



APPLICATION OF DC-DC CONVERTER FOR GRID CONNECTED INVERTER USING PV CELL

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Abstract — The purpose of this paper is to provide general knowledge about photovoltaic (PV) cells. The modeling of photovoltaic cell is carried out to obtain typical I-V and P-V characteristics of photovoltaic cells. The voltage available at PV panel terminals is rapidly changing and for that it needs to process constant voltage output. A boost converter is used for step up the input voltage and keep output voltage constant. Photovoltaic array has an operating one point and it's called maximum power point, which depending on cell temperature and the irradiation level and array voltage. The maximum power point tracking (MPPT) is needed to operate the PV array at its maximum power point. The maximum power point tracking is used for utilizing a boost converter method. Solar panel voltage and current are continuously observed by a closed loop microcontroller based control system and the duty cycles of the boost converter continuously adjust at maximum power. Various algorithms for MPPT are available. In this paper used the perturb-and-observe algorithms to achieve maximum power.

Keywords— PV array, Maximum power point tracking(MPPT), DC-DC Boost converter.

I. INTRODUCTION

Energy is the most important factor and basic requirement for our daily life. But due to increasing population coupled with global warming and reducing fossil resources, for produce electrical energy need of alternative renewable energy technologies based on wind, solar cell biomass etc. further, continuous increased technology for that to reduced product cost, increased in the scale of production of renewable energy products, renewable energy friendly government policies are catalyzing the growth of renewable energy [1][2].

In today's investment in solar photovoltaic energy (PV) is fastly increasing worldwide[1]. Solar photovoltaic energy is a pollution free renewable energy sources with attributes high durability and reliability. In PV capability of energy conversion without intermediate thermal process. [2]

In existing research, A circuit based system of PV modules helps to analyze the performance of commercial PV modules. PV system shows Current-Voltage (I-V) and Power-Voltage (P-V) characteristics with different types of environmental and electrical parameters [2]. This paper presented the MATLAB simulation of PV cell that made prediction of performance the PV cell under different varying parameters such as solar radiation, ambient temperature, ideality factor, series and shunt resistance, combination of series and parallel solar cells. The model of PV cell is based on mathematical equation using basic blocks is developed in MATLAB/Simulink [3][4]. The change in insulation conditions and temperature level then also change efficiency and output power of PV modules[5]. To improve the efficiency and maintaining constant output power of PV modules Maximum power point tracking (MPPT) required[5]. In this paper most popular of MPPT technique perturb and observe (P&O) method will involved. This model can be used as a common system to analyze the performance of any PV modules by entering the required parameters[4][7].

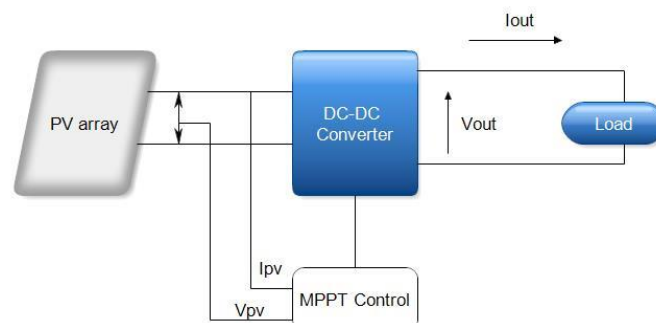


Figure 1. DC-DC converter for operation with MPPT

This paper also focus on design of DC-DC boost converter and integration of DC-DC Boost converter with PV module using MPPT algorithms (P&O)[5]. In this paper also mention about hardware of DC-DC converter using PV modules.

This paper organized as follows: Section I gives the Introduction of the PV module and MPPT. Section II gives the PV array Introduction. Section III gives the DC-DC Converter Information. Section IV gives the MPPT algorithms. Section V gives the Simulation results and the Section VI give the conclusion.

II. PV ARRAY

A Solar cell generally is a p-n semiconductor junction. When light exposed to it is generated DC current[2][6][9]. The generated DC current changed linearly with the solar irradiance [4]. The power generated by a single solar cell is very low. So, solar cells are connected in ether series or parallel combination for more power[1-3][6][8]. The equivalent circuit of an ideal solar cell shown in figure 2.

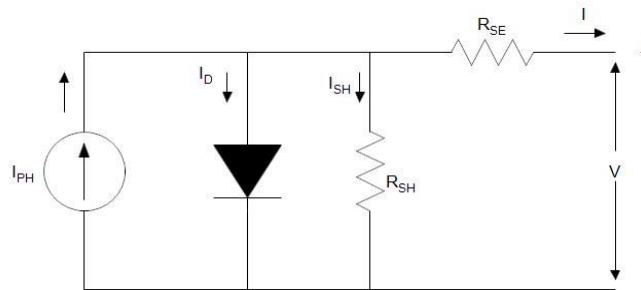


Figure 2. General model of solar cell

A general model of the solar cell is current source (I_{PH}) connected in anti-parallel with a diode (D), series resistance (R_{SE}) and shunt resistance (R_{SH}).

I-V and P-V characteristics of PV cell are shown in figure 3. The PV cell generated maximum power at only one point is called maximum power point (MPP)[3][4][7]. Maximum current maximum voltage and the maximum power of the PV cell is I_m , V_m and P_m respectively.

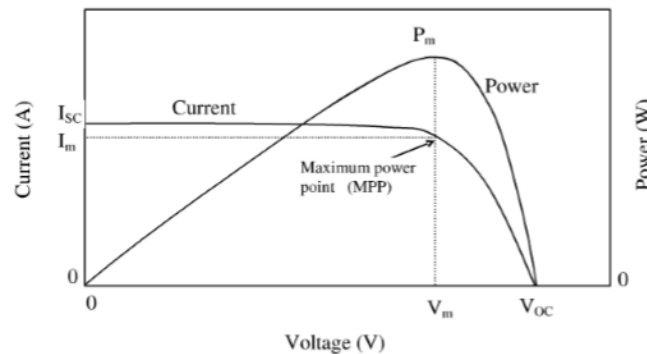


Figure 3. I-V and P-V Characteristics of solar cell

The mathematical equation for output current of ideal cell [1-4].

$$I = I_{PH} - I_D \quad (1)$$

Where,

I_{PH} is the light generated current

I_D is the Shockley equation.

The PV generated current is depends on solar irradiation and its working temperature is,

$$I_{PH} = [I_{SC} + K_I(T_C - T_{REF})].G \quad (2)$$

Where,

I_{SC} = short circuit current of PV cell at 25°C temperature and $G = 1$,

K_I = short-circuit current temperature co-efficient of cell,

T_C = operating temperature of cell

T_{REF} = reference temperature of cell

The Shockley equation

$$I_D = I_S \left\{ \exp \left(\frac{q}{AKT_C} \right) - 1 \right\} \quad (3)$$

Where,

I_S = saturation or leakage current of diode

q = electron charge [1.60×10^{-19} oC]

K = Boltzmann constant [1.38×10^{-23} J/K]

A = Ideality factor of diode

Based on general model, the output current of PV cell can be defined as

$$I = I_{PH} - I_D - I_{SH} \quad (4)$$

$$I = I_{PH} - I_S \left\{ \exp \left(\frac{qV}{AKT_C} + IR_{SE} \right) - 1 \right\} - \frac{V + IR_{SE}}{R_P} \quad (5)$$

For the Analysis of PV the value of ' R_p ' is neglected because is extremely high. The appropriate model of PV cell [4] is shown in figure 4. Re written the equation (5)

$$I = I_{PH} - I_S \left\{ \exp \left(\frac{qV}{AKT_C} + IR_{SE} \right) - 1 \right\} \quad (6)$$

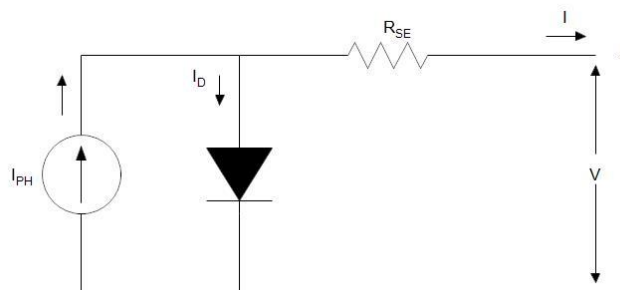


Figure 4. Appropriate model of solar cell

The PV cell generally connected in series or parallel for obtain the desired output voltage and current the mathematical equation for the PV array of simple model with series and parallel connected modules can be described

$$I = I_{PH}N_P - I_S N_P \left\{ \exp \left(\frac{qV}{AkT_C N_S} + \frac{I_{RS}E}{N_F} \right) - 1 \right\} \quad (7)$$

Where,

N_P & N_S = number of modules connected in parallel and series respectively.

The diode saturation current of cell varies with the cell temperature which can expressed [2] as,

$$I_S = I_{RS} \left(\frac{T_C}{T_{Ref}} \right)^3 \cdot \exp \left[\frac{qE_G}{kA} \left(\frac{1}{T_{Ref}} - \frac{1}{T_C} \right) \right] \quad (8)$$

Where,

I_{RS} = reverse saturation current of cell

E_G = band gap energy of the semiconductor

Using equation (9), the reverse saturation current of cell at reference temperature of 250C can be calculated.

$$I_{RS} = \frac{I_{SC}}{\exp \left(\frac{qV_{OC}}{N_S K A T_C} \right) - 1} \quad (9)$$

III. DC-DC CONVERTER

Basically DC-DC converter is increase or decrease the voltage level that given in input of DC converter[2][8]. There are various types of DC-DC converter; Buck, Boost, Buck-boost, Cuck, Sepic etc. In here using for step up the voltage that's why using Boost converter, Boost converter convert DC low voltage to high voltage. DC-DC boost converter used for regulate the voltage generated by PV cell[2]. The equivalent circuit diagram of DC-DC boost converter is shown in figure 5.

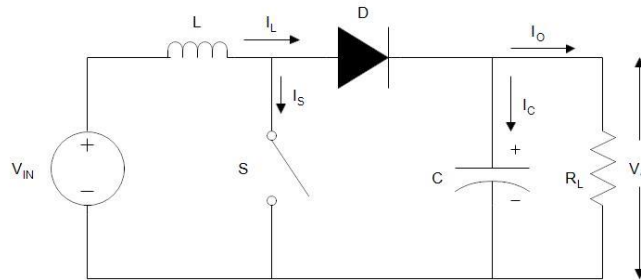


Figure 5. Equivalent Circuit of Boost converter

The boost converter output voltage is build upon on the duty cycle of control switch (MOSFET,IGBT)[8]. If change the ON time of switch then change in output voltage, for the duty cycle “D” average output voltage can be calculated using

$$\frac{V_O}{V_{IN}} = \frac{1}{(1-D)} \quad (10)$$

Where,

V_{IN} = input voltage of converter

V_O = output voltage of converter

D = duty cycle of control switch

The inductor and capacitor value are calculated using the formula[5].

Equation for the Inductor value of the boost converter

$$L = \frac{V_{IN}}{(f_s \Delta I_L)} \quad (11)$$

Where,

f_s = switching frequency of control switch

ΔI_L = input current ripple

Current ripple factor calculated by used ratio between input current ripple and output current. Good inductor value of current ripple factor estimated should be within 30 %, the current rating is always higher than maximum output current in inductor[2][5][8].

Equation for the Capacitor value of the boost converter

$$C = \frac{I_O}{(f_s \Delta V_O)} \quad (12)$$

Where,

ΔV_O = output voltage ripple which usually considered as 5 % of output voltage.

III. MAXIMUM POWER POINT TRACKING

Without using the MPPT PV system do not operate at the maximum power point that's why amount of available energy are wasted, for that a DC-DC converter required to better match the PV generation [6]. The operating point of PV array in I-V and P-V characteristics that point called MPP, the MPP changed with changing the temperature and irradiation, for that tracking of that MPP is needed and its tracking called Maximum power point tracking(MPPT)[4][6]. Perturb and Observe (P&O) algorithm used for tracking the MPP, flow chart of P&O algorithm shown in figure 6.

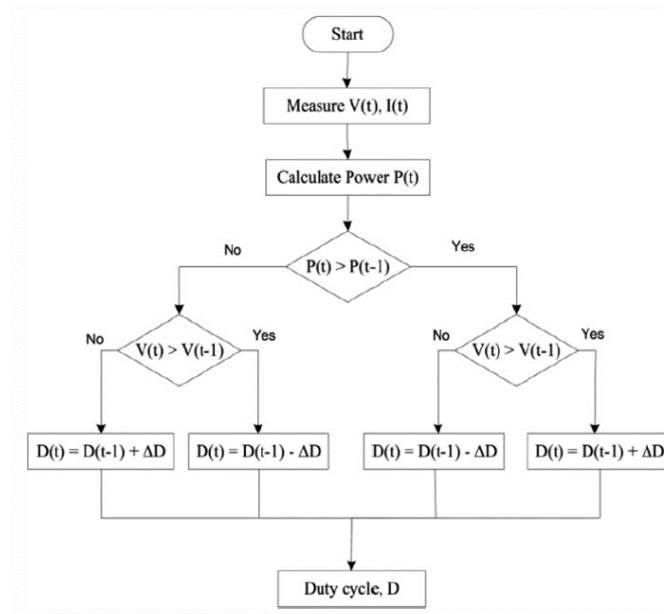


Figure 6. Flow chart of P&O algorithm

IV. SIMULATION AND RESULTS

A. Simulation of PV module

The model of PV module simulated using MATLAB/Simulink is shown in figure 7. The PV subsystem is built with light generated current (I_{PH}), saturation current (I_S), Shockley equation (I_D)[2].

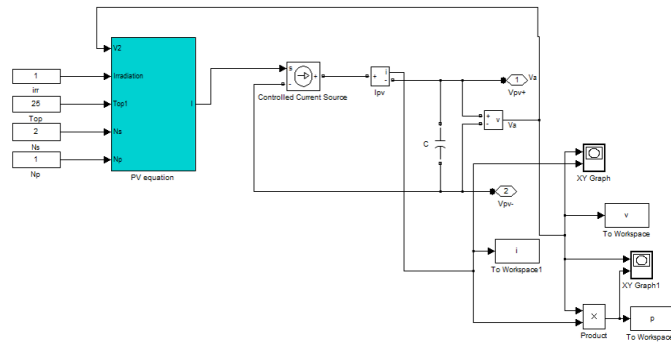


Figure 7. Simulation of PV module

Figure 8(a) and 8(b) shows the I-V and P-V characteristics curves of PV module obtained from the simulation with different irradiation levels and constant temperature (25°C).

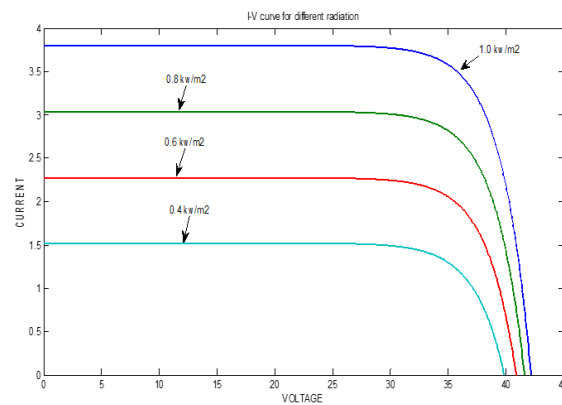


Figure 8(a) I-V characteristics curves at different irradiation level and constant temperature ($T = 25^{\circ}\text{C}$)

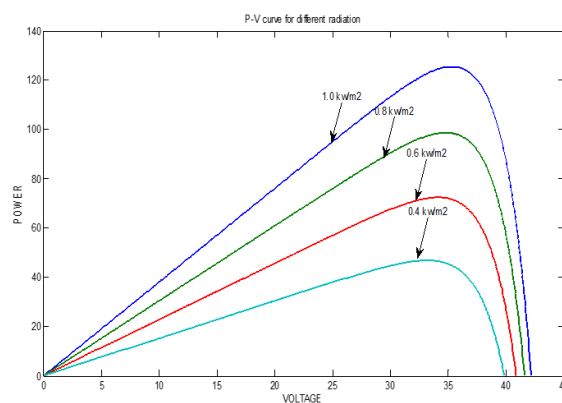


Figure 8(b) P-V characteristics curves different irradiation level and constant temperature ($T = 25^{\circ}\text{C}$)

Figure 9(a) and 9(b) shows the I-V and P-V characteristics curves of PV module obtained from the simulation with different temperature levels and constant irradiation ($G=1000\text{ Wb/m}^2$).

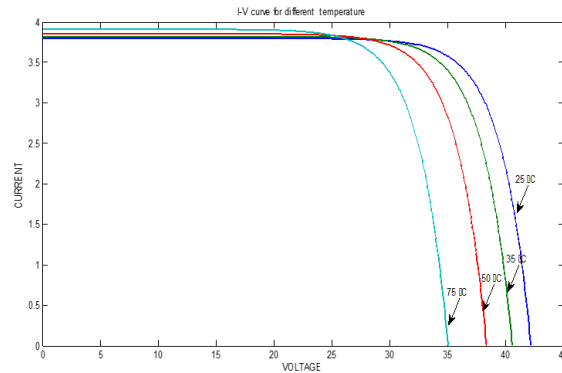


Figure 9(a) I-V characteristics curves at different temperature and constant irradiation ($G = 1000 \text{ Wb/m}^2$)

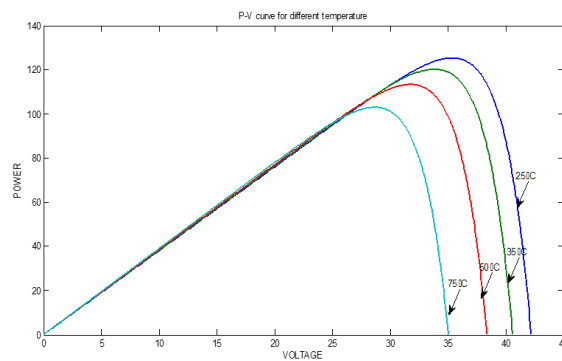


Figure 9(b) P-V characteristics curves at different temperature and constant irradiation ($G = 1000 \text{ Wb/m}^2$)

B. Simulation of PV module with DC-DC Boost converter

Figure 10 shown the MATLAB Simulation of PV module with DC-DC boost converter. Here sub system of PV module with P&O MPPT algorithm for achieving maximum power point, give the duty cycle “D” to switch, in this simulation MOSFET used as a switch. Boost converter using for step up the input voltage.

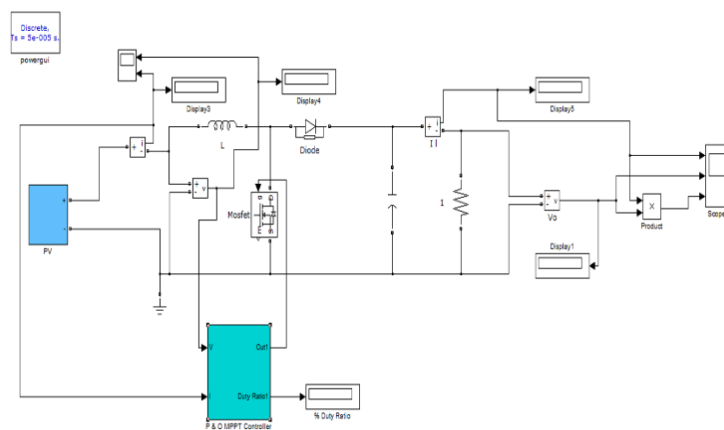


Figure.10. PV fed DC-DC Boost converter

In this model PV module output voltage and current is 41.1 volt and 1.0 ampere respectively, this output voltage and current of PV module is input for Boost converter; then the boost converter convert voltage and current at 55.2 volt and 0.72 ampere respectively.

Figure 11(a) shows Input voltage and Output voltage of PV fed Boost converter and figure 11(b) shows Input and Output current respectively.

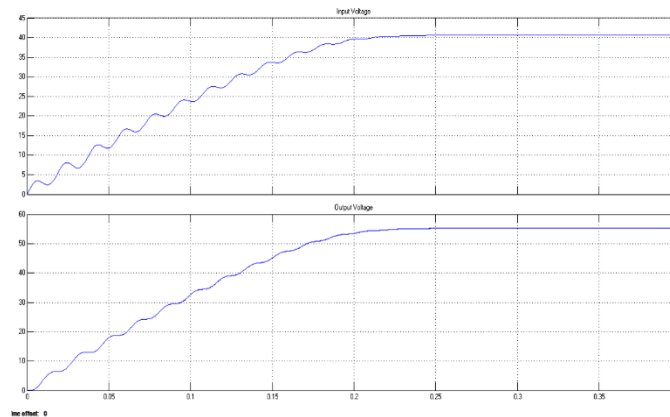


Figure 11(a). Input voltage and output voltage of PV fed Boost converter

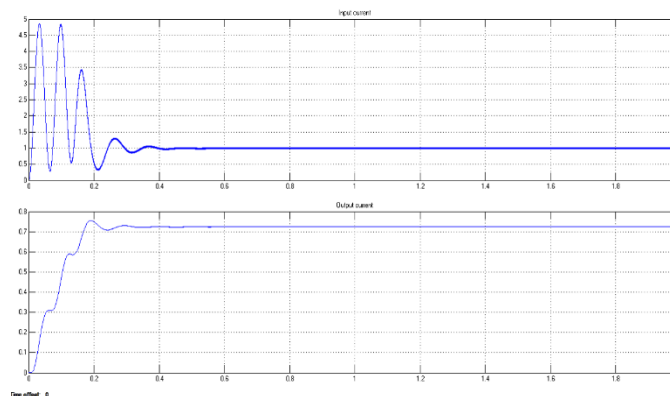


Figure 11(b). Input current and output current of PV fed Boost converter

V. CONCLUSION

This paper presents a general circuit and appropriate system of PV cell help to analyze the performance of PV modules. A general model of PV module developed using mathematical equation in the form of subsystem block in MATLAB. The model can give the I-V and P-V Curve characteristics for different radiations and temperature levels of PV modules.

In this paper, The mathematical model of PV fed Boost Converter with P and O MPPT algorithm is simulated and the result obtained from the constant DC input supply, Also the result of input/output voltage and input/output current of PV fed boost converter.

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