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# Boost Converter based Photovoltaic Energy System–Design and Simulation

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**Abstract—***The studies on the photovoltaic system are extensively increasing because of a large, secure, essentially exhaustible and broadly available resource as a future energy supply. The output power induced in the photovoltaic modules is influenced by an intensity of solar cell radiation, temperature of the solar cells. Though Photovoltaic power generation system implements an effective utilization of solar energy, but generally it has very low conversion efficiency. Therefore, Maximum power point tracking (MPPT) is used in photovoltaic (PV) systems to maximize the photovoltaic array output power, irrespective of the temperature and irradiation conditions and of load electrical characteristics. In this paper utilization of a boost converter for control of photovoltaic power using Maximum Power Point Tracking (MPPT) control mechanism is presented. The photovoltaic module is analyzed using SIMULINK software. The simulation results show that the proposed MPPT control can avoid tracking deviation and result in improved performance in both dynamic response and steady-state.*

## 1. INTRODUCTION

In the recent years, with the growth in population, the demand for electrical energy has also increased. As a result, the research has been extended to generating power from solar energy. The key element required for producing electricity from sun is the solar panel or photovoltaic panel (PV panel). Photovoltaic (PV) sources are used today in many applications from satellite power systems to battery chargers and home appliances. PV is an important green energy source because it has the advantages of being pollution free, low maintenance, with no noise or wear due to the absence of moving parts.

Usually, when a PV module is directly connected to a load, the operating point is rarely at the maximum power point or MPP. Thus tracking the maximum power point (MPP) of a photovoltaic (PV) array is usually an essential part of a PV system. A converter is therefore required to produce a constant voltage that is matched to the requirements of the load and supplied efficiently. A MPPT is used for extracting the maximum power from the solar PV module and transferring that power to the load. 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. Therefore, a MPPT technique is required to obtain maximum power from a PV system. A maximum power point tracker (MPPT) is a system that directs the converter to track the maxi- mum power of a solar panel and deliver it to load Photovoltaic (PV) sources.

MPPT is used in photovoltaic (PV) systems to maximize the photovoltaic array output power, irrespective of the temperature and radiation conditions and of the load electrical characteristics with the use of DC-DC converter like buck converter, boost converter and buck-boost configurations. Maximum Power Point Tracking, frequently referred to as MPPT, is an electronic system that operates the Photovoltaic (PV) modules in a manner that allows the modules to produce all the power they are capable of. Many tracking algorithms and techniques have been developed. The Perturbed and Observed method [1] and the Incremental Conductance method [2], as well as variants of those techniques [3, 4] are the most widely used. The Perturb and Observe method is known for its simple implementation, but it deviates from and observe method oscillates close to a maximum power point (MPP) in the atmospheric conditions are constant or slowly changed.

## 2. BASIC BLOCK DIAGRAM

The basic block diagram is as shown in **fig. 1**. It consists of Solar panel, DC-DC power converter, MPPT controller, Load. Initially voltage and current from the solar panel is sensed by using voltage and current sensor. These voltage and current values can be input to the MPPT controller. The output of MPPT block is used as input to DC-DC converter which may be voltage parameter or duty cycle.

DC-DC converter helps in maintaining the operating voltage at the maximum power point, by varying the duty cycle of DC-DC converter. Usually Buck, Boost, Buck- Boost configuration is used according to requirement. In this paper Boost converter is used to step up the operating voltage at the maximum power point. DC-DC power converter is connected between the solar panel and load.

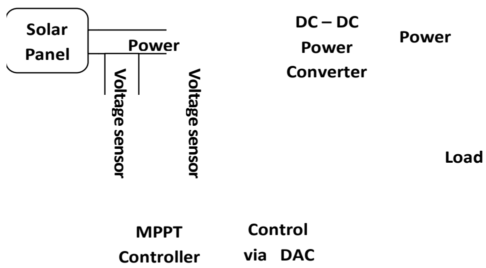


**Fig. 1: Basic Block Diagram**

DC-DC power converter is connected between the solar panel and load. The voltage and current values can later be proceed according to MPPT algorithms, which in turn gives gating signal to Boost converter.

## 3. MODELING OF PV CELL

Solar cell convert sunlight directly to dc power. Photovoltaic cell generates electricity from the sun. PV panel works under the phenomenon of photoelectric effect. When solar cell are exposed to sunlight , it converts solar energy into electrical energy. The system configuration for the topic is as shown **fig. 2**.

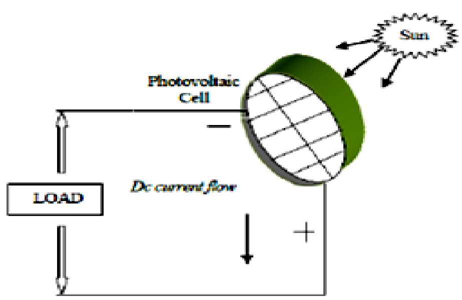


**Fig. 2: Photovoltaic Cell [6]**

Here the PV array is a combination of series and parallel solar cells. This array develops the power from the solar energy directly and it will be changes by depending up on the temperature and solar irradiances.

**Fig. 3** shows the equivalent circuit of the general model which consists of a photo current, a diode, a parallel resistor expressing leakage current, and a series resistor describing an internal resistance to the current flow in the circuit. [5]

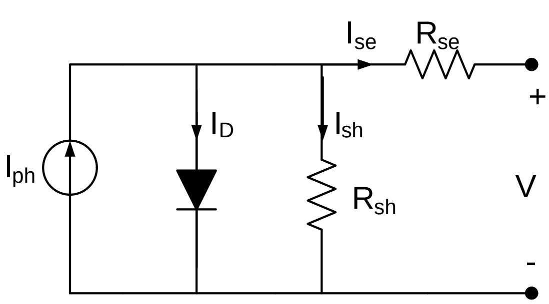


**Fig. 3: Equivalent Circuit of PV Cell**

A solar panel cell basically is a p-n semiconductor junction. When exposed to the light, a DC current is generated. The generated current varies linearly with the solar irradiance [9].

The I-V characteristics of the equivalent solar cell circuit can be determined by following equations [9]. The current through diode is given by:

$$I_D = I_0\left[\exp\left(q\left(V + IR_{se}\right)/KT\right) - 1\right] \qquad (1)$$

While, the solar cell output current:

$$I_{se} = I_{ph} - I_D - I_{sh} \qquad (2)$$

$$I_{se} = I_{ph} - I_0\left[\exp\left(q\frac{V + IR_{se}}{KT}\right) - 1\right] - \left(\frac{V + IR_{se}}{R_{sh}}\right) \qquad (3)$$

where,

$I_{se}$ : Cell current (A).

$I_{ph}$ : Light Generated Current (A).

$I_0$ : Diode Saturation Current.

Q : Charge of Electron = 1.6x10-19 (Coul).

K : Boltzmann Constant (J/K)

V : Cell Output Voltage (V)

$R_{se}$ , $R_{sh}$ : Cell Series and Shunt Resistance (Ohms).

## 4. ROLE OF MPPT IN PV SYSTEM

The efficiency of a solar cell is very low. In order to increase the efficiency, methods are to be undertaken to match the source and load properly. One such method is the Maximum Power Point Tracking (MPPT). This is a technique used to obtain the maximum possible power from a varying source. In photovoltaic systems the I-V curve is non-linear, thereby making it difficult to be used to power a certain load. This is done by utilizing a boost converter whose duty cycle is varied by using a MPPT algorithm.

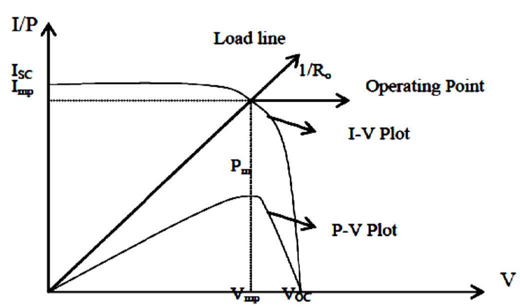


**Fig. 4: Maximum power point**

The point at which $I_{mp}$ and $V_{mp}$ meet is the maximum power point as shown in **fig. 4**. This is the point at which maximum power is available from the PV cell. If the “load line“ crosses this point precisely, then the maximum power can be transferred to this load.

## 5. MPPT TECHNIQUES

There are many methods used for maximum power point tracking a few are listed below

- Perturb and Observe method
- Incremental Conductance method
- Constant Voltage method
- Constant Current method

## 6. PERTURB AND OBSERVE METHOD

The Perturb and Observe(P&O), as the name itself states that the algorithm is based on the observation of the array output power and on the perturbation (increment or decrement) of the power based on increments of the array voltage or current. In this method a slight perturbation is introduce system. This perturbation causes the power of the solar module changes. If the power increases due to the perturbation then the perturbation is continued in that direction. After the peak power is reached the power at the next instant decreases and hence after that the perturbation reverses. When the steady state is reached the method oscillates around the peak point. In order to keep the power variation small the perturbation size is kept very small. [7] [8]

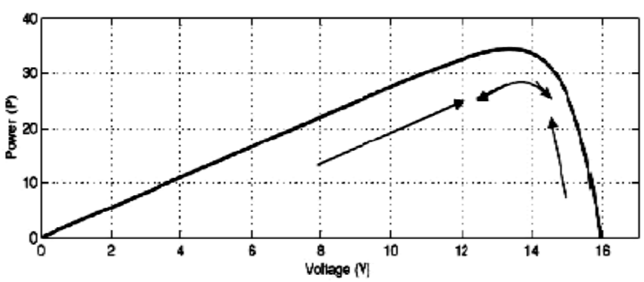


**Fig. 5: P-V characteristic for P&O Algorithm**

The logic of this algorithm and the flowchart are explained in Fig. 5. The operating voltage of the PV system is perturbed by a small increment of ΔV, and this resulting change in ΔP. If ΔP is positive, the perturbation of the operating voltage needs to be in the same direction of the increment. On the contrary, if ΔP is negative, the obtained system operating point moves away from the MPPT and the operating voltage needs to move in the opposite direction of the increment.[9]

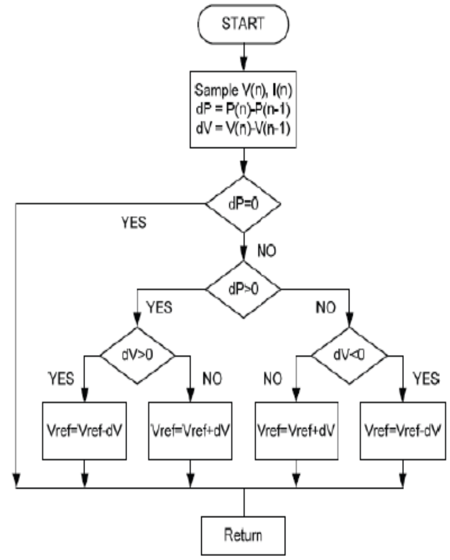


**Fig. 6: Flow chart of Perturb and Observation algorithm**

## 7. BOOST CONVERTER AND ITS OPERATION

The fig. 7 shows a step up or PWM boost converter. It consists of a dc input voltage source Vg , boost inductor L , controlled switch S, diode D , filter capacitor C , and the load resistance R. When the switch S is in the on state , the current in the boost inductor increases linearly and the diode D is off at that time. When the switch S is turned off, the energy stored in the inductor is released through the diode to the output RC circuit.

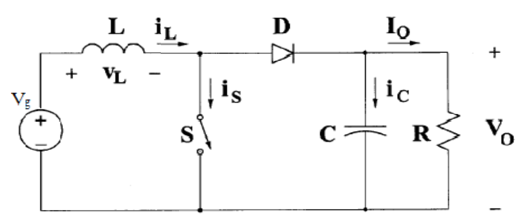


**Fig. 7: Circuit diagram of boost converter**

## 8. MODE I : CHARGING MODE

When the switch is closed the inductor gets charged through the battery and stores the energy. In this mode inductor current rises (exponentially) but for simplicity we assume that the charging and the discharging of the inductor are linear. The diode blocks the current flowing and so the load current remains constant which is being supplied due to the discharging of the capacitor.

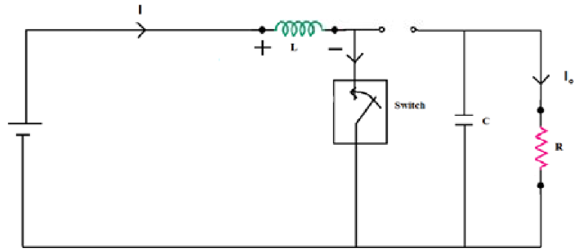


**Fig. 8: Mode 1 operation of Boost Converter**

## 9. MODE II : DISCHARGING MODE

In mode 2 the switch is open and so the diode becomes short circuited. The energy stored in the inductor gets discharged through opposite polarities which charge the capacitor. The load Current remains constant throughout the operation. The waveforms for a boost converter are shown in **fig. 9**

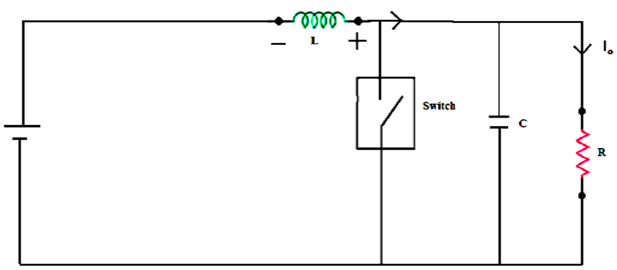


**Fig. 9: Mode 2 operation of Boost Converter**

## 10. SIMULATION OF PV PANEL USING

The equivalent circuit of PV cell shown in fig. 3, in view that the current to the load given by equation 3 i.e.

$$I_{se} = I_{ph} - I_0 \left[ \exp\left( q \frac{V + IR_{se}}{KT} \right) - 1 \right] - \left( \frac{V + IR_{se}}{R_{sh}} \right)$$

As a result, the complete physical behavior of the PV cell is in relation with Iph, Ise, Rse and Rsh from one hand and with two environmental parameters as the temperature and the solar radiation from the other hand.

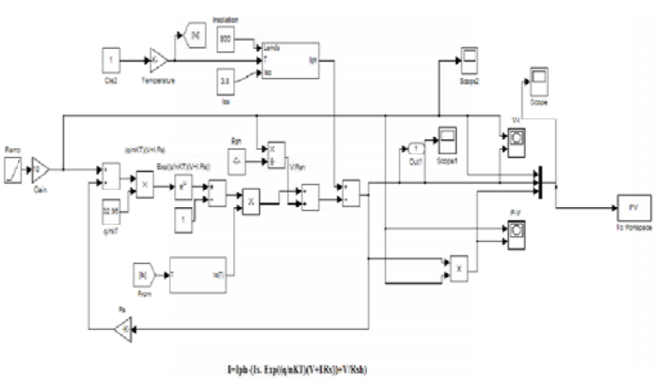

**Fig. 10: Simulation of PV panel**

Based on equation (3), the Matlab/SIMULINK model of Fig. 3.4 was developed. For a given radiation, temperature, Rs and Rsh ,the I-V P-V curves are generated.

## 11. SIMULATION RESULT OF PV PANEL

➢ **I-V Characteristics of PV Panel :**

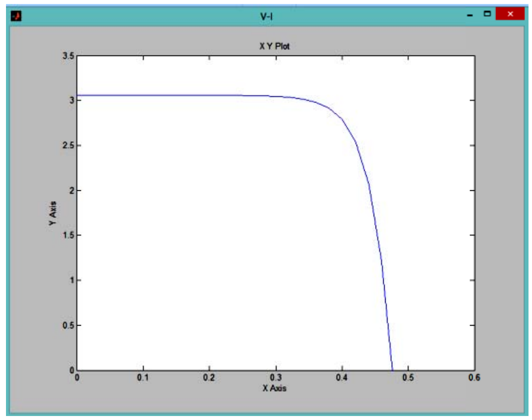


**Fig. 11: I-V characteristics of PV panel**

The I-V characteristic of panel is shown in fig. 11 above. The Voltage V is plotted on x- axis and Current I is plotted on y-axis. as we are seeing that there is one maximum point where the panel will provide maximum power output .since in a day there is not constant sunlight hence the voltage and current values changes accordingly.

➢ **P-V Characteristics of PV Panel:**

The P-V characteristic of panel is shown in fig. 12. The Voltage V is plotted on x- axis and Power is plotted on y- axis. as we are seeing that there is one maximum point where the panel will provide maximum power output .since in a day there is not constant sunlight hence the voltage and current values changes and also changes the power output.

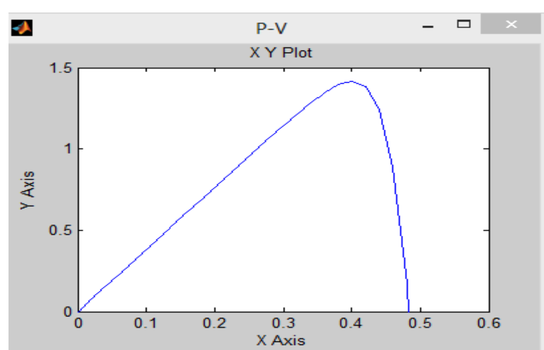


**Fig. 13 P-V characteristics of the PV Panel**

## 12. SIMULATION OF BOOST CONVERTER

Boost Converter is DC to DC Converter with an output voltage greater than the source voltage. The main aim here is to attain maximum output as much we can get from the DC. The simulation circuit is shown in fig. 11

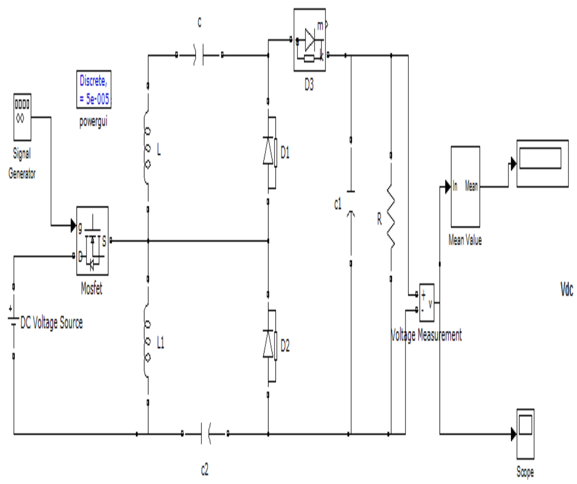


**Fig. 11: Simulation Design of Boost Converter**

The parameters values Vs = 15V, L=1e$^{-3}$H, C1=C2= 47e$^{-6}$ F, C3=220e$^{-6}$F, R $_{load}$=400 ohms, V$_o$= 56 V. Simulation of boost converter consist of DC input voltage source, MOSFET switch,2 inductor ,3 capacitor and 3 diode. We connect the scope to verify the result and signal generator to give pulses for the circuit and Finally, Powergui. The purpose of project is to develop DC to DC converter(Boost). The boost converter will able to boost the 15 V input to 56 V.

## 13. OUTPUT WAVEFORM OF BOOST CONVERTER

The output waveform of boost converter is shown in fig. 15. On the x-axis is time t and on the y-axis is output voltage V. The input given to the boost converter is 15 V and output voltage is 55.64. i.e approximately 56 V.

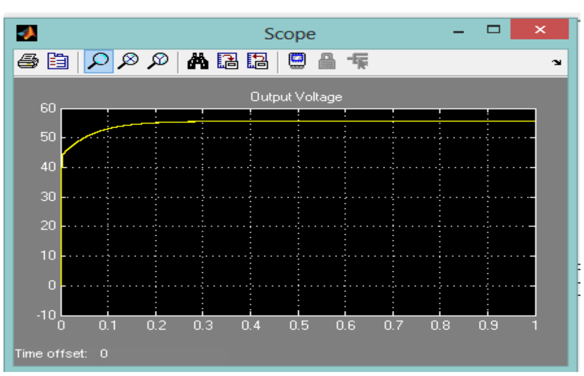


**Fig. 15: Output Waveform of Boost Converter**

## 14. CONCLUSION

The proposed model is established in SIMULINK software, and output characteristics of photovoltaic array is studied and analyzed. Mainly perturb and observation MPPT algorithm is used to obtain the maximum power point of solar array. Boost converter is used to obtain this maximum power point which helps in step down the array voltage to the maximum operating point voltage. So by using MPPT algorithm and boost converter solar array is operated at maximum power point irrespective of solar irradiance.

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