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# Design and Analysis of Standalone PV based Boost Converter With P & O MPPT Technique

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## ABSTRACT

This paper deals with the design and analysis of standalone solar PV based boost converter with P& O (Perturb and Observe) MPPT (Maximum Power Point Tracking) Techniques. An intermediate converter can therefore increase efficiency by matching the PV system to the load and by operating the solar cell arrays at their maximum power point. MPPT (Maximum Power Point Tracking) controller is used for extracting the maximum power from the solar PV module. P&O (Perturb and Observe) MPPT (Maximum Power Point Tracking) is used because of simple implementations. The proposed converter system results in low ripple content, which improves the array performance. Solar PV stand–alone system with boost converter is modeled in MATLAB/SIMULINK environment using the sim power system toolboxes. The performance of the proposed system is obtained in both dynamic and steady-states.

**Keywords :** MPPT (Maximum Power Point Tracking), P&O (Perturb and Observe), PV (Photovoltaic), Boost Converter

## I. INTRODUCTION

Solar energy is one of the most important renewable energy sources. Compared to conventional non renewable resources such as gasoline, coal, etc., solar energy is a good choice for electric power generation, it is quite, clean and reliable. It does not cause pollution and can be installed easily. Among the many applications of PV energy used for solar street lighting, home lighting system, SPV water pumping system etc [1].

The solar energy is directly converted into electrical energy by solar photovoltaic cells. These are made up of silicon cells [2]. When many PV cells are connected in series and parallel combinations they produce solar PV array and module, which is suitable for obtaining higher power application [3]. Constant voltage required to supply the load irrespective of the variation in solar irradiance and temperature. So it is necessary to couple the PV module with a boost converter [4-5]. The energy extracted from the PV module is dependent of the climatic conditions, such module has an optimum operating point, called the Maximum Power Point (MPP), which depends greatly on the intensity of illumination [6]. The adaptation of the PV panels to the load is therefore necessary to extract the PV module maximum power. This is done through the DC-DC energy converters controlled by a control command called Maximum Power Point Tracking MPPT [7].

Maximum Power Point Tracking (MPPT) algorithms have led to increase the efficiency of operation of the solar modules and effective in the field of utilization of renewable sources of energy [8]. Tracking of the maximum power point (MPP) of a photovoltaic (PV) array is generally an necessary part of PV Systems [9]. There are Several different technique for maximum power point tracking, among them Perturb and Observe (P & O) are mostly used in PV system because of simple implementation [10].

This paper presents a standalone solar PV based boost converter with P & O MPPT techniques. In the proposed system, duty cycle of boost converter is controlled to maintain the DC link voltage at required level.

## II. METHODS AND MATERIAL

### A. System Configuration and Principle of Operation

Fig.1 shows schematic diagram for the stand-alone solar PV based boost converter. The proposed system consists of solar PV panel, a boost converter and MPPT block. An individual PV cell is usually quite small, typically producing about 1 or 2W of power. To increase the power output of PV cells, these cells are connected in series and parallel to assemble larger unit called PV module. The PV array is connected to the DC to DC boost converter to increase the output voltage level. In order to change the input resistance of the panel to match the load resistance (by varying the duty cycle), a DC to DC converter is required. The input of boost converter is connected to PV array and output is connected to load. MPPT block receives $V_{pv}$ and $I_{pv}$ signals from PV array. The output of MPPT block is series of pulses. These pulses are given to boost converter. Converter works based on these pulses to make the PV system operate at Maximum power point (MPP).

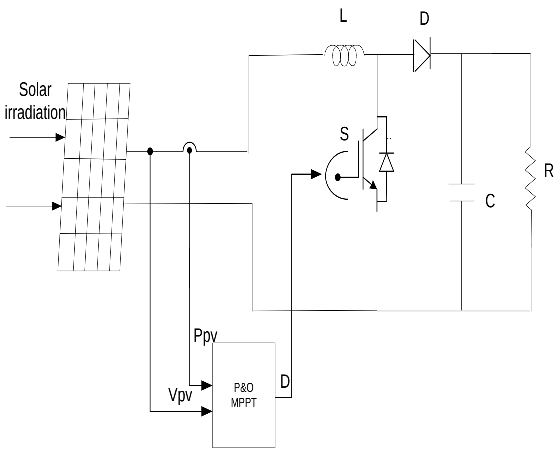


**Figure 1 :** PV based Boost converter

### B. Control Scheme

Fig.1 shows the control scheme for a standalone solar PV based boost converter with MPPT techniques. The control scheme is discussed in two parts, i.e. MPPT controller for extracting the maximum power from the solar PV module and control of boost converter to maintain constant DC link voltage.

- MPPT with boost controller scheme

Perturb and Observe (P&O) is the simplest method. Which is used one sensor, that is the voltage sensor, to sense the PV array voltage. Cost of implementation is less and hence easy to implement. The time complexity of this algorithm is very less but on reaching very close to the MPP it does not stop at the MPP and keeps on perturbing on both the directions. Under this condition algorithm has reached very close to the MPP.

dP/dV = 0, at MPP (1)

dP/dV > 0, left of MPP (2)

dP/dV < 0, right of MPP (3)

Fig. 2 shows the flow chart of perturb & observe method. (P & O) algorithm states that when dP/dV > 0 and the operating voltage of PV array is perturbed in a specific direction, it known that perturbation moves the operating point of PV array to the MPP. P&O method will then continue to perturb the PV voltage in the same direction. When dP/dV <0, the perturbation moves the operating point of PV array away from the MPP and the P&O method reverses the direction of the perturbation[10].

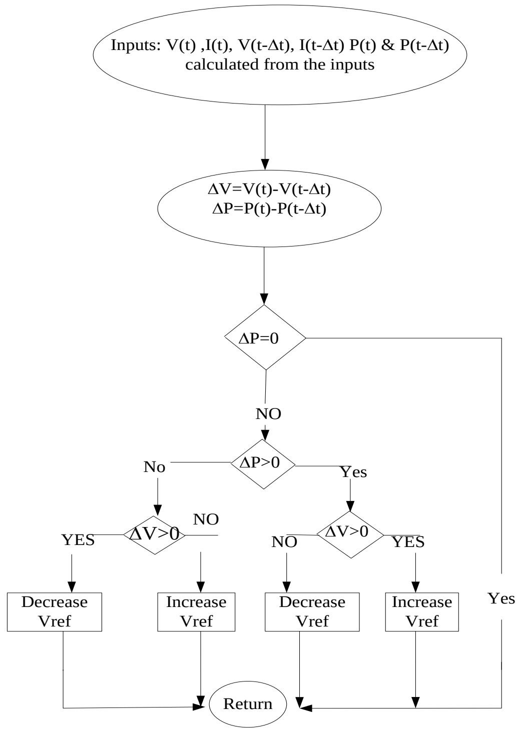


**Figure 2 :** Flowchart of Perturb & Observe algorithm

- Control of Boost Converter

A DC – DC boost converter is used which consists of boost inductor, diode, IGBT used as a switch, capacitance and resistive load. When supply voltage is given, inductor current increases when the switch is closed. When the switch is opened, both inductor voltage and supply voltage gets discharged through the load. Hence a higher voltage at the output is obtained than the given input voltage.
When switch S is closed

$$V_L = V_S \quad (4)$$

$$V_L = V_S = L\frac{di}{dt} \quad (5)$$

$$\frac{di}{dt} = \frac{V_S}{L} \quad (6)$$

Change in inductor current is as,

$$\frac{\Delta i_L}{\Delta t} = \frac{\Delta i_L}{DT} = \frac{V_S}{L} \quad (7)$$

$\Delta i_L$ when switch is closed,

$$\left(\Delta i_L\right)_{closed} = \frac{V_S DT}{L} \quad (8)$$

Inductor voltage when switch S is open

$$V_L = V_S - V_O = L\frac{di}{dt} \quad (9)$$

$\Delta i_L$ for the switch opened

$$\left(\Delta i_L\right)_{opened} = \frac{\left(V_S - V_O\right)\left(1-D\right)T}{L} \quad (10)$$

For steady-state operation

$$(\Delta i_L)_{closed} + (\Delta i_L)_{opened} = 0 \quad (11)$$

$$\Rightarrow V_o = \frac{V_s}{1-D} \quad (12)$$

The average inductor voltage must be zero for periodic operation. Average inductor voltage over one switching period.

$$V_L = V_S D + \left(V_S - V_O\right)\left(1-D\right) = 0 \quad (13)$$

From the equation (12) average output voltage is higher than input voltage.
Input power is Vs Is =Vs $I_L$.
Equating input and output powers and using eq. (12),

$$I_L = \frac{V_s}{\left(1-D\right)^2 R} \quad (14)$$

Average value of inductor current is,

$$V_S I_L = \frac{\left[V_S/\left(1-D\right)\right]^2}{R} = \frac{V_S}{\left(1-D\right)^2 R} \quad (15)$$

$$I_L = \frac{V_S}{\left(1-D\right)^2 R} = \frac{V_O^{\,2}}{V_S R} \quad (16)$$

**C. Matlab Based Modlling Of Pv Based Boost Converter**

*1. PV Module*

A solar cell is the building block of a solar panel. A photovoltaic module is formed by the following equations as,

The current through diode is

$I_D = I_O$ [exp (q (V + I $_{RS}$)/$K_T$) – 1] (17)

While, the solar cell output current is,

$I = I_{ph} – I_D – I_{sh}$ (18)

$I = I_{ph} – I_O$ [exp (q(V + I $_{RS}$)/$K_T$)) – 1] – ( V + $I_{RS}$ )/ $R_{sh}$ (19)

Where,
I : Solar cell current (A), $I_{ph}$ : Photo current (A), Io : Diode saturation current (A), q : Electron charge (1.6×10-19 C), K: Boltzmann constant (1.38×10-23 J/K), T:Cell temperature in Kelvin (K), V : Solar cell output voltage (V), Rs : Solar cell series resistance (Ω), $R_{sh}$ : Solar cell shunt resistance.

*2. Boost Converter*

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 load and the module. 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. Basic equations of boost converter are as follows,

$$V_{pv} t_{on} = \left(V_{out} - V_{pv}\right) \cdot t_{off} \quad (20)$$

$$V_{off} = \frac{t_{on}}{t_{on} + t_{off}} V_{pv} \quad (21)$$

$$T = t_{on} + t_{off} \quad (22)$$

The $t_{on}/t_{off}$ is a duty cycle $\alpha$ and therefore

$$\alpha = \frac{t_{on}}{t_{off}} \quad (23)$$

From equation (23), the voltage can be derived

$$V_{out} = \frac{1}{1-\alpha} V_{pv} \quad (24)$$

The value of a boost inductor L is given as,

$$L = \frac{V_{pv} D}{2 * \Delta i * f_{sw}} \quad (25)$$

Where D is duty cycle, $V_{pv}$ is output voltage of PV array, $f_{sw}$ is switching frequency, Δi is ripple in output current of PV array.

A MATLAB simulated model of PV system with boost converter shown in Fig.3. By using this model, maximum power of PV system has been observed.

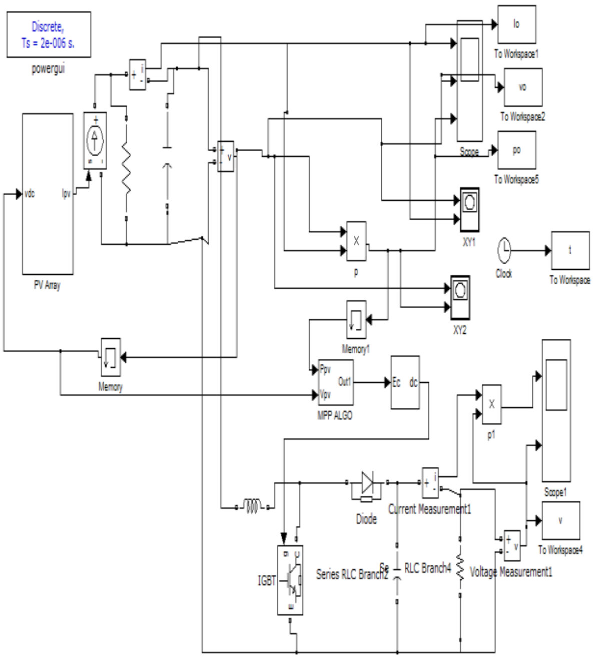

**Figure 3:** MATLAB simulated modal of PV based boost converter

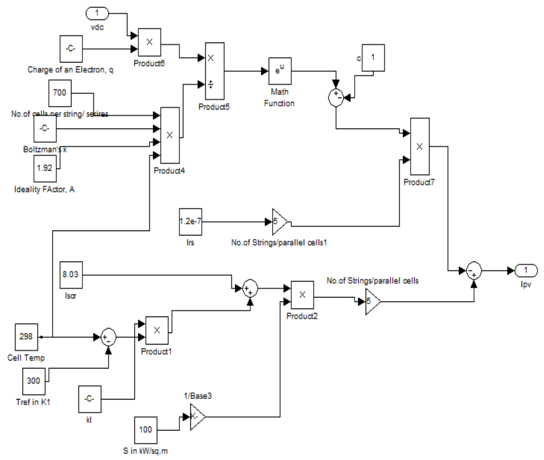

**Figure 4 :** Unmasked block diagram of the modeled solar PV panel

## III. RESULTS AND DISCUSSION

The model of standalone PV based system with boost converter is developed in MATLAB/SIMULINK environment. The performance of PV is evaluated and observed current ($I_{pv}$), voltage ($V_{pv}$), power ($P_{pv}$), Dc link voltage ($V_{dc}$), power-voltage (P-V) characteristics and current-voltage (I-V) characteristics.

### *A Starting Performance of PV System with Boost Converter*

Fig.5 shows the starting performance of standalone PV with boost converter. It is observed that at starting 0.1s DC link voltage is maintained constant and ripple free. PV system achieves maximum power in 10 ms.

### *B Steady State Performance of Standalone PV Based Boost Converter*

Fig.6 shows the steady state performance of PV system with boost converter. It is observed that, PV current and DC link voltage is maintained constant and ripple free.

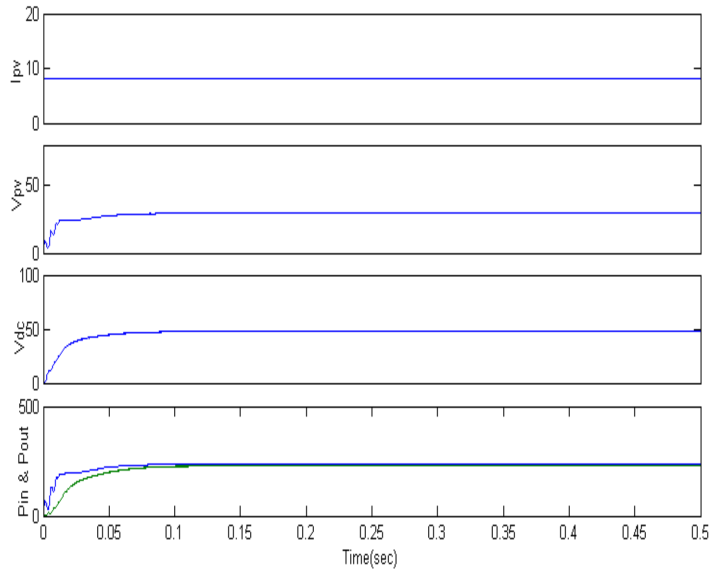


**Figure 5 :** Starting performance of standalone PV based boost converter

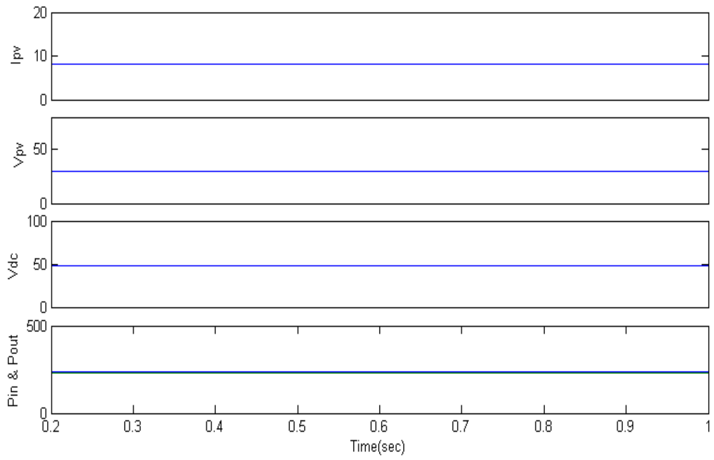


**Figure 6 :** Steady State Performance of Standalone PV based boost converter

## IV. CONCLUSION

In this paper, the photovoltaic system with maximum power point controller has been developed; a mathematical model of the PV has been also presented. Obtained $I_{pv}$, $V_{pv}$ and $P_{pv}$ from PV array. PV array depend on the irradiation level and temperatures. The system has been simulated with MATLAB - Simulink environment using simpower toolbox.

The results obtained from simulation employing P & O approach show the effectiveness of the proposed power tracking and control strategies with quick power tracking response.

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