SIMULATION OF PERTURB & OBSERVE MPPT TECHNIQUE USING SEPIC CONVERTER

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Abstract
Solar energy is becoming one of the most popular resources in the field of renewable energy (RE). The reason for its popularity is reliability i.e. continuously available throughout the year. And also the solar panels are modular in nature and the cost of energy is less when compared to other conventional resources. Like other renewable energy sources it is intermittent in nature and the output power induced in thephotovoltaic modules is influenced by the intensity of solar radiation and temperature of solar cells. It is necessary to track the maximum power during the irradiation changes. This paper proposes the perturb and observe (P&O) Maximum power point tracking (MPPT) algorithm to improve the conversion efficiency of single ended primary Inductor converter (SEPIC). The system consisting of solar modules and SEPIC converter and resistive load is simulated by MATLAB/Simulink software.

Keywords: *Photovoltaic (PV) System, Maximum power point tracking (MPPT), Perturb and observe algorithm (P&O), MATLAB, SEPIC 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 SEPIC converter for maximum utilization of available power using MATLAB software. Fig 1 shows the block diagram of the system used for simulation. E is solar irradiance and T is cell temperature.

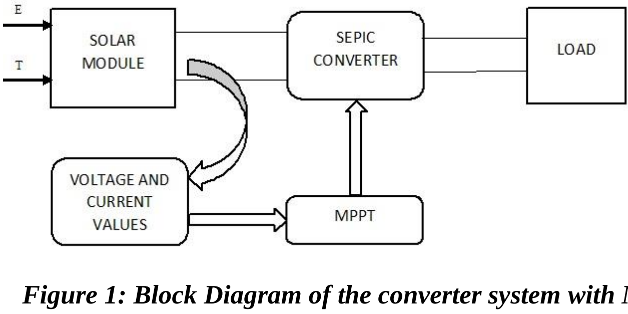


Figure 1: Block Diagram of the converter system with MPPT

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

II. PV GENERATION IN DISTRIBUTION SYSTEMS

Although PV panel cost has been continuously declining as a result of PV technology advances, it is still relatively expensive compared to conventional energy sources. In many countries, the installation of PV generation systems is driven by government grant and it is still an efficiency driven market due to the high cost. Therefore, efficiency and cost are the most important driving factors in the PV market [10], [11]. The centralized inverter architecture has been widely employed due to its high efficiency and low cost. The efficiency of the PV power circuit is relatively high and the cost per watt is reduced due to its high power capacity. However, mismatch between panels caused by partial shading and panel characteristic differences makes it difficult to achieve individual maximum power point tracking (MPPT) for each PV module [12].However, the structure is not suitable for applications such as residential rooftop or BIPV generation system due to the partial shading problem and safety issues of high voltage wiring [13].

2.1 Mathematical model of PV module

The solar cell can be seen as a current generator which generates current I_L. The dark current flows in the opposite direction and is caused by a potential between the + and – terminals. The series resistance (R_s) is caused by the fact that solar cell is not a perfect conductor. The shunt resistance (R_{sh}) is caused by leakage of current from one terminal to the other due to poor insulation, for example on the edges of the cell. In an ideal solar cell, Rs=0 and R_{sh}=∞. The simplified equivalent circuit of solar PV cell is shown in Figure 2.

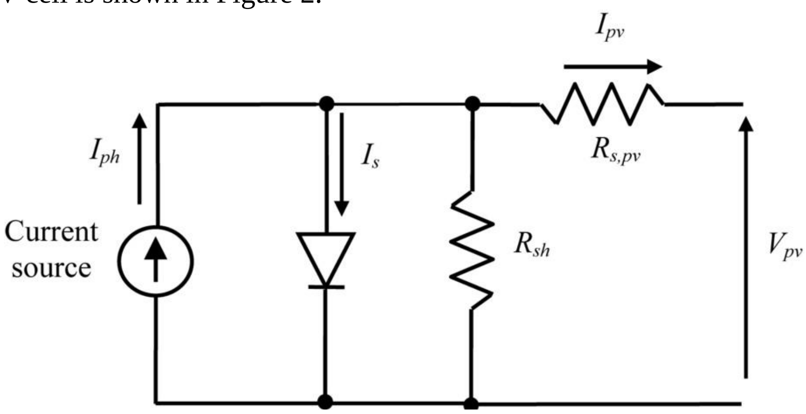


Figure2: Equivalent circuit of PV cell

The characteristic equation of Photovoltaic cell is

$$I = I_{pv} - I_s \left\{ \exp\left(\frac{q(V + IR_s)}{AkT_c} \right) - 1 \right\}$$

$$I = I_L - I_d - I_{sh}$$

Where,

I = Output current of PV panel (A)

I_L =Current generated by PV cell (A)

I_D =Current through diode (A)

I_{sh}=Current through shunt resistor (A)

R_s =Series Resistance(R)

Q =Electron charge (1.6 x 10-19C)

K=Boltzmann’s constant (1.381 x 10-23J/K)
T=Junction temperature (K)
N=Diode ideality factor (1~2)
The PV cell power is

$$I = I_L - I_d - I_{sh}$$

Where, V=Output voltage of PV panel
I =Output current of PV panel

2.2 *PV panel specifications and design calculation*

Table 1: Parameters of PV Module

PARAMETERS	VALUES
R_s	0.62 Ω
I_s	2.54 A
R_{sh}	250.57 Ω
V_{oc}	24 V
I_g	1.13 A
T_c	298

Table 1 shows the Parameters for the Solar PV panel. From the specifications the experimental operation had been done.

III. SEPIC CONVERTER

The power circuit of a traditional SEPIC converter is shown in Fig. 3. The step-up and step-down static gains of SEPIC converter is an interesting operation characteristic for wide input voltage applications. The circuit diagram of SEPIC converter is shown in Figure 3.

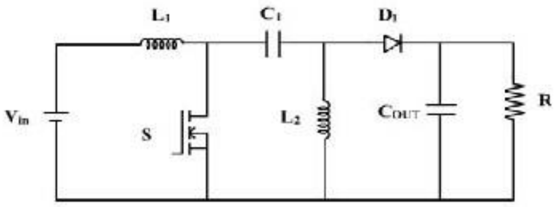


Figure 3: Circuit diagram of SEPIC converter

For the SEPIC, when the pulse is high the MOSFET is on, inductor 1 is charged by the input voltage and inductor 2 is charged by capacitor 1. The diode is off and the output is maintained by capacitor 2. When the pulse is low the MOSFET is off, the inductors output through the diode to the load and the capacitors are charged. The greater the percentage of time (duty cycle) the pulse is low, the greater the output will be. This is because the longer the inductors charge, the greater their voltage will be. However, if the pulse lasts too long, the capacitors will not be able to charge and the converter will fail.

3.1 Design Equations of converter

- Output Voltage Equation

$$V_o = \frac{(D \times V_i)}{(1-D)}$$

Where,
D = Duty Cycle of the converter. V_i = Input Voltage.

- Duty Cycle (D)

$$D = \frac{(V_o + V_D)}{(V_i + V_o + V_D)}$$

- Inductance L

$$L = \frac{(V_i \times D)}{(\Delta I_o \times f)}$$

Where, ΔI_0 = Current ripple of the inductor.
F = Switching Frequency.

- Capacitance (C)

$$C = \frac{(I_o \times D)}{(\Delta V \times f)}$$

Where, I_0 = Output Current. ΔV= Voltage Ripple of the Capacitor. F = Switching Frequency.

Table 2 Rating of converter

PARAMETERS	VALUES
Input voltage	24 V
Output Voltage	48V
Switching Frequency	20kHz
Duty Cycle (α)	0.53
Inductance(L)	127 µH
Capacitance (C)	3900 µF
Resistor	28 Ω

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 Perturb & Observe (P&O) algorithms are widely used in control of MPPT thanks to their simple structure and reduced number of necessary measured parameters. The implementation of P&O method is given in figure 4. As the name implies, the concept behind of this method is based on observation of PV array output power and its perturbation by changing the current or the voltage of PV array operation. The algorithm increments or decrements continuously the reference voltage or current based on the previous value of power until reaches the MPP. 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. Although this method can result in oscillation of power output. It is referred to as a hill climbing method. Because, it depends on the rise of power against voltage below MPP and above MPP.

Figure 5 Shows typical P-V curve at 800 W/m2. On the LHS of the MPP there is linear increase in power with respect to voltage (dP/dV>0). But on RHS of the MPP there is increase voltage with decrease in power (dP/dV<0). So, this P&Oalgorithm will try to maintain the maximum power point byperturbing voltage with respective power. At MPP change inpower with respect to change in voltage is zero (dP/dV=0).

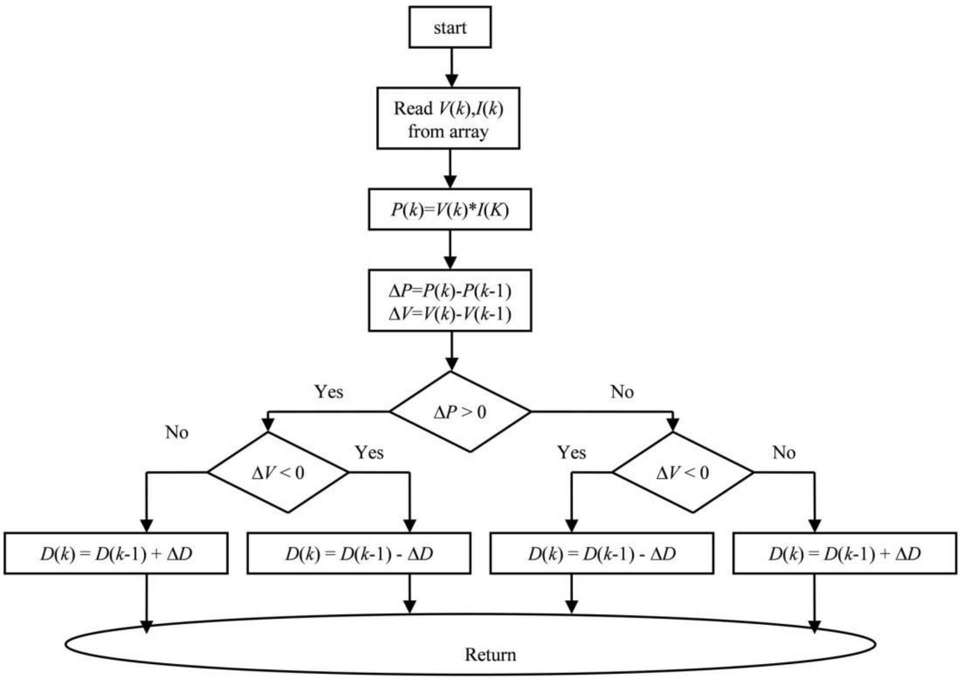


Figure 4: Flowchart of P&O algorithm

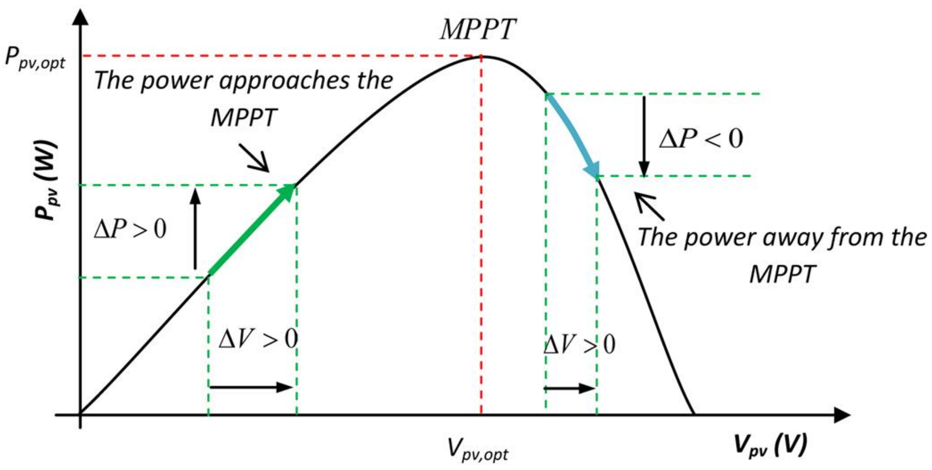


Figure 5: Typical PV curve

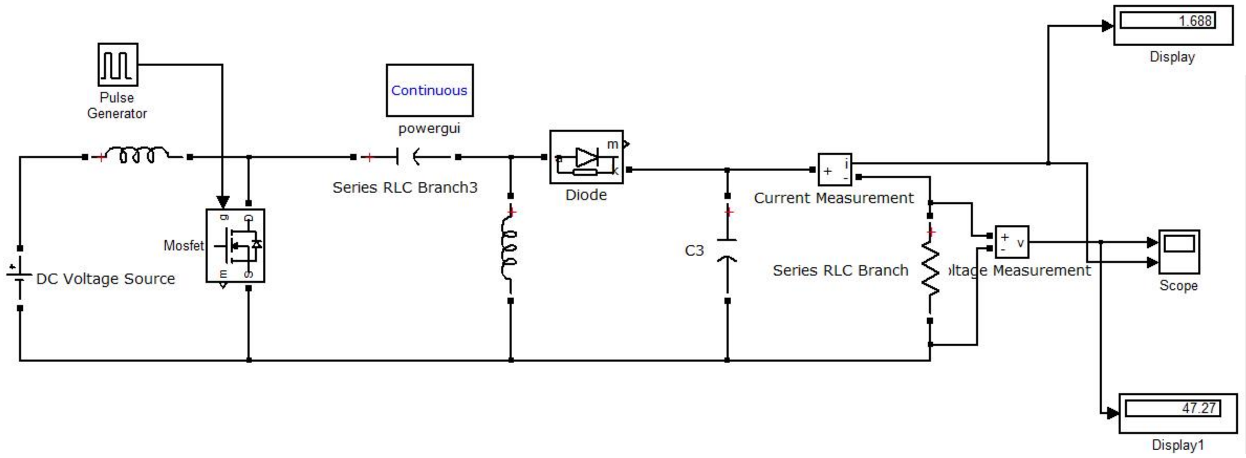
There are two common approaches for achieving the P&O algorithm. They are reference voltage perturbation, direct duty ratio perturbation.In Reference voltage perturbation, the PV array output voltage reference is used as the control parameter in conjunction with a controller (usually a PI controller) to adjust the duty ratio of the MPPT power converter. The PI controller gains are tuned while operating the system at a constant voltage equal to the standard test condition (STC) value of the MPP voltage. These gains are kept constant while the reference voltage is controlled by the MPPT algorithm.

In direct duty ratio perturbation, the duty ratio of the MPPT converter is used directly as the control parameter. The duty ratio is perturbed directly eliminating the need for a PI controller which in turn reduces the complexity and enhances the stability of the system. This method also offersbetter energy utilization and better stability characteristics at a slower transient response and worse performance at rapidly changing irradiance.

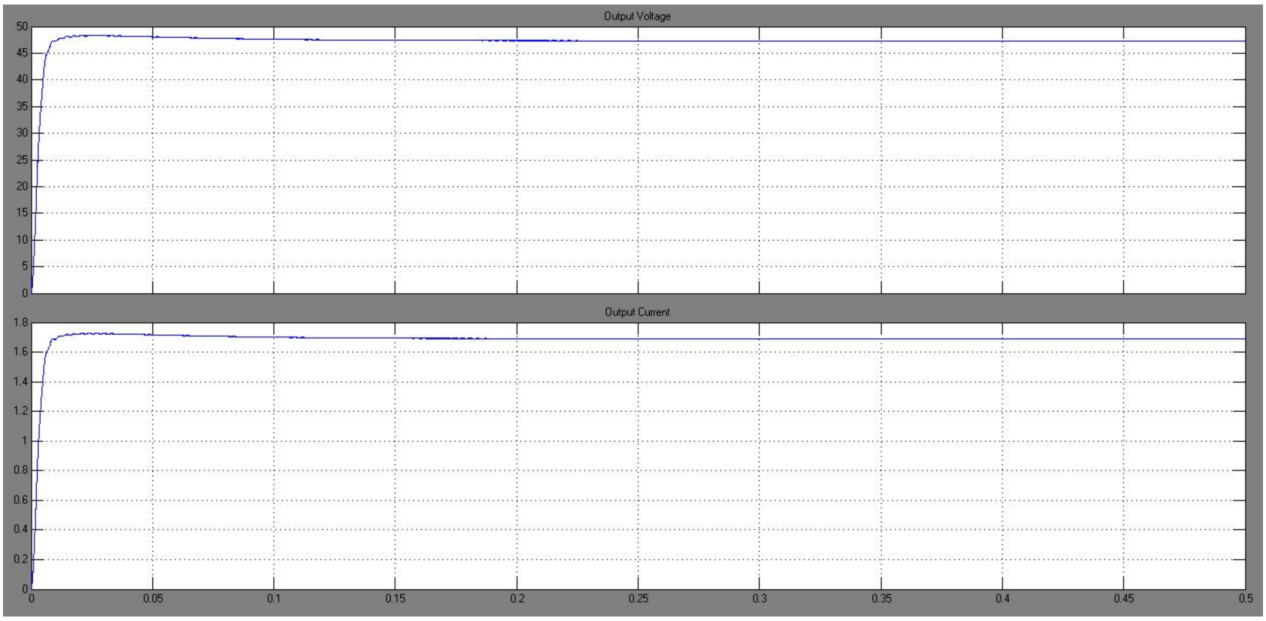
V. RESULTS AND SIMULATION

5.1 Design of SEPIC converter

Here the response of the converter has been shown with respect to the constant DC supply under normal open loop condition where the gating pulse are given to the converter by the pulse generator.



(a)

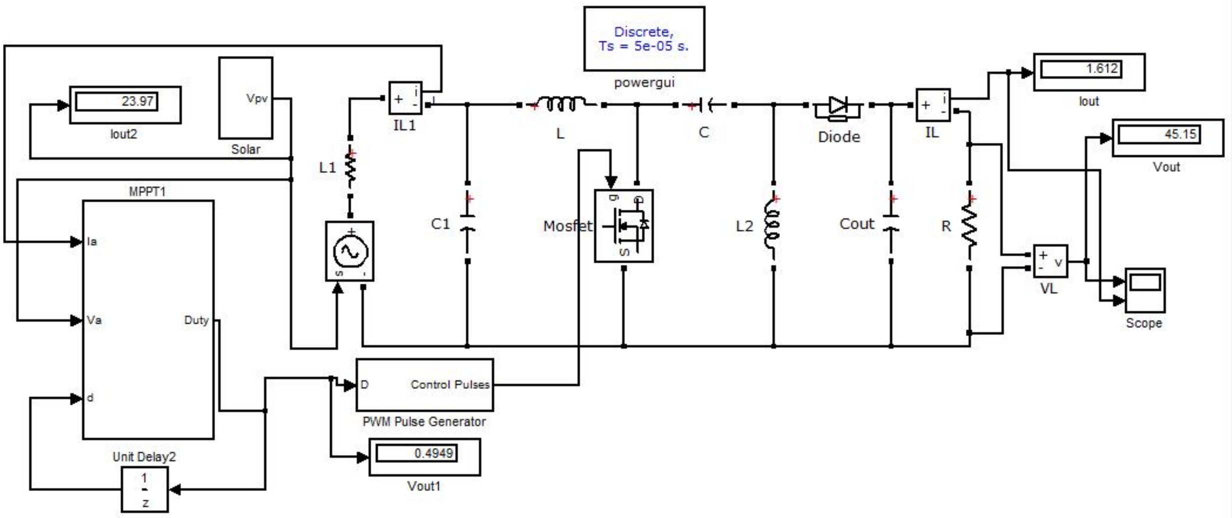


(b)

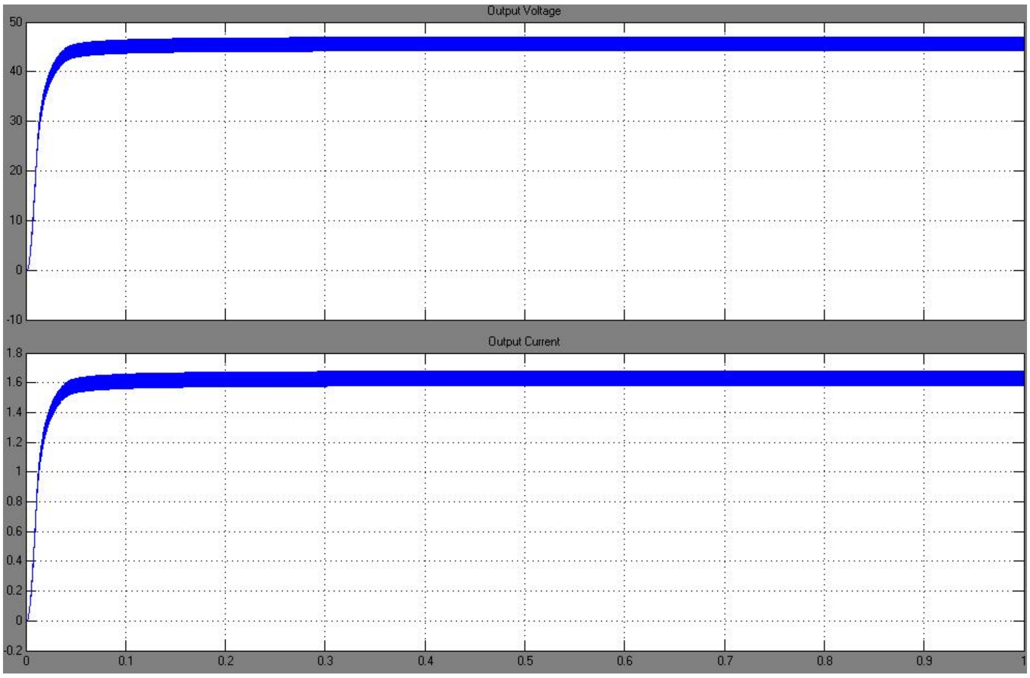
Figure 6: Modelling of SEPIC converter (a) Simulink circuit of converter (b) Output voltage and current waveform of the converter

5.2 Design of converter with PV solar system

Here the response of the converter has been shown with the solar PV system as the input and pulses to the converter switch is given through the MPPT controller.



(a)



(b)

Figure 7: Modelling of SEPIC converter with MPPT. (a) Simulink circuit of converter under closed loop control with MPPT. (b) Output voltage and current waveform of converter with MPPT.

5.3 Comparison results

Table 3 shows the comparison results of the converter with and without MPPT.

Table 3 Comparison value with and without MPPT

CONDITIONS	RISE TIME(S)	SETTLING TIME(S)
Without MPPT	0.03	0.1
With MPPT	0.1	0.05

VI. CONCLUSION

The Solar energy is gaining much importance in the field of power production due to its reliability i.e. available throughout the year and the cost of power production is less when compared to conventional methods because of free available of solar throughout the day. The power electronics plays a vital role in harvesting solar energy. Because the output of solar power is very small and it cannot be used directly for the power production so with the help of power electronic converter the output can increased to desired value by changing the parameters of converter. The output of converter is subjected to changes due to change in irradiation level of the solar energy which results in oscillations and the power production get disturbed results in the less efficiency. In order to increase the efficiency the maximum power should be maintained under various irradiation conditions, an MPPT technique has been used. Here P&O algorithm has been used and their response with the solar irradiation level has been analysed by using MATLAB/Simulink.

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