

# SIMULATION OF IMPROVED PERTURB AND OBSERVE MPPT USING SEPIC CONVERTER

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**ABSTRACT:** Because of the nonlinear I-V characteristic of PV array and maximum power point (MPP) varying in different condition it is necessary to use one of the conventional MPP tracking (MPPT) methods to reach optimum state of PV array working. There are a many methods for MPPT that used widely. The method that is used in this paper is perturb and observe (P&O) method. P&O isn't the best method to reach MPP, but due to its low-cost and ease of implementation is first choice to use. In this paper using adaptive P&O through SEPIC converter solves slow dynamic of conventional P&O in fast irradiation level changing. The simulation is done using MATLAB/SIMULINK

**Keywords:** Simulation, PV, MPPT, converter

## 1. INTRODUCTION

Need for renewable energy source is rising due to more word request of energy. One of the proper renewable energy source is the solar energy and it is available with good quality in some part of word. Inexhaustibility and clean energy are some advantages of solar energy.

Today solar energy is used in a wide range in power generation, water pumping, battery charging, satellite power system and etc.

The major disadvantage of PV cells is nonlinear I-V characteristic. Due to this property maximum power point (MPP) only occurs at a special point that is changed in different working conditions. To reach maximum efficiency, it is necessary to work at MPP. Many engineers researched different methods to achieve MPP to use PV arrays at maximum efficiency, this methods are named as maximum power point tracking (MPPT) [1-4].

### 1.1. MPPT Methods

There are a lot of MPPT methods are used in industry such as[5]:

- Perturb and Observe (P&O)
- Modified P&O
- Artificial Intelligence
- Constant Voltage
- Constant Current
- Incremental Conductance
- Parasitic Capacity

Each of MPPT methods have advantages and disadvantages, but P&O is the most commonly used method, because this method is simple and it can set up easily [6-9].

Maybe in theory the incremental conductance (INC) is better than P&O, but in practice INC can't reach to MPP exactly, and INC method needs to a lot of hardware and complicated method.

The biggest limitation of P&O is on reaching very close to MPP, and it doesn't stop at MPP and keeps on perturbing in both directions[10].

Another problem with this method is bad response of this method in rapid changing of irradiation level, but in this paper with adaptive P&O this disadvantage can be minimized [10].

## 2. PV MODELING

A photovoltaic cell or photoelectric cell is a semiconductor device that converts solar energy to electrical energy by photovoltaic effect. If the energy of photon of light is greater than the band gap then the electron is emitted and the flow of electrons creates current [10].

### 2.1. Classic Circuit Model

Typically a solar cell can be displayed by a current source and an inverted diode connected in parallel to it that is shown in Fig. 1. It has its own series and parallel resistance. Series resistance is due to hindrance in the path of flow of electrons from n to p junction and parallel resistance is due to the leakage current. The shunt resistance (RSH) in parallel is very high, has a negligible effect and can be neglected [11-12]. This model is shown in Fig. 1.

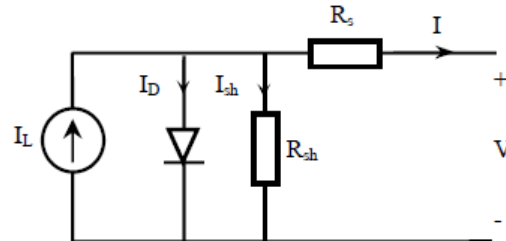


Figure. 1. Classic circuit model of PV.

### 2.2. Mathematical Model

The PV array output voltage is (1), as can be seen voltage is the function of array current and array current depending on irradiation level and array temperature. With neglecting from I<sub>sh</sub> the function is[13]:

$$V = \frac{AkT_C}{e} \ln \left[ \frac{I_L + I_D + I}{I_D} \right] - R_S I \tag{1}$$

The parameters are defined as follows:

- k : Boltzmann constant
- T<sub>C</sub> : reference cell operating temperature
- e : electron charge
- I<sub>L</sub> : photocurrent
- I<sub>D</sub> : reverse saturation current of diode

$R_s$ : series resistance of cell

$I$  : cell output current

$A$  : fitting factor

$I_L$  is the function of irradiation level and cell temperature then in order to consider these parameters, equation (2-8) can be used[14-17]:

$$\frac{V_{out}}{V_g} = \frac{D}{1-D} \tag{2}$$

$$I_L = C_{TI} C_{SI} I_L \tag{3}$$

where:

$$C_{TV} = 1 + \beta_T (T_a - T) \tag{4}$$

$$C_{TI} = 1 + \frac{\gamma_T}{S_C} (T_X - T) \tag{5}$$

$$C_{SV} = 1 + \beta_T \alpha_S (S_X - S) \tag{6}$$

$$C_{SI} = 1 + \frac{1}{S_C} (S_X - S) \tag{7}$$

With use these equation complete equivalent mathematical model of PV array can be achieved.

### 3. DC-DC CONVERTER

To implement MPPT algorithm a proper DC-DC converter is necessary, because with switching in converter the PV output voltage can be varied and then it is possible to reach maximum power point in PV array working. In this paper SEPIC converter that is shown in fig.2 is selected to use in MPPT algorithm, due to this converter is buck-boost converter and it can be used to decrease and increase voltage and the output voltage of converter is positive in comparison to cuk converter that the its output voltage is negative. SEPICs are useful in applications in which a battery voltage can be above and below that of the regulator's intended output.

The relation between input and output voltage of SEPIC converter is shown in equation (8).  $D$  in this equation is the switch duty cycle.

$$\frac{V_{out}}{V_g} = \frac{D}{1-D} \tag{8}$$

The Perturb & Observe algorithm states that when the operating voltage of the PV panel is perturbed by a small increment, if the resulting change in power  $\Delta P$  is positive, then we are going in the direction of MPP and we keep on perturbing in the same direction. If  $\Delta P$  is negative, we are going away from the direction of MPP and the sign of perturbation supplied has to be changed

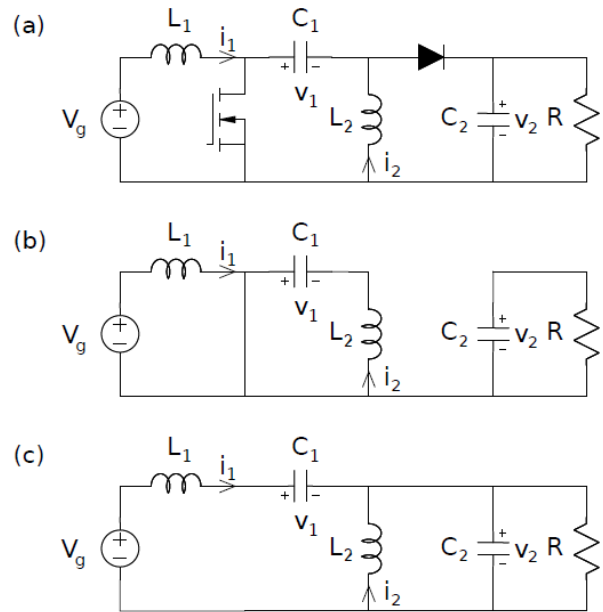


Figure. 2. An ideal SEPIC converter: (a) practical realization using IGBT and diode, (b) when the IGBT conducts, (c) when the diode conducts.

### 4. MPPT ALGORITHM

#### 4.1. Traditional P&O

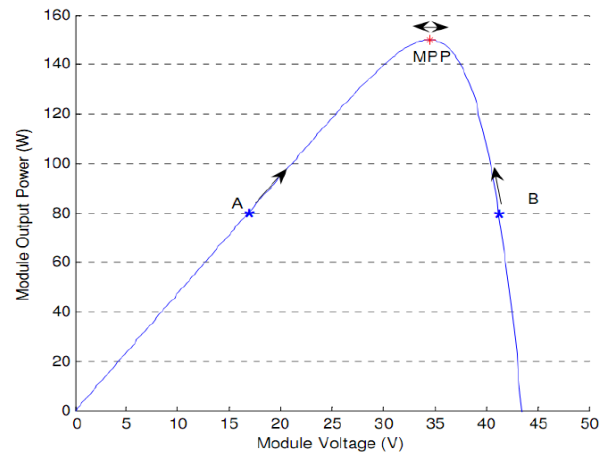


Figure. 3. Solar panel characteristics showing MPP and operating points A and B.

Fig.3 shows the plot of module output power versus module voltage for a solar panel at a given irradiation. The point marked as MPP is the Maximum Power Point, the theoretical maximum output obtainable from the PV panel. Consider A and B as two operating points. As shown in the Fig.3, the point A is on the left hand side of the MPP. Therefore, we can move towards the MPP by providing a positive perturbation to the voltage. On the other hand, point B is on the right hand side of the MPP. When we give a positive perturbation, the value of  $\Delta P$  becomes negative, thus it is imperative to change the direction of perturbation to achieve MPP.

In a situation where the irradiance changes rapidly, the MPP also moves on the right hand side of the curve. The algorithm takes it as a change due to perturbation and in the next iteration it changes the direction of perturbation and hence goes away from the MPP as shown in the figure. The time complexity of this algorithm is very less but on reaching very close to the MPP it doesn't stop at the MPP and keeps on perturbing in both the directions. When this happens the algorithm has reached very close to the MPP. It can be seen traditional P&O fails to track MPP in rapid changing of irradiation but adaptive P&O has faster dynamic and stability.

The P&O MPPT method is very easy for digital control implementation. But PV array voltage is perturbed in each cycle of switching control pulse in this method. Therefore the output power oscillate around the MPP[10]. To reduce this oscillation perturbing time can be increased, but this is suitable for constant irradiation level, and in rapid changing of irradiation level this method fails to reach MPP.

**4.2. Adaptive P&O**

In adaptive P&O with use variable perturbation problems of conventional P&O are solved. In this paper to change IGBT duty cycle, an exponential equation is used. This equation is shown in (9). This equation value is large for large ΔP and is small for small ΔP and then with large perturbation improves the dynamic performance and with small perturbation good stability is guaranteed.

$$\Delta D = \Delta D_{min} + \frac{\exp(|P - P_{Old}|)}{P_M} \quad (9)$$

In (9) the ΔD is variation in switch duty cycle that as can be seen when operation point is close to MPP the exponential term approximately is zero and alternate in small domain around MPP, but when the operation point is far from MPP with large variation in D, get to MPP very fast. The (10) shows how this method reaches to maximum power point:

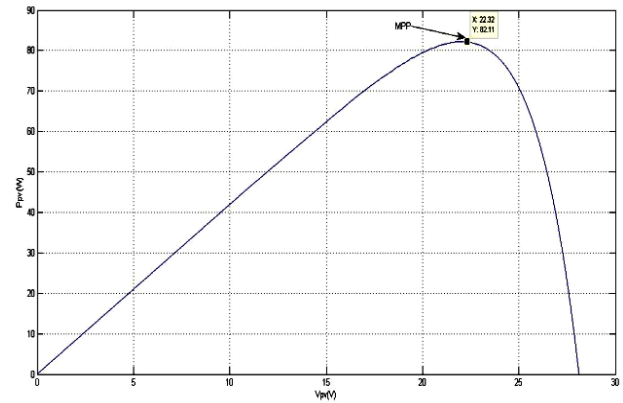
$$R_{PV} = \frac{V_{PV}}{I_{PV}} = \frac{1-D}{D} V_{load} = \left[ \frac{1-D}{D} \right]^2 R_{load} \quad (10)$$

This equation shows that D varies until maximum power point achieve and around the maximum power point oscillation is small because of (9).

**5. SIMULATION RESULTS**

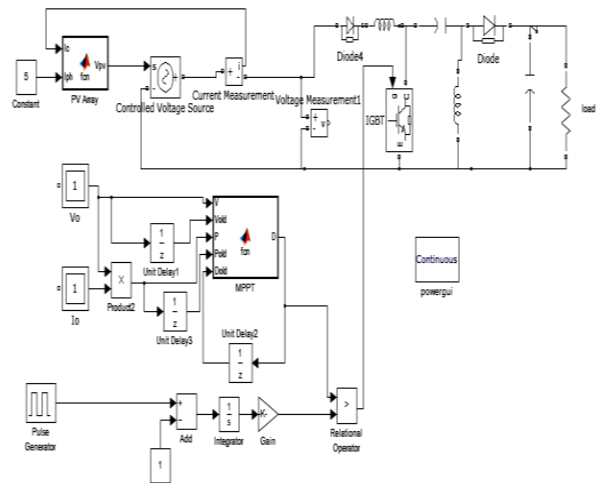
At first to PV array validation in Fig. 4, the I-V characteristic of PV array that is achieved from PV model, is shown. As can be seen in this Fig the maximum power point of this PV is marked, and its value is 82W at standard conditions.

The diagram of the closed-loop system designed in MATLAB and SIMULINK is shown in Fig. 5, which includes the PV mathematical model, the SEPIC converter and the adaptive P&O algorithm.



**Figure. 4. I-V characteristic of PV array.**

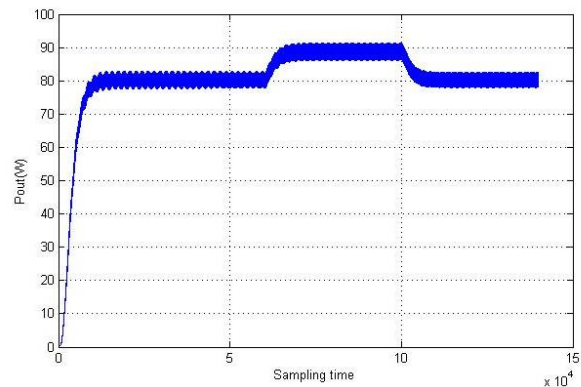
To test the system operation, the condition of irradiation change is modelled. The temperature is constant at 20 °C and irradiation level is varying at t=3s, this changing is done by changing in light generation current value.



**Figure. 5. Diagram of closed loop system.**

The results in fig. 6 show the output power, voltage and current. The results in Fig. 7 show the PV array power, voltage and current. This results show that system provides best operation point for achieving to maximum electrical power at PV array output.

(a)



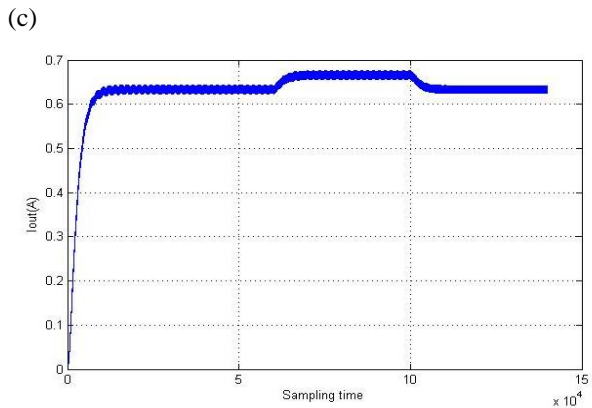
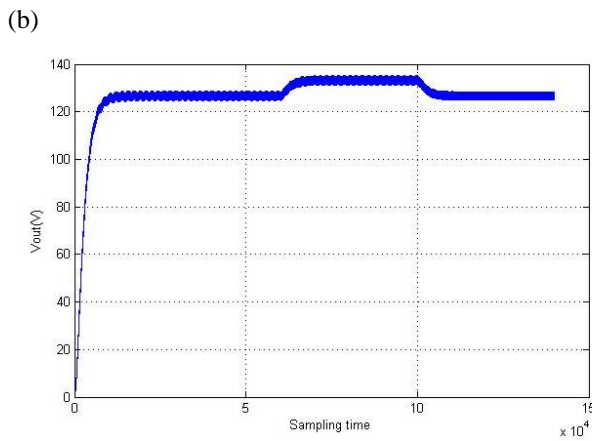


Figure 6. Output results, (a) power, (b) voltage, (c) current.

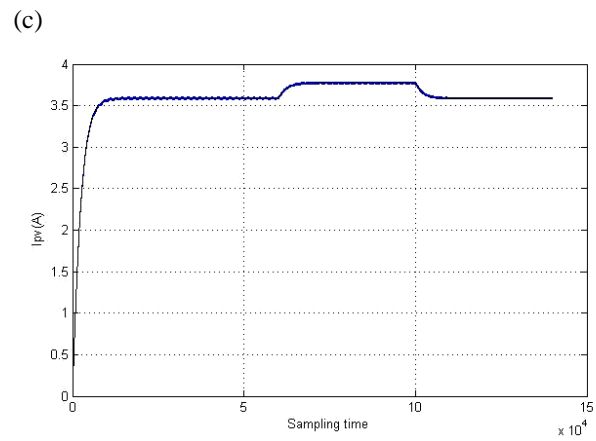
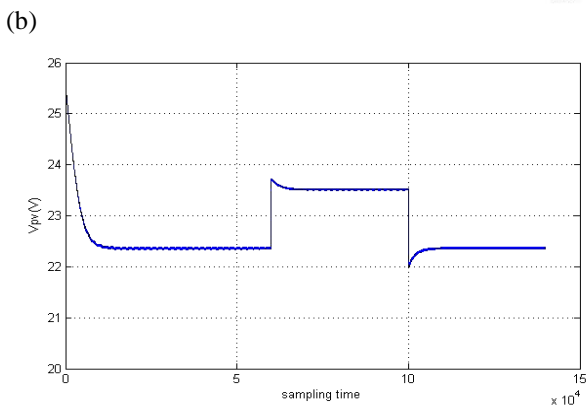
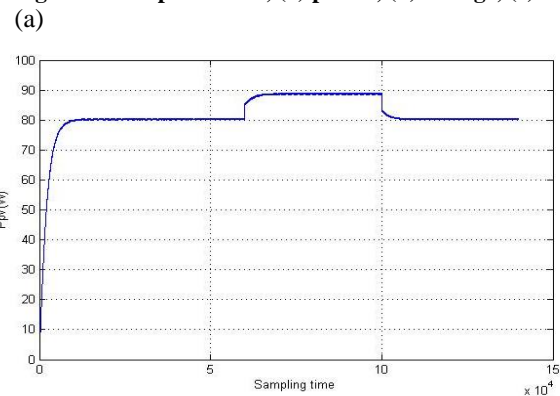


Figure 7. PV array results, (a) power, (b) voltage, (c) current.

It can be seen that this closed loop system can tracks the maximum power point when the irradiation level changes rapidly, because of (9) with proper  $D$  in each switching stability is reached.

## 6. CONCLUSION

In this paper after explaining of PV array modeling, P&O MPPT method and SEPIC converter, to decrease P&O disadvantages the improved P&O method is used. With this new method the MPPT efficiency increased. This new nonlinear perturbation is used to reach fast response to rapid irradiation level changing in PV array environment, also this model has good stability in this variable conditions.

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