Performance analysis of ‘Perturb and Observe’ and ‘Incremental Conductance’ MPPT algorithms for PV system

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Abstract. Photovoltaic (PV) system usually employed The Maximum power point tracking (MPPT) techniques for increasing its efficiency. The performance of the PV system perhaps boosts by controlling at its apex point of power, in this way maximal power can be given to load. The proficiency of a PV system usually depends upon irradiance, temperature and array architecture. PV array shows a non-linear style for V-I curve and maximal power point on V-P curve also varies with changing environmental conditions. MPPT methods guarantees that a PV module is regulated at reference voltage and to produce entire usage of the maximal output power. This paper gives analysis between two widely employed Perturb and Observe (P&O) and Incremental Conductance (INC) MPPT techniques. Their performance is evaluated and compared through theoretical analysis and digital simulation on the basis of response time and efficiency under varying irradiance and temperature condition using Matlab/Simulink.

1. Introduction

Renewable Energy (RE) is the best choice among all resources to fulfil the plea of energy [1]. The (RE) sources compromises of solar energy, wind energy, Tidal energy and etc. These sources going to be famous due to these advantages e.g. reliable, easy to available, friendly to environmental, has long life, has low maintenance cost and pollution free [2-3]. The energy from sun is a vital source of energy for generation of electricity [4]. Solar energy is assumed to be safe, favourable and long lasting source of energy. The (PV) Module PV array shows a non-linear style for V-I curve and maximal power point on V-P curve also varies with changing environmental conditions. The efficiency of PV module is in the range (10-25) % [5]. To maximize their proficiency and decrease the cost of modules, (MPPT) algorithms are connected with overall system [6-9]. PV system usually employed The (MPPT) techniques to increase its efficiency under these varying conditions. The performance of the PV system perhaps boosts by controlling at its apex point of power, in this way maximal power can be given to load [10-14]. The (MPPT) approaches are employed to maximize the power of the system. The commonly used methods are Hill climbing, Incremental Conductance (INC), Perturb and Observation (P&O), Constant Current (CI) and Constant Voltage (CV) [15-20]. This paper gives analysis between two commonly employed Perturb and Observe (P&O) and Incremental Conductance (INC) MPPT techniques. The performance of these two methods are evaluated and compared through theoretical analysis and digital simulation under varying irradiance and temperature condition using Matlab/Simulink.

2. Modelling of a solar cell
The solar cell is usually made up of crystalline silicon (Si) material, which conducts electricity when sunlight is made to fall on solar cell and converts radiations from sun to electrical energy. The proportionate model of a solar cell is presented in Figure 1. The overall equation for a single diode PV cell is given by equation (1-2) [5].

\[ I = I_p - \frac{I_D}{\exp(qV / aKT_c)} - I \]  
\[ I = I_p - \frac{I_D}{\exp(V + Rs / V_t)} - (V + Rd / R_p) \]  

Where \( I_p \) is the current induced due to incident of light, \( I_D \) is the current due to reverse saturation, \( q \) is the Charge on electron, \( K \) is the Boltzmann constant, \( T_c \) is the temperature for p-n junction, \( V_t \) is the thermal Voltage for PV array, \( R_s \) is the Series Resistance, \( R_p \) is the Parallel Resistance. BP MSX 120 is employed in modelling of PV module. Electrical specifications of this module are shown in Table 1.

| Parameters | 1 Module | 12 KW array |
|------------|----------|-------------|
| \( I_{ph} \) | 3.8713 A | 38.71 A |
| \( I_D \) | 0.323 μA | 3.23 μA |
| \( A \) | 1.3977 | 1.3977 |
| \( R_s \) | 0.473 Ω | 0.18 Ω |
| \( R_{sh} \) | 1367 Ω | 520 |

3. Characteristics of PV cell

PV array shows a non-linear style for V-I curve and maximal power point on V-P curve also varies with changing environmental conditions as shown in Figure 2. The changing of the temperature has a great effect to the array’s output voltage as compared to output. The power-voltage curve which shows that as irradiance decreases the MPP of the PV module also going to be decreased.

4. Perturb and Observe (P&O) algorithm

P&O is frequently used (MPPT) approach for most of PV systems [6-7]. This approach regularly adds or subtracts the assigned voltage value back on checking the last power pattern value. The P&O is primitive technique that has less cost and its implementation is so much easy. Drawback is that some
time its operating point is fluctuating about MPP. As a result, some power will be lost. (P&O) algorithm flow chart is described in detail in Figure 3.

5. Incremental conductance (INC) Algorithm
INC algorithm is also very common MPPT algorithm for many PV system [4]. This approach can be extracted by differentiating two quantities i.e. power against voltage and keeping the resultant value equal to zero as shown in equation (3).

\[ \frac{dP}{dV} = \frac{d(VI)}{dV} = I + V \cdot \frac{dI}{dV} = 0 \quad \text{on MPP} \quad (3) \]

When the controlling point is not lie on MPP and going to be changed, than that condition will be shown one of these equations that are given below (3-5). When MPP arrived, INC method try to keep at that point as long as fluctuation in atmospheric condition is occurred. Figure 4 presents a flowchart of INC algorithm.

\[ \frac{dI}{dV} = -I \quad (dP/dV = 0) \quad \text{on MPP} \quad (4) \]
\[ \frac{dI}{dV} > -I \quad (dP/dV > 0) \quad \text{on left of MPP} \quad (5) \]
\[ \frac{dI}{dV} < -I \quad (dP/dV < 0) \quad \text{on right of MPP} \quad (6) \]

6. Simulation result and Analysis
The performance of two (P&O and INC) methods are evaluated and compared through theoretical analysis and digital simulation under two conditions by using Matlab/Simulink. The PV module is connected to the load through converter which in turn control by two different algorithms: P&O and INC, one by one.

6.1. Steady Condition
6.2. Dynamic Condition

6.1. Steady condition
First, these methods are evaluated under steady weather conditions i.e. 1000W/m² irradiance and 25°C temperature. Figure 5(a) shows the comparative simulation result of (P&O) algorithm for power achieved by PV array and boost converter. Figure 5(b) shows the comparative simulation result of (INC) algorithm for Power achieved by PV module and boost converter. The output of the PV module is represented by the blue line while orange line is used to represent the output of the boost converter. It can be seen from fig. 10 that INC method has good and less response time and it has nearly minor oscillations in power around MPP. On the other hand, P&O method requires high response time and it
has immense oscillations in power at MPP. So, for uniform conditions INC shows best result than P&O.

![Figure 5](image.png)

**Figure 5.** Steady condition simulation result (a) P&O MPPT algorithm; (b) INC MPPT algorithm.

### 6.2. Dynamic condition

In this section of simulation, (P&O and INC) MPPT methods are analysed and tested under dynamic weather conditions. Figure 6(a) shows the comparative simulation result of (P&O) algorithm for power achieved by PV array and boost converter under dynamic condition. Figure 6(b) shows the comparative simulation result of (INC) algorithm for Power achieved by PV module and boost converter under dynamic condition. The output of the PV module is represented by the blue line while orange line is used to represent the output of the boost converter. This shows that the PV module maximum power declines, when the irradiance decreases and also current declines significantly when the irradiance decreases. So from above discussion, we can say that the PV array MPP varies with variations in shading, temperature and radiation. It has been seen that the PV system output power boosts with rise in amount of solar irradiance and drops in cell temperature. Consequently, the proficiency of the PV cell is better in winter than summer season.

![Figure 6](image.png)

**Figure 6.** Dynamic condition simulation result (a) P&O algorithm (b) INC algorithm.

INC algorithm has high response speed and can be controlled accurately. However, it has complex hardware design and needs precise sensors. The features of this method huge response speed, working under rapid changes in atmospheric conditions. On the other hand, P&O methodology is very simple, but its operating point is fluctuating about MPP so as a result some power will be lost. Additionally, its exhibits less accuracy and response is also slow.

### 7. Conclusion

This paper gives the detailed analysis about two widely employed MPPT algorithms under uniform and non-uniform conditions of temperature and irradiance in the Matlab/Simulink background. These two MPPT methods are compared on the basis of efficiency and response time. The INC shows the
best proficiency among these two techniques. It exhibits the perfect efficiency and response time in steady as well as in dynamic conditions of weather. So, INC algorithm is terrific as compared to P&O.

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