

Simulation of P & O Algorithm using Boost Converter

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Abstract: Solar energy is most popular amongst the renewable energy sources. The reason being, the solar panels are modular in nature, has long life with non-moving parts and the time for commissioning is less compared to other sources. Like other renewable energy sources it is intermittent in nature and the output power induced in the photovoltaic modules is influenced by the intensity of solar radiation and temperature of solar cells. It is necessary to track the maximum power point of the input source. In this paper, a maximum power point tracker(MPPT) using perturb and observe algorithm is proposed to improve energy conversion efficiency with boost converter. The system is consisting of solar module, boost converter and resistive load simulated using PSIM software.

Keywords: photovoltaic (PV) system; maximum power point tracking system (MPPT); perturb and observe algorithm (P&O); PSIM; Boost converter.

I. INTRODUCTION

Solar energy generated from Photovoltaic effect has become increasingly important as Renewable source because of ubiquity, large quantity and sustainability of solar energy. It offers many advantages as incurring no fuel cost, less maintenance, pollution free and emitting no noise among others. [1]

The output characteristic of PV (photovoltaic) module mainly depends on intensity of solar radiation, cell temperature and the output voltage of the PV module. Since PV module has non-linear characteristic output it is necessary to model it for the design and simulation of PV system applications. [3] Maximum utilization of power is of special interest as the efficiency of the module is very low, hence maximum power point tracking system (MPPT) is incorporated. Many MPPT algorithms are available,[2]-[4],[9] of which perturb and observe (P&O) is most simple which moves operating point towards maximum power point periodically by increasing or decreasing PV voltage.

In this paper the P & O (perturb and observe) MPPT algorithm has been simulated along with boost converter for maximum utilization of available power using PSIM software. Fig 1 shows the block diagram of the system used for simulation. E is solar irradiance and T is cell temperature. MPPT block is realized using c block available in PSIM.

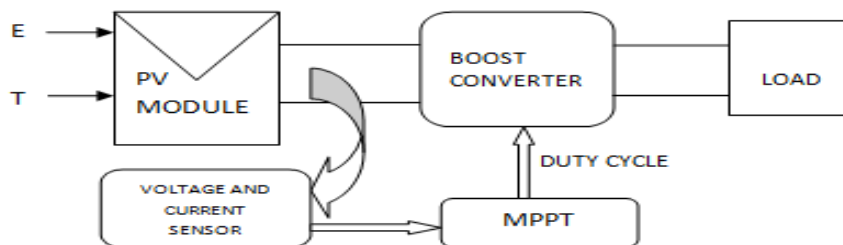


Fig. 1 block diagram of the system

The paper is organized in following manner in section I Introduction, Section II modelling of PV module, Section III Boost converter, Section IV MPPT tracking, Section V Simulation model and Results, and Section VI concludes the paper.

II. MODELLING OF PHOTOVOLTAIC MODULE

The photovoltaic (PV) system can generate direct current electricity when exposed to sunlight. The basic building block of PV module is the solar cell, which is basically a p-n semiconductor junction as shown in Fig.2. The V-I characteristic of a solar cell is given by Eq. (1)

$$I = I_{ph} - I_o \left(e^{\frac{q(v+I \times R_s)}{n \times k \times T}} - 1 \right) - \frac{v+I \times R_s}{R_{sh}} \quad (1)$$

Where:

V and I represent the output voltage and current of the solar cell respectively.

R_s and R_{sh} are the series and shunt resistance of the cell.

q: the electron charge, 1.6×10⁻¹⁹C;

I_o: the reverse saturation current;

I_{ph}: Light-generated current;

T: cell temperature in Celsius;

n, k: Ideality constant and Boltzmann's constant, 1.38×10⁻¹⁹ J/k;

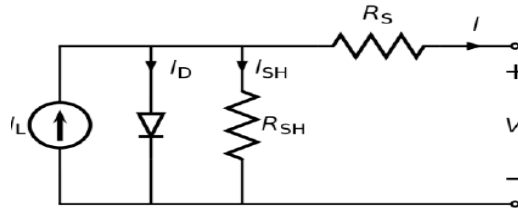


Fig. 2: Equivalent circuit of a solar cell

III. BOOST CONVERTER

The boost converter is used to get controlled dc output from the unregulated dc input by adjusting duty cycle. The boost converter connected to solar panel and the resistive load is illustrated in fig.3. The duty cycle of the converter is given by equation 2. The typical waveform of boost converter is illustrated in fig.4.

$$\text{Duty cycle } D = 1 - \frac{V_{in}}{V_{out}} \quad (2)$$

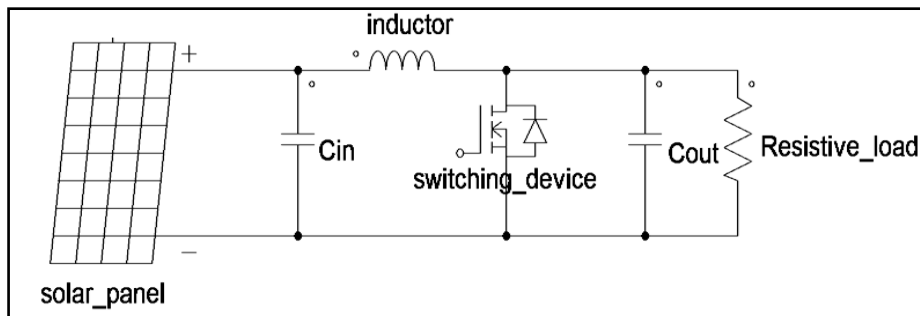


Fig. 3. Boost converter [1]

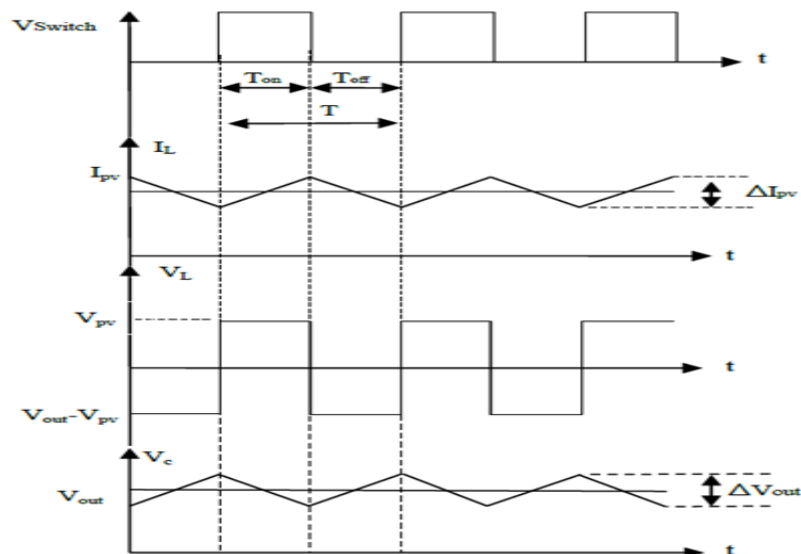


Fig. 4 waveform of boost converter

IV. MPPT TRACKING

To increase the utilisation of solar panel MPPT (maximum power point tracking) method is used. Here the maximum power is extracted from the module and transferred to the load. Interfacing device used is DC/DC converter wherein, by changing duty cycle, load impedance is varied to match with source impedance for extraction of maximum power. The impedance matching is given by equation 3. where R_{eff} is effective resistance of module.

$$R_{eff} = \frac{V_{in}}{I_{in}} = \frac{(1-D^2) \times V_{dc}}{I_{dc}} = (1 - D^2) \times R_{load} \quad (3)$$

PERTURB & OBSERVE TECHNIQUE is used because of its ease in implementation. The advantage is, the circuitry used for the method is simple and requires only two sensors. The algorithm is generated by perturbing a small increment in voltage of PV and observing resultant change in power. If ΔP is positive, then perturbation will lead towards maximum power point and if ΔP is negative, then operating point has moved away from maximum point. Hence the perturbation should be reversed to return back to the maximum point. [4]-[9] The flow chart P&O technique as in [4] has been shown in Fig 5 wherein voltage perturbation is corresponding to change in duty cycle.

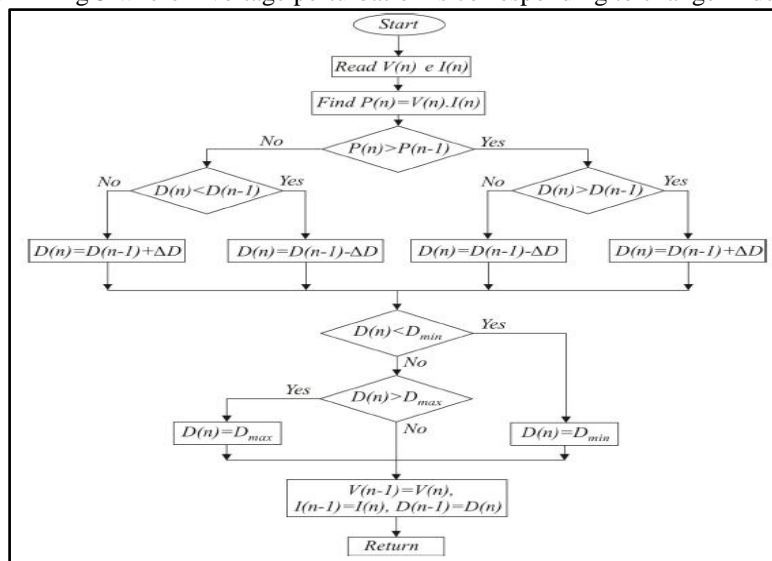


Fig. 5 flowchart of P&O algorithm

V. SIMULATION MODEL AND RESULTS

A. The Model

Simulation of proposed model is carried out in PSIM. PSIM is designed for fast simulation and friendly user interface. First physical model of solar module is designed using panel specification in solar module utility available in powersim as shown in fig 6. and the simulation of boost converter is carried out using resistive load with MPPT in PSIM as shown in fig.7. The PV panel output voltage is boosted to 24V DC by using boost converter. P&O algorithm is implemented in C block as per flowchart shown in fig.5. Low pass filters are used for filtering output voltage and current of PV.

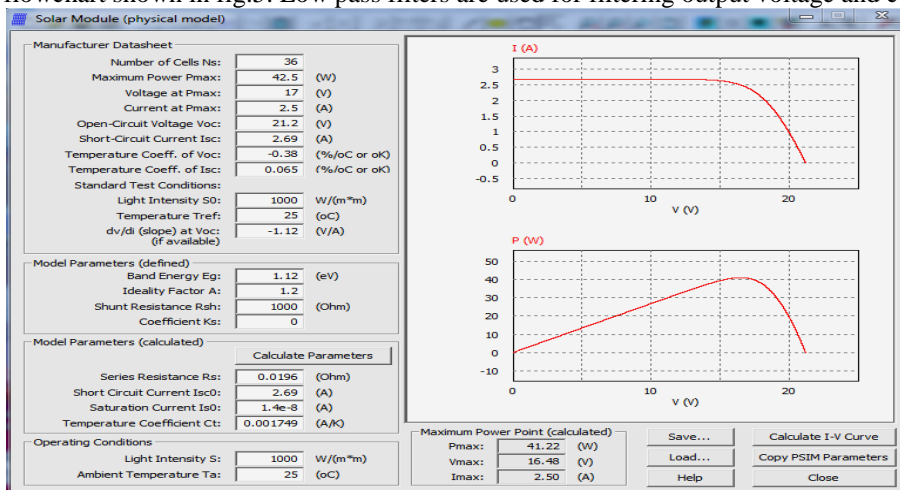


Fig. 6: physical model of PV module in PSIM

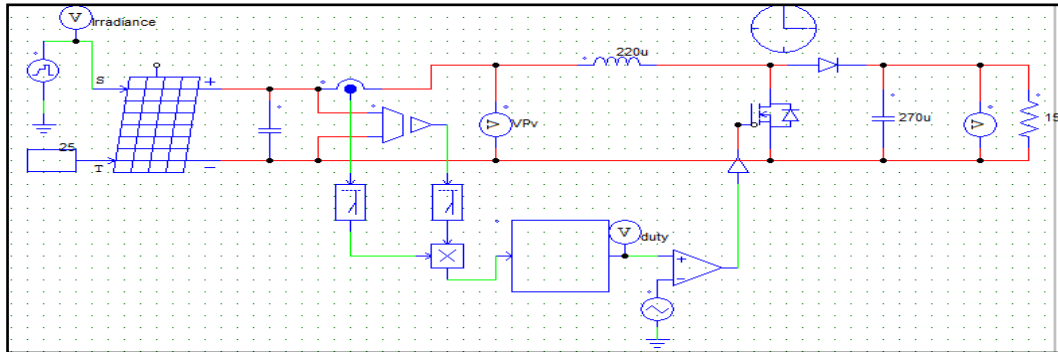


Fig. 7. Simulated circuit for MPPT system in PSIM

B. Specifications of PV panel and Boost converter

The PV module used is TBP1240 M. the specification for panel and ratings of boost converter are shown in table I&II respectively.

TABLE I. PANAEL SPECIFICATION

Pn(nominal)	Pm(minimum)	Nominal output voltage	No. of cell	Open circuit voltage, Voc	Short circuit current, Isc
40	37	12+	36	21.2	2.69

TABLE II. CONVERTER SPECIFICATION

Parameters	Values
Input voltage, Vin	10V to 22V
Maximum output voltage, Vout	24V
Load resistance, R	14 ohm
Switching frequency ,Fs	25 kHz
Inductor value, L	220uH
Capacitor value, C	270 uF
Input capacitor,Cin	15uF
Dmax	0.583

C. Waveforms showing simulated output for different irradiance and temperature levels

The model circuitry is simulated for different irradiance [1000w/m^2 ; 600w/m^2 ; 800w/m^2] and cell temperature [25; 45; 60 degrees] levels as shown in below figures. Simulated results for output power without MPPT is shown in fig.8 for 0.5 duty cycle and with MPPT algorithm is shown in fig. 9 onwards. It can be seen that the algorithm can efficiently track the output power to give maximum outputs at different irradiance and temperature.

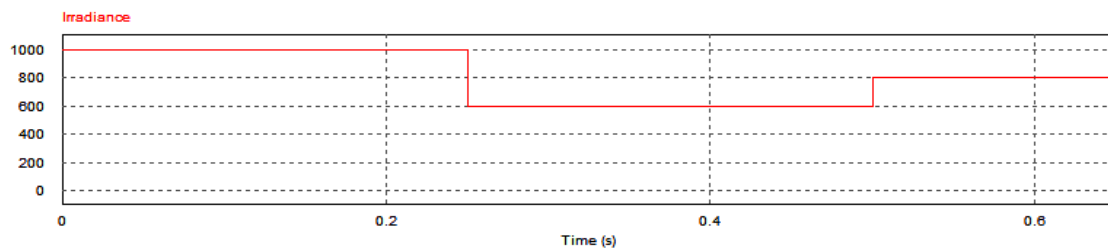


Fig. 8. Irradiance levels during simulation with time [1000w/m^2 ; 600w/m^2 ; 800w/m^2]

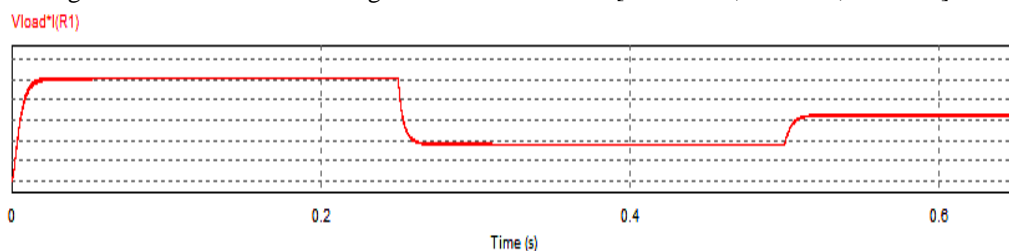


Fig. 9 Output power for different irradiance at 0.5 duty cycle without MPPT

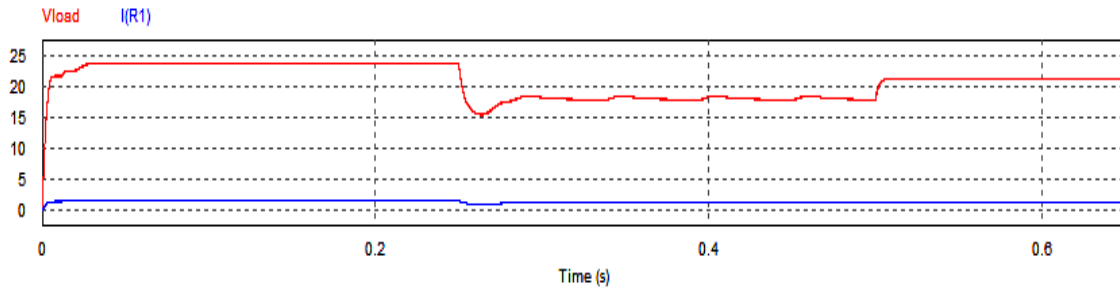


Fig. 10: Output voltage and current with MPPT for different irradiance level at 25 degrees

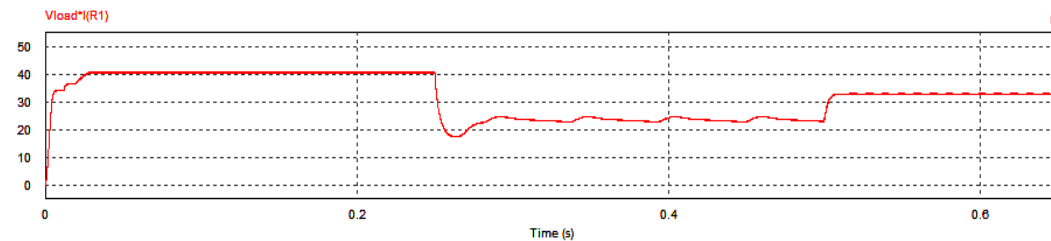


Fig. 10: Output power with MPPT for different irradiance level at 25 degrees

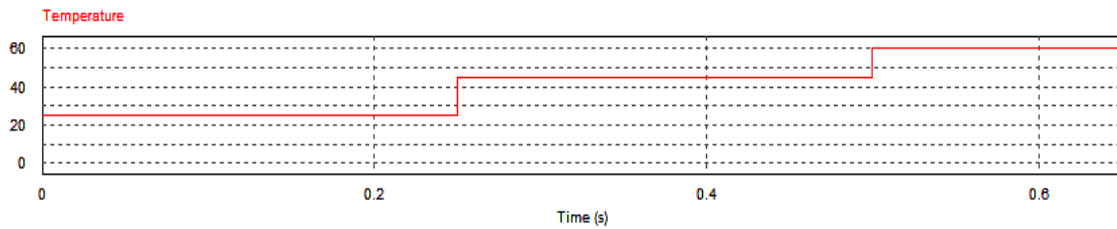


Fig. 11: Temperature levels with time [25;45;60] in degrees

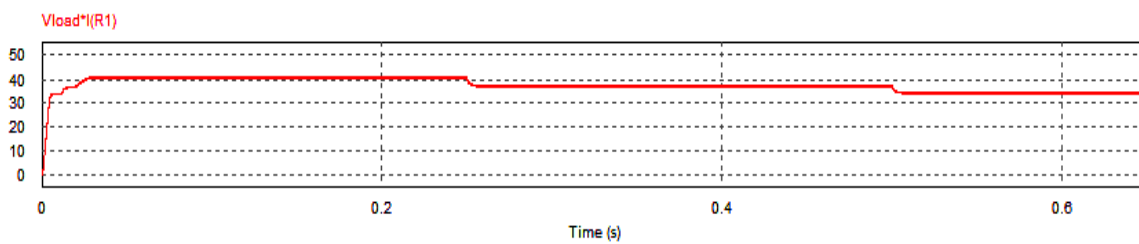


Fig. 12: Output power with MPPT for different temperature [25;45;60] in degrees at 1000w/m²

D. Comparison with theoretical outputs

Comparisons of theoretical and simulated results at 25 degrees are shown in table III. Theoretical calculations of output power are obtained with FF of 0.74 and efficiency of cell as 13%.

TABLE III. Comparison of theoretical and simulated output power for different irradiance

Irradiance W/m ²	Theoretical output power(W)	Simulated output power (W)
1000	41.6	40.93
800	33.28	33.11
600	24.96	24.73

VI. CONCLUSION

This paper presents simulated output of P&O algorithm using PSIM software with boost converter as power conditioning unit and also results at constant duty cycle of 50%. The result also shows the effect of variation in temperature and irradiance on output power. It is noticed that output power decreases with corresponding increase in cell temperature and decrease in irradiance level. The results were verified by comparing simulated results with theoretical calculations. The system is capable of tracking the PV module to get maximum available power.

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