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Efficiency and Performance Evaluation of MPPT Algorithms with the Boost converter

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Abstract

Maximum power point tracking system is a necessary factor to increase the potency of any photovoltaic system. The maximum power point tracking system wants to extract outermost power from the photovoltaic array. The maximum power point is achieved by using specialized algorithms like p and o and incremental condition algorithm. Compared to other algorithms used in MPPT systems, these two algorithms are most widely used based on their specialty and simplicity in implementation. This paper demonstrates the positive impact of the MPPT system and also it illustrates the operation of each algorithm at different irradiance MATLAB Simulink is used for the simulation work which evaluates both the algorithm at different conditions (Temperature & solar irradiance) which represents that individual algorithm has its benefits over the other. Perturb and observe algorithm is the fastest to influence the maximum power point and also extract maximum power from the photovoltaic array, but still, it cannot retain the maximum power point as incremental condition algorithm can do, concurrently with lower perturbation at low switch rate an incremental algorithm can reach maximum PowerPoint.

Keywords: *P and O algorithm, INC algorithm, Maximum Power Point.*

1. INTRODUCTION

In renewable energy sources, solar energy is the furthermost efficient and clean energy source. Due to its numerous benefits and its advantages, it will attract human attention. The major advantages are clean power, continuity, price reduction, and reliability. Electric power can be generated using the photovoltaic system. To convert alternate energy to an electrical energy PV cell is essential. Solar radiation is an alternative source of energy which results in low power generation due to its temperature variation.To extract maximum power from the photovoltaic panel MPPT that is maximum power point tracking technique is used in the PV system, this controller helps to trace and achieve the maximum PowerPoint. The controller conjointly has to hold and preserve the MPPT to evade major power loss which will affect the system efficiency. The effectiveness of the photovoltaic system is mainly depending on the efficiency of the photovoltaic panel, the efficiency of DC – AC converter the potency of the maximum power point tracking controller.

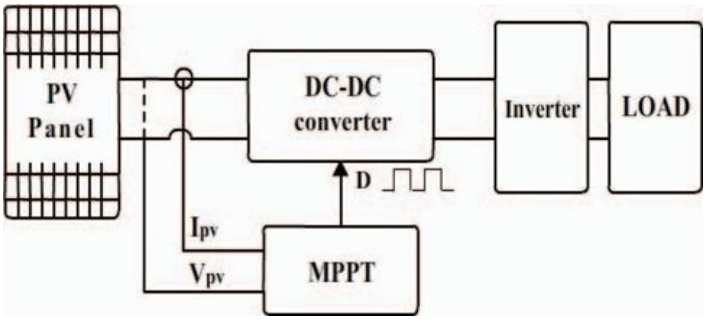

Fig 1 MPPT technique

The load impedance must be acceptable to the source impedance to deliver the maximum power to the load. By inserting a dc-dc converter between the photovoltaic array and the load, to realize the

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matching condition between load impedance and the source. Figure 2. shows the PV and IV characteristics of the PV cell using the MPPT technique. To extract maximum power point, DC-DC Converter is used for transmission of power from photovoltaic array to load. The duty cycle will control the shift rate of the DC-DC Converter. MPPT system will adjust the duty cycle till it senses the effective duty value which results in load impedance coordinated to the supply impedance.

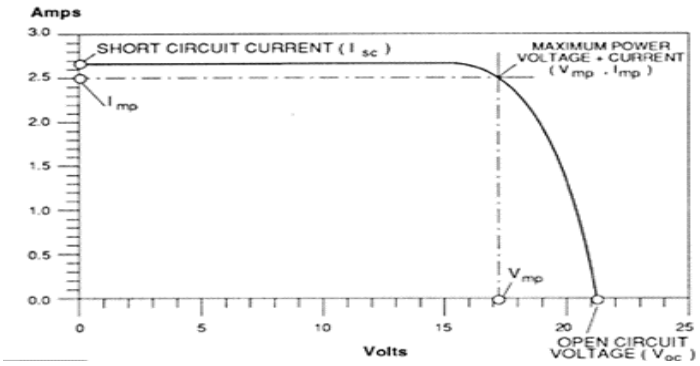

Fig-2. P-V and I-V characteristics of the PV cell.

From Fig 2, it's clear that the photovoltaic system should be functioned on definite current and voltage values to reach maximum PowerPoint. The importance and benefits of using the Maximum power point tracking technique in a photovoltaic system are demonstrated. Moreover, the simulation work can reveal the results of the algorithms that are Perturb and Observe (P&O), and Incremental condition algorithm used for maximum power Extraction. Obtained results from both the algorithms are compared and evaluated.

2. PHOTOVOLTAIC SYSTEM

Solar PV system formed by the solar configuration of modules in series and parallel. The photovoltaic cell equation parameters changed with the module and array configuration and condition of Maximum PowerPoint is analyzed based on the electric circuit voltage condition. The Maximum power point condition analysis generates the equation for computation of resistances without iteration thephotovoltaic array model is developed to convey their ratings given in Table 1 represents the PV array rating at STC of 25℃ and 1000 W/m2.

TABLE 1. PV ARRAY RATINGS

Parameter	**Values**	**Units**
Isc	8.55	*A*
Voc	37.6	*V*
IMPP	8.06	*A*
VMPP	31	*V*
PMPP	2000	*W*

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Photovoltaic (PV) panels are the main part of the photovoltaic installation, as they convert solar radiation to electrical energy. A solar photovoltaic system created by the solar configuration of modules in series and parallel. The solar cell equation parameters customized with the module and array configuration and condition of maximum power point is analyzed based on the open-circuit voltage (Voc) condition. Figure 3 represents the equivalent circuit of the photovoltaic cell, which includes series resistance, current source, shunt resistance and a diode. The photovoltaic array comprises of series and parallelly connected photovoltaic cells. High output voltage is obtained when cells are connected in seriesand also high output current obtained with cells are connected in parallel. These two principals are essential to make efficient photovoltaic systems [7].

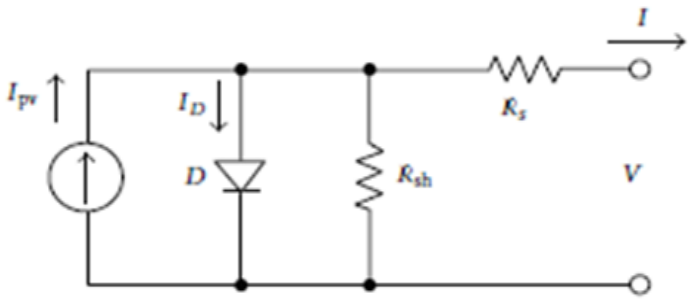

Fig-3. Equivalent circuit of photovoltaic cell.

Equation (1) expresses the equivalent circuit of Photovoltaic cell Fig-3

$$I = Ipv - Io\left[\exp\left(\frac{V+IRs}{\alpha V_T}\right) - 1\right] - \frac{V+IR_S}{R_{sh}} \qquad (1)$$

Where:

Ipv = Photovoltaic module current (A),

V= Photovoltaic module voltage (V),

Rs= series resistance (Ω),

vt=kT/q thermal voltage (V),

T=cell temperature,sh= shunt resistance (Ω),

3. Boost converter

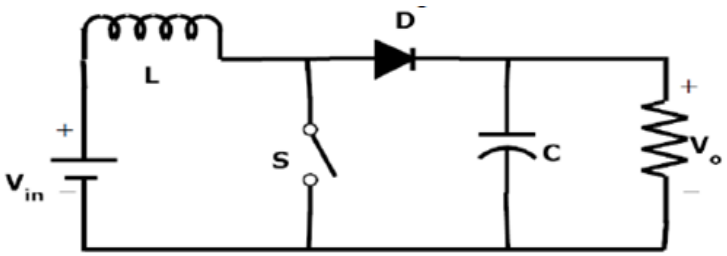

Fig 4 Boost converter

The output voltage of the boost converter depends on D i.e. duty ratio

$$V_{OUT} = \frac{V_{IN}}{(1-D)}$$

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The duty cycle is designed by the block containing a maximum power point tracking system which will generates firing pulse consequently for this switch.

3.1 Calculation of a Boost Converter

a. **Duty cycle:** $D = 1 - \frac{V_{IN(\min)} \times \eta}{V_{OUT}}$

b. **Inductor ripple current:** $\Delta I_{L} = \frac{V_{IN(min)} \times D}{f_s \times L}$

c. **Inductor Selection:** $L = \frac{V_{IN} \times (V_{OUT} - V_{IN})}{\Delta I_L \times f_s \times V_{OUT}}$

d. **Estimated inductor ripple current,**

$$\Delta I_L = 0.2 \times I_{OUT(max)} \times \frac{V_{OUT}}{V_{IN}}$$

e. **Output Capacitor Selection:**

$$C_{OUT(\min)} = \frac{I_{OUT(\max)} \times D}{f_s \times V_{OUT}}$$

D = Duty cycle
C_{OUT} = Output capacitance
I_{OUT} = Output current.
fs = Switching frequency
V_{OUT} = Output voltage
η = Efficiency
L = Inductor value
ΔIL = Inductor ripple current,

4. MPPT TRACKING TECHNIQUES

To extend and enhance the potency of solar modules, the Maximum Power Point Tracking "MPPT" is a unique technique to extract maximum power from the PV module. From a practical point of view the efficiency, routines need to be considered to match the source and load appropriately. In PV frameworks the I-V bend is non-direct, and it is hard to utilize the power to a specific load. Hence MPPT method is employed to extract maximum power from a fluctuating source. This is accomplished by employing the converter, whose duty cycle is different by utilizing an MPPT algorithm.

4.1 (P &O) Perturbation and Observation Technique

The algorithm program conjointly called a Hill Climbing technique based on the voltage perturbation MPPT system is been controlled by increasing or decreasing the amplitude DC-DC converter will get directly affected by the perturbation.

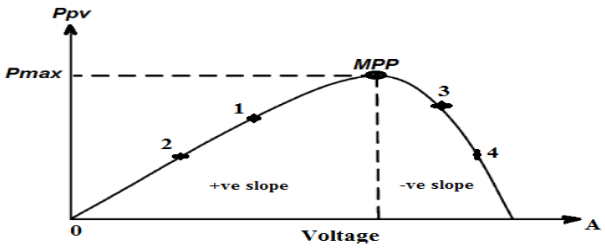

Fig.5 Hill climbing technique

The algorithm directly perturbs the duty cycle and also check if the voltage and power of the photovoltaic array have to increase or decrease and the next perturbation is in the same direction or the direction of perturbation is changed. Consider point 1 when at Positive slope as shown in figure 5, the solution is to move towards the MPP by increasing the perturbation in the same direction. Whereas in point 3 when $\Delta P<0$ at the negative slope where the point moving away from MPP as shown in fig5, the solution is to move towards the MPP by perturbation increment must be reversed i.e the point 3 has to move back towards MPP. Granting the implementation of the perturbation and observation algorithm is simple and straightforward, its efficiency is restricted.

4.2 Incremental Conductance Technique (INC)

Based on the observation of the power and voltage characteristic curve, the Incremental Conductance method is designed. This INC algorithm is designed to conquer some drawbacks of the Perturb & Observe algorithm. This incremental algorithm will improve the tracking time on immense irradiation changes environment. It is possible to calculate the MPP using the relationship dI/dV and –I/V. If dP/dV is -ve, then Maximum power point tracking lies on the right side of the recent position and if the maximum power point is +ve, the MPPT is on the left side.

5. RESULTS AND OBSERVATION

To analyses the benefits of each algorithm over the other the results of both algorithms must be demonstrated at different temperatures and irradiance conditions and extraction of maximum power from the photovoltaic array which will support the MPPT techniques, duty cycle to know at which MPP is achieved.

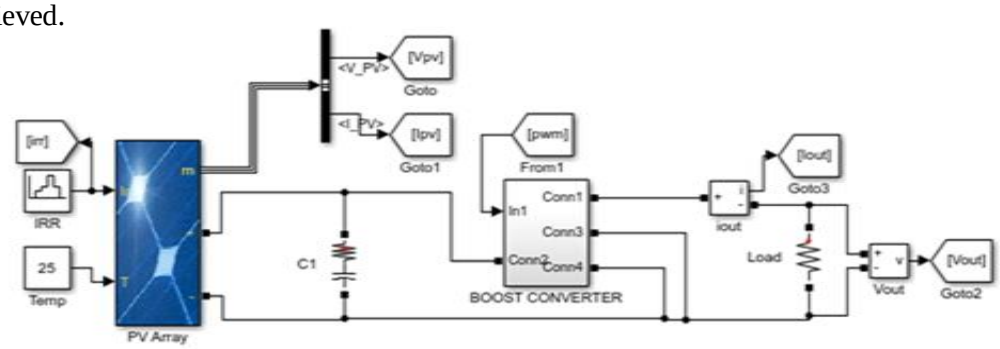

Fig 8. Simulink model of boost converter

The simulation is done for different irradiation and temperature condition to acknowledge the effect of atmospheric variation on the photovoltaic system and also to analyses if the algorithm can act can adopt to operate in different conditions. The output voltage of the photovoltaic array is especially tormented by encircling temperature degree. The output panel decay by 0.25% for amorphous cells and 0.5% for the crystalline cell when each degree rises in temperature 25℃. By increasing the temperature of photovoltaic panel grades in a decrease in output voltage and consequently cause a reduction in output power from the PV panel. The output current of the photovoltaic array is affected by the solar irradiance level due to a change in temperature with respect to time. The system is simulated and the results are documented for the different atmospheric conditions which are to evaluate the performance of both perturb and observe and incremental condition algorithms.

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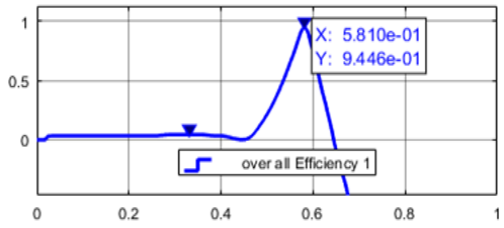
5.1 P&O and INC of 1000W/m2 @ 25℃

TABLE 2. PV System at IRR=1000W/m2 and T=25℃

Algorithms	P&O	INC
Irradiance(W/m2)	1000	1000
Temperature (℃)	25	25
P_pv (W)	1998.5	1999
P_out (W)	1987	1990



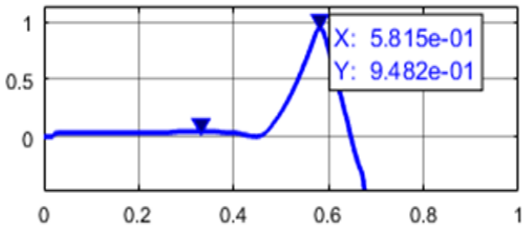


Fig-9 (P&O algorithm) **Fig-10 (INC algorithm)**

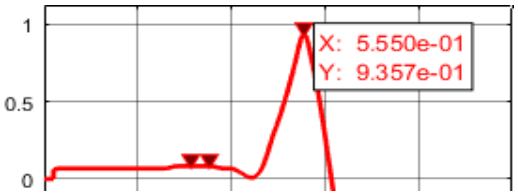
Fig (9-10) Efficiency of the photovoltaic systemfor IRR=1000W/m2 @ T=25℃

Table 2, shown the maximum power extracted from photovoltaic array Ppv = 1998.5W for P&O and 1999 W for INC. The system output power which is distributed to the load, Pout = 1987W for P&O and 1999W for INC. Based on the obtained results, it clearly shows that the extracted output power and the system efficiency using incremental condition algorithm is 9.48% greater than perturb and observe algorithm9.4%.

5.2 P&O and INC of 1000W/m2 @ 35℃

TABLE 3. PV System at IRR=1000W/m2 and T=35℃

Algorithms	P&O	INC
Irradiance (w/m2)	1000	1000
Temperature (℃)	35	35
P_pv (w)	1970	1977
P_out (w)	1948	1952



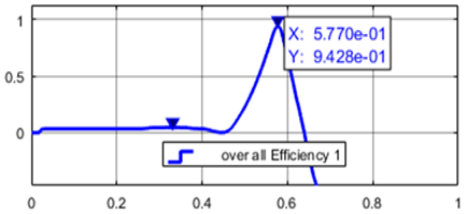


Fig-11. (P&O algorithm) **Fig-12. (INC algorithm)**

Fig(11-12) Efficiency of the photovoltaic system forIRR=1000W/m2 @ T=35℃

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Table 3, shown the maximum power extracted from photovoltaic array Ppv = 1970 W for P&O and 1977 W for INC. The system output power which is distributed to the load, Pout = 1948 W for perturb and observe and 1952 W for INC. Based on the obtained results,it clearly shows that the extracted output power and the system efficiency using incremental condition algorithm is 9.42% greater than perturb and observe algorithm 9.35%.

5.3 P&O and INCof 1000W/m2 @ 45℃.

TABLE 4. System at IRR=1000W/m2 and T=45℃.

Algorithms	P&O	INC
Irradiance (w/m2)	1000	1000
Temperature (℃)	45	45
P_pv (w)	1877	1884
P_out (w)	1863	1876

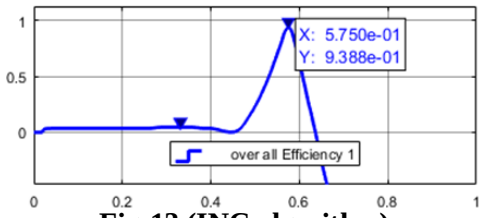

Fig-13 (INC algorithm)

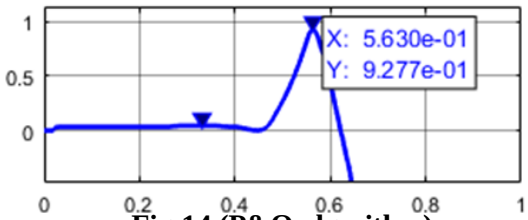

Fig-14 (P&O algorithm)

Fig (13-14).) Efficiency of the photovoltaic system for IRR=1000W/m2 @ T=45℃.

Table 4, shown the maximum power extracted from photovoltaic array P_pv = 1877 W for P&O and 1884 W for INC. The system output power which is delivered to the load, Pout = 1863 W for P&O and 1876 W for incremental condition algorithm. Based on the obtained results, it clearly shows that the extracted output power and the system efficiency using incremental condition algorithm is 9.38% greater than perturb and observe algorithm 9.27%.

5.4 P&O and INC of 800W/m2 @ 25℃

TABLE 5. The system at IRR=800W/m2 and T=25℃

Algorithms	P&O	INC
Irradiance (w/m2)	800	800
Temperature (℃)	25	25
P_pv (w)	1598	1613
P_out (w)	1572	1601

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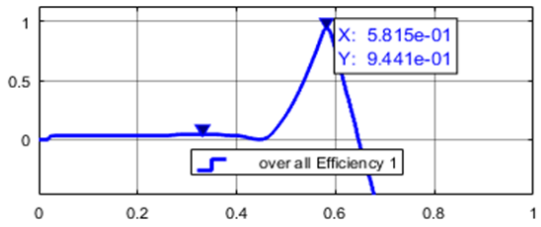

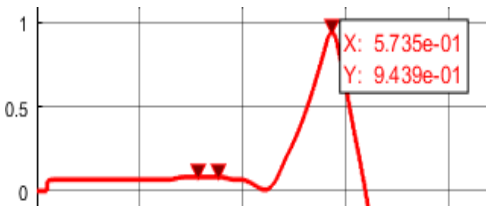

Fig-15 (INCalgorithm) **Fig-16(P&O algorithm)**

Fig (15-16) Efficiency of the photovoltaic systemfor IRR=800W/m2 @ T=25℃

Table 5, shown the maximum power extracted from photovoltaic array P_pv = 1598 W for P&O and 1613 W for INC. The system output power which is distributed to the load, Pout = 1572 W for perturb and observe and 1601 W for incremental algorithm. Based on the obtained results, it clearly shows that the extracted output power and the system efficiency using incremental condition algorithm is 9.44% greater than perturb and observe algorithm 9.43%.

6. CONCLUSION

The simulation results characterize the advantages of each algorithm that is perturbed and observe the algorithm and incremental condition algorithm. By using the maximum power point tracking technique, maximum power can be extracted at different temperatures and also at different irradiance conditions, which will be reflected on the load. From the obtained results it is shown that incremental condition algorithm has low variation in duty cycle value compared to the P and O algorithm. The incremental algorithm had better system efficiency, low switching rate, cost reduction. The extracted output power delivered to the load when using each algorithm is nearly identical for every atmospheric condition's case based on the observation both algorithms has its returns, so selecting the algorithm will mostly be contingent on the application and its requirements.

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