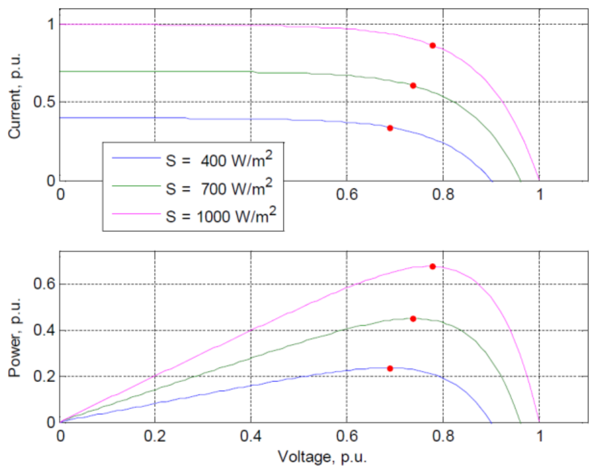


Fig. 1. V-I and V-P curves at constant temperature (25°C) and three different insolation values.

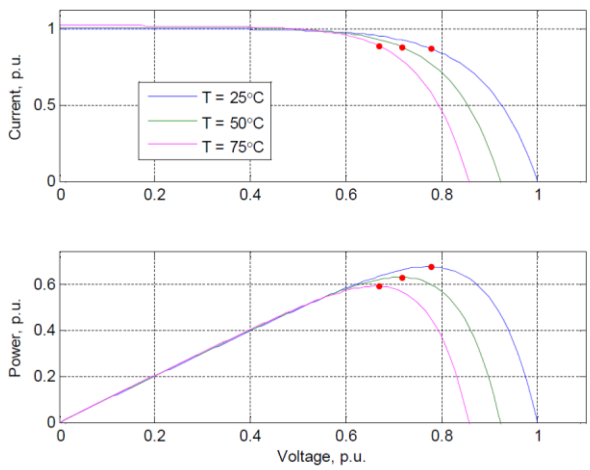


Fig. 2. V-I and V-P curves at constant irradiation (1 kW/m2) and three different temperatures.

2. MPPT

Maximum power point tracking (MPPT) is the method of tracking maximum output power from a solar panel. Several MPPT algorithms are available nowadays. The MPPT algorithm used in this particular work is Proportional plus Integral (PI) control.

In Fig. 3, P_m is the maximum power that can be obtained from a particular panel. The aim of a MPPT algorithm is to track P_m by making V_{PV} to V_M or I_{PV} to I_M.

3. SYSTEM DESCRIPTION

The overall system consist of solar panel that generates power according to the irradiation levels.

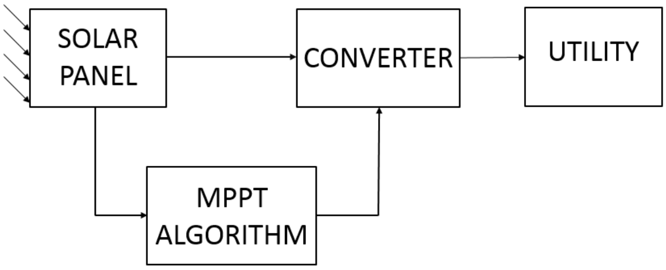


Fig. 4. Overall system

The overall system consist of solar panel that generates power according to the irradiation levels. The MPPT algorithm calculates the duty cycle for the converter corresponding to the maximum power point. The variation of the power and voltage of a solar panel is given in figure 3.

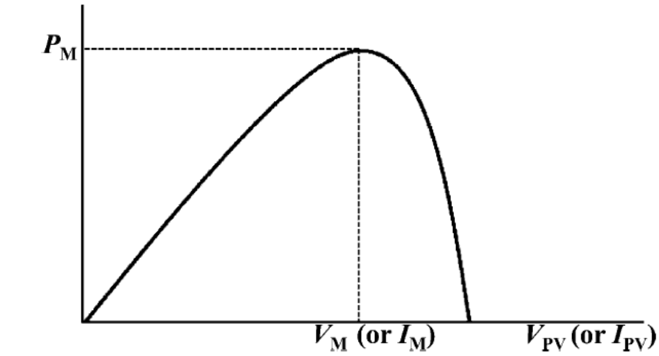


Fig. 3. Power–voltage characteristics of photovoltaic systems.

There will be one maximum power point for a particular irradiation.

4. MODELLING OF SOLAR PANEL & CONVERTER

For modelling this thesis work, solar panel, MPPT algorithm and boost converter has to be modelled. The specifications of the particular solar panel is given in the table 1.

4.1 SOLAR PANEL

The solar panel is modelled according to the data sheet of a Tata TP250 standard cell that is available in the market. Table 1 is the data sheet. The equivalent circuit

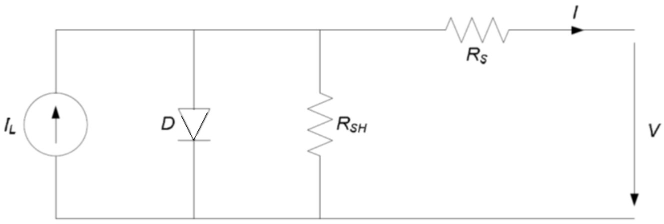


Fig. 5. Single solar cell

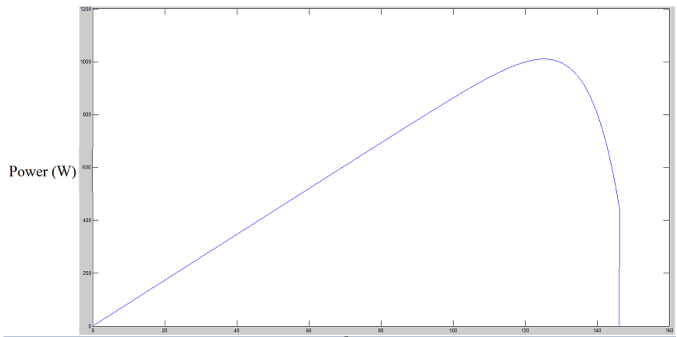
The basic equation for a solar cell is given in equation 2.

$$I = I_L - I_o\left(e^{\frac{q(V-IR_s)}{AkT}} - 1\right) - \frac{V - IR_s}{R_{sh}} \qquad (2)$$

Where

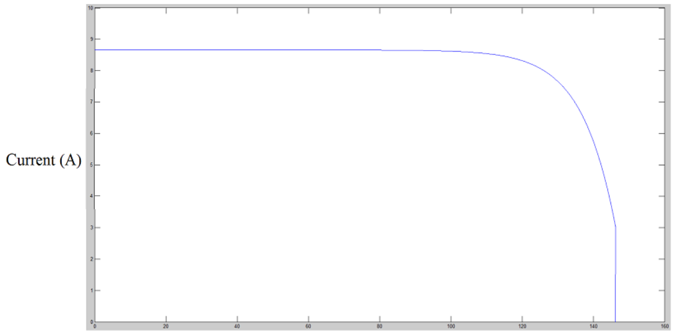
I = Solar cell output current
V = Solar cell output voltage
I_0 = Dark saturation current
q = charge of an electron = $1.60 * 10^{-19}$ C
A = diode ideality factor
k = Boltzmann constant = $1.38 * 10^{-23}$ J/K
T = temperature in K
R_s and R_{sh} = Series and shunt resistance

The particular panel used in this paper consist of 4 modules of which one generates 250W of power. The P-V and I-V characteristics of this particular cell is given in figure 6 and figure 7 respectively. The P-V and I-V characteristics of this particular cell is obtained for an irradiation of 1000 W/m² and 25⁰C.



Voltage (V)

Fig. 6. P-V characteristics of the 1kW solar panel



Voltage (V)

Fig. 7. I-V characteristics of the 1kW solar panel

4.2 BOOST COVERTER

A Boost converter can be used step up voltage according to the requirements. The Boost converter used in this paper is given in the figure 9.

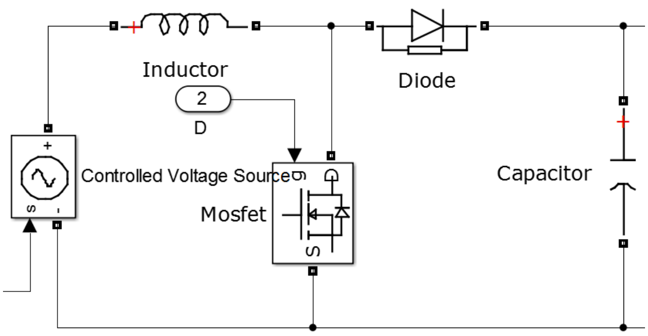


Fig. 8. Boost converter model

Values of the various components used in the boost converter are given in table 1.

Boost Converter	
Components	***Values***
Inductor, L_0	$100*10^{-6}$ H
Capacitor, C_0	$2200*10^{-6}$ F
Output voltage, V_0	115.6 V

Table 1. Boost converter parameter values

4.3 MPPT ALGORITM : PROPORTIONAL – INTEGRAL CONTROLLER

The proportional plus integral controller produces an output signal, u(t) proportional to both input signal, $v_i(t)$ and integral of the input signal, $v_i(t)$ and is given by

$$u(t) = K_p v_i(t) + K_i \int v_i(t)dt \qquad (1)$$

The control structure using PI control is given in figure 9.

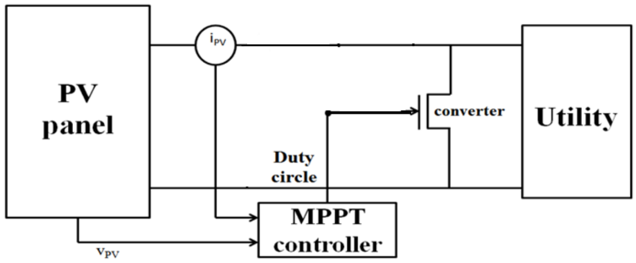


Fig. 9. Control structure

The algorithm is works according to the equation of the PI control.

.

Sl. No.	Parameter	Description	Value
1	K_p	Proportional gain	1
2	K_i	Integral gain	-1

Table 2. Parameters in PI control

From the MPPT a reference voltage V_{ref} is obtained. This V_{ref} is compared with the PV voltage, V_{pv} and an error signal is obtained and is given to the PI control. By properly selecting the proportional gain, K_p and integral gain, K_i the desired response can be obtained. Once boost converter is injected with the power from the PV panel and the PI controller starts function, it varies the value of the duty cycle which will change the input value that is sensed by the PI controller.

5. SIMULATION RESULTS AND DISCUSSIONS

The specifications of the solar panel that is developed in this particular work is given in table 2.

Tata TP250 solar panel specifications	
Electrical parameters	***Rating***
Nominal power output	250 W
Voltage at P_{max}	30.20 V
Current at P_{max}	8.30 A
Open circuit voltage, V_{OC}	32.80 V

Tata TP250 solar panel specifications	
Electrical parameters	***Rating***
Short circuit current, I_{SC}	7.35 A
No. of cells in series, N_s	60
No. of cells in parallel, N_p	1

Table 3. Solar panel specifications

The overall system obtained in MATLAB is given in Fig. 11.

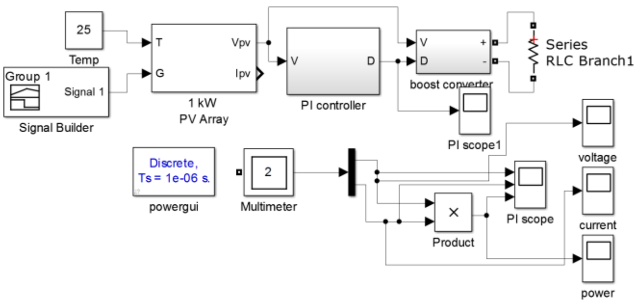


Fig. 10. MATLAB model of the overall system

The output power obtained for a varying irradiation of 400 W/m^2, 1000 W/m^2 and 700 W/m^2 respectively is shown in Fig. 12.

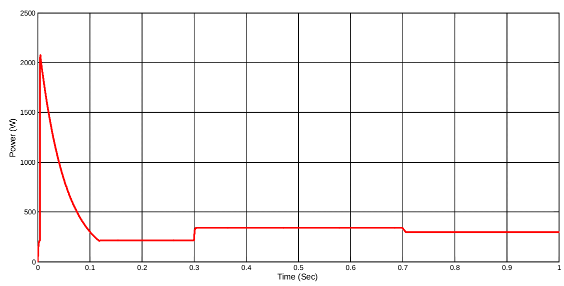


Fig. 11. MPPT using PI control method for irradiations 400 W/m^2, 1000 W/m^2 and 700 W/m^2 respectively.

The graph shows that the maximum output power is tracked for the corresponding irradiations. The spikes are due to the ripples in the power electronic devices connected in the model.

6. CONCLUSIONS

In order to improve the efficiency of photovoltaic systems, MPPT control algorithms are used to optimize the power output of the systems. The essential considerations are the accuracy and convergence time.

In the future work, other controllers can be designed to improve the performance of MPPT algorithm. The Model reference adaptive controller (MRAC) can be coupled with the Beta algorithm so that the maximum power can be tracked more efficiently and the tracking can be improved.

ACKNOWLEDGEMENT

The authors would like to thank the anonymous reviewers and the editors for their valuable advice and comments and also like to thanking Prof. Shajilal Sir, Dept. of Electrical and Electronics engineering, MBCET for his insightful suggestions.

REFERENCES

[1] Zhao Chaohui. "Emerging Technology: Photo-Voltage Generation Status and Trends". Journal of Shanghai Dianji University, 2008, 11(1): 104-109.

[2] Peter Wurfel "Basic principles of solar cells and the possible impact of nanostructures" IEEE Cat. No. 03CH37497 3rd World Conference on Phofovoltaic Energy Conversion May 11-18, 2003 Osab. Japan, Page 2672 - 2675 Vol.

[3] Matt Boreland and Darren Bagnall, "Current and future photovoltaics", Foresight - Horizon Scanning Report, 5th July 2006. http://eprints.soton.ac.uk/id/eprint/264403

[4] Tim Bruton, et al, "Towards 20% Efficient Silicon Solar Cells Manufactured at 60 MWp Per Annum", Proceedings of the 3rd World Conference on Photovoltaic Energy Conversion, 2003, Vol.1, pt. 1, pp. 899-902

[5] W. Xiao, W. G. Dunford, and A. Capel, "A novel modeling method for photovoltaic cells", in Proc. IEEE 35th Annu. Power Electron. Spec. Conf. (PESC), 2004, vol. 3, pp. 1950–1956.

[6] P G Nikhil and D Subhakar "An Improved Simulation Model for Photovoltaic Cell" IEEE 978-1-4244-8165-1/11 2011.

[7] J. A. Gow, C. D. Manning "Development of a photovoltaic array model for use in power electronics simulation studies", IEE Proceedings on Electric Power Applications, vol. 146, no. 2, pp. 193-200, March 1999.Datasheet Vikram Solar ELDORA 40-P

[8] Muhammad H. Rashid "Power Electronics: Circuits, Devices & Applications" Text Book.

[9] A. Roman, R. Alonso, P. Ibanez, S. Elorduizapatarietxe and D. Goitia, "Intelligent PV module for grid-connected PV systems," IEEE Trans. on Ind. Electron., Vol. 53, No. 4, Aug. 2006.

[10] W. Xiao, N. Ozog and W. G. Dunford, "Topology Study of Photovoltaic Interface for Maximum Power Point Tracking," IEEE Transactions on Industrial Electronics, vol. 54, no. 3, June 2007.