

# Comparison of MPPT Algorithms for DC-DC Converters Based PV Systems

A.Pradeep Kumar Yadav<sup>1</sup>, S.Thirumaliah<sup>2</sup>, G.Haritha<sup>3</sup>

<sup>1</sup> PG Scholar, St.Johns College of Engineering and Technology, Yemmiganur, Andhra Pradesh

<sup>2</sup> EEE Department, St.Johns College of Engineering and Technology, Yemmiganur, Andhra Pradesh

<sup>3</sup> PG Scholar, St.Johns College of Engineering and Technology, Yemmiganur, Andhra Pradesh

Email: pradeep\_yadav\_k@yahoo.co.in

## Abstract:

The comparative study between two most popular algorithms technique which is incremental conductance algorithm and perturbs and observe algorithm. Two different converters buck and boost converter use for comparative in this study. Few comparison such as voltage, current and power output for each different combination has been recorded. MATLAB Simulink tools have been used for performance evaluation on energy point.

**Key Words:** Maximum power point tracking MPPT, Photovoltaic PV, Direct current DC

## I. INTRODUCTION

The rapid increase in the demand for electricity and the recent change in the environmental conditions such as global warming led to a need for a new source of energy that is cheaper and sustainable with less carbon emissions. Solar energy has offered promising results in the quest of finding the solution to the problem. The harnessing of solar energy using PV modules comes with its own problems that arise from the change in insulation conditions. These changes in insulation conditions severely affect the efficiency and output power of the PV modules[1-3].A great deal of research has been done to improve the efficiency of the PV modules. A number of methods of how to track the maximum power point of a PV module have been proposed to solve the problem of efficiency and products using these methods have been manufactured and are now commercially available for consumers [1-3]. As the market is now flooded with varieties of these MPPT that are meant to improve the efficiency of PV modules under various insulation conditions it is not known how many of these can really deliver on their promise under a variety of field conditions. This research then looks at how a different type of converter affects the output power of the module and also investigates if the MPPT that are said to be highly efficient and do track the true maximum power point under the various conditions [1].

A MPPT is used for extracting the maximum power from the solar PV module and transferring that power to the load [4, 5]. 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 figure 1 . By changing the duty cycle the load impedance as seen by the source is varied and matched at the point of the peak power with the source so as to transfer the maximum power [5].

Therefore MPPT techniques are needed to maintain the PV array's operating at its MPPT [6]. Many MPPT techniques have been proposed in the literature; example are the Perturb and Observe (P&O) methods [4, 6-9], Incremental Conductance (IC) methods [7, 10-12], Fuzzy Logic Method [2, 4, 6, 11], etc. In this paper two most popular of MPPT technique (Perturb and Observe (P&O) methods and Incremental Conductance methods) and three different DC-DC converter (Buck and Boost converter) will involve in comparative study [13].

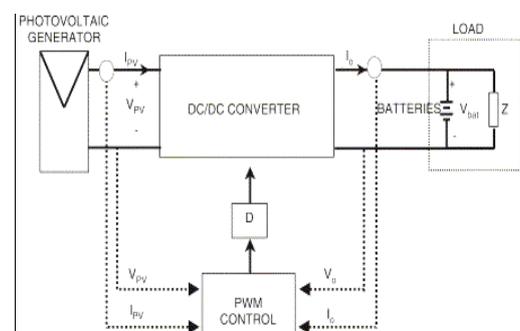


Fig. 1: Block diagram of Typical MPPT system

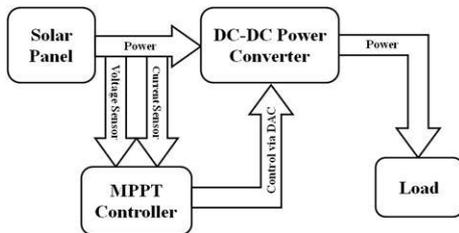


Fig. 2: DC – DC converter for operation at the MPP

Few comparison such as voltage, current and power output for each different combination has been recorded. Multi changes in duty cycle, irradiance, temperature by keeping voltage and current as main sensed parameter been done in the simulation. The MPPT techniques will be compared, by using MATLAB tool Simulink, considering the variant of circuit combination.

This paper is organized as follows: Section I gives the Introduction to the MPP Techniques. Section II gives the PV array introduction. Section III gives the DC-DC Converter Information. Section IV gives the Problem Overview. Section V gives the MPPT algorithms and Section VI and VII give the results and the conclusion respectively.

## II. PV ARRAY

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 [14]. The equivalent electrical circuit of an ideal solar cell can be treated as a current source parallel with a diode shown in figure 3.

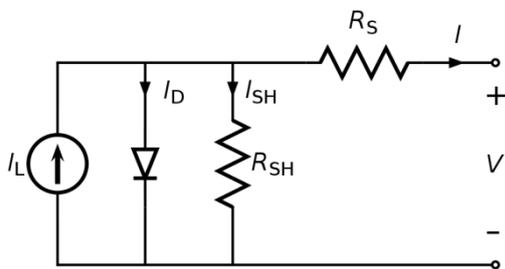


Fig. 3: Equivalent electrical circuit of a solar cell

The I-V characteristics of the equivalent solar cell circuit can be determined by following equations [14]. The current through diode is given by:

$$I_D = I \left[ \exp \left( \frac{q(V + I R_S)}{KT} \right) - 1 \right] \quad (1)$$

While, the solar cell output current:

$$I = I_L - I_D - I_{sh} \quad (2)$$

$$I = I_L - I \left[ \exp \left( \frac{q(V + I R_S)}{KT} \right) - 1 \right] - (V + I R_S) / R_{sh} \quad (3)$$

Where:

I : Solar cell current (A)

I : Light generated current (A) [Short circuit value assuming no series/ shunt resistance]

I<sub>D</sub>: Diode saturation current (A)

q : Electron charge (1.6×10<sup>-19</sup> C)

K : Boltzman constant (1.38×10<sup>-23</sup> J/K)

T : Cell temperature in Kelvin (K)

V : solar cell output voltage (V)

R<sub>s</sub>: Solar cell series resistance (Ω)

R<sub>sh</sub>: Solar cell shunt resistance (Ω)

## III. DC-DC CONVERTER

### A. Buck Converter

The buck converter can be found in the literature as the step down converter [15]. This gives a hint of its typical application of converting its input voltage into a lower output voltage, where the conversion ratio  $M = V_o/V_i$  varies with the duty ratio  $D$  of the switch [15, 16].

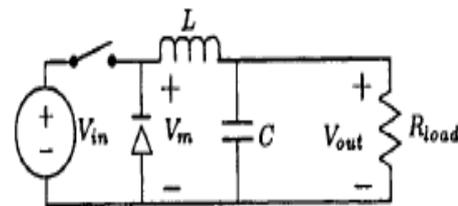


Fig. 4: Ideal buck converter circuit

### B. Boost Converter

The boost converter is also known as the step-up converter. The name implies its typically application of converting a low input-voltage to a high out-put voltage, essentially functioning like a reversed buck converter [15, 16].

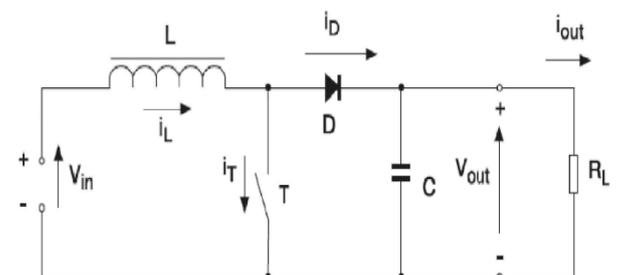




Fig. 5: Equivalent Circuit of a Boost Converter

**IV. PROBLEM OVERVIEW**

The problem considered by MPPT techniques is to automatically find the voltage  $V_{MPP}$  or current  $I_{MPP}$  at which a PV array should operate to obtain the maximum power output  $P_{MPP}$  under a given temperature and irradiance. It is noted that under partial shading conditions, in some cases it is possible to have multiple local maxima, but overall there is still only one true MPP. Most techniques respond to changes in both irradiance and temperature, but some are specifically more useful if temperature is approximately constant. Most techniques would automatically respond to changes in the array due to aging, though some are open-loop and would require periodic fine tuning. In our context, the array will typically be connected to a power converter that can vary the current coming from the PV array [6, 11, 14, 15].

**V. MPPT CONTROL ALGORITHM**

**A. Perturb and Observe (P&O)**

In this algorithm a slight perturbation is introduced into the system [7]. This perturbation causes the power of the solar module to change. If the power increases due to the perturbation then the perturbation is continued in that direction [7]. 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 algorithm oscillates around the peak point. In order to keep the power variation small the perturbation size is kept very small. A PI controller then acts moving the operating point of the module to that particular voltage level. It is observed that there is some power loss due to this perturbation also it fails to track the power under fast varying atmospheric conditions. But still this algorithm is very popular and simple [7].

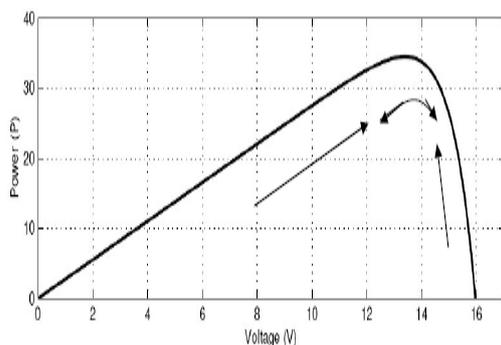


Fig. 7(a): Graph Power versus Voltage for Perturb and Observe Algorithm [7]

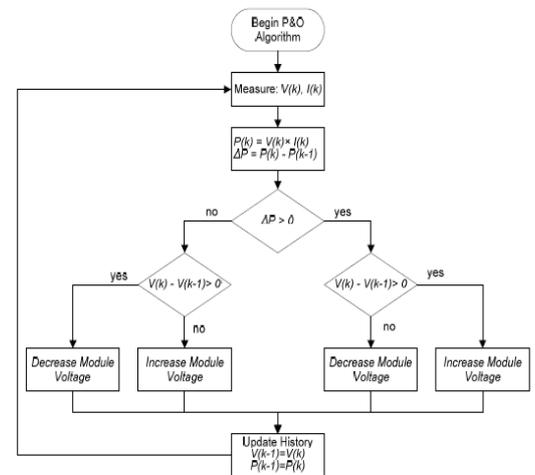


Fig. 7(b): Perturb and Observe Algorithm [17]

**B. Incremental Conductance (IC)**

The disadvantage of the perturb and observe method to track the peak power under fast varying atmospheric conditions is overcome by the IC method [7, 18]. The IC can determine when the MPPT has reached the MPP and stop perturbing the operating point. If this condition is not met, the direction in which the MPPT operating point must be perturbed can be calculated using the relationship between  $dI/dV$  and  $-I/V$  [7]. This relationship is derived from the fact that  $dP/dV$  is negative when the MPPT is to the right of the MPP and positive when it is to the left of the MPP. This algorithm has advantages over P&O in that it can determine when the MPPT has reached the MPP, where P&O oscillates around the MPP. Also, incremental conductance can track rapidly increasing and decreasing irradiance conditions with higher accuracy than perturb and observe [7]. One disadvantage of this algorithm is the increased complexity when compared to P&O [7].

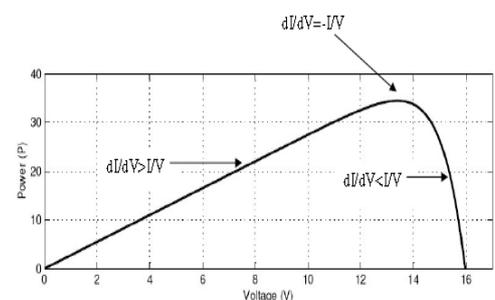


Fig. 8(a): Graph Power versus Voltage for IC



Algorithm [7]

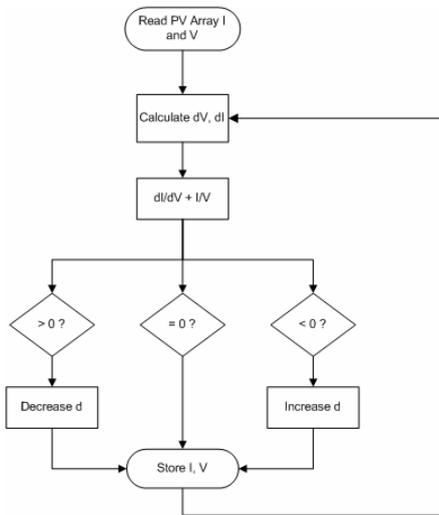


Fig. 8(b): IC Algorithm [7]

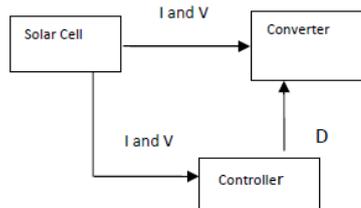


Fig.9: Basic Block Diagram for MPPT

**VI. RESULTS AND SIMULATION**

All simulation and result for every converter have been recorded to make sure the comparison of the circuit can be determined accurately. The input, output, voltage, current and power is the main comparison to take into consideration. The complexity and simplicity of the circuit have been determined based on the literature. Convergence speed, hardware required and range of effectiveness [4, 6]. Figure 10 take an insolation of 100 and temperature 50 as initial value.

*A. PV Panel Simulation*

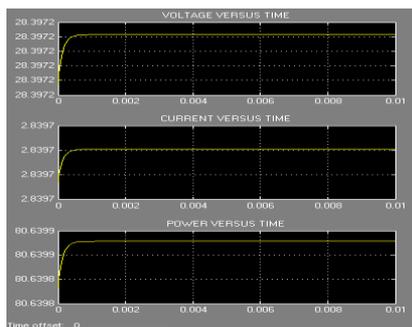


Fig. 10: Output Voltage, Current and Power for PV panel

Table 1: Output Value for PV Panel

Output Voltage	Output Current	Output Power
28.4 V	2.84 A	80.64 W

Result for insolation = 100 and temperature = 48<sup>o</sup>.

Table 2 show the comparison between three converter in theoretical and simulation value

Converter	Analysi s	Theoretical Value(V)	Simulation value (V)	Percentage Difference (%)
Buck	Vin	12	12	0
	Vout	5	5.087	1.74
Boost	Vin	12	12	0
	Vout	24	21.92	8.7

**COMPARISON BETWEEN BUCK, BOOST AND CONVERTER**

From table 2 calculate theoretical result and simulation result can be observe. The percentage between theoretical value and experimental value also can be seen from the simulation output. All three simulations give difference type of curve. Theoretical value calculated from the basic equation of converters. This involved the calculation when selection of component. Meanwhile the experimental value is from the simulation result using MATLAB simulink environment. In this comparison show that buck converter will give the best simulation result, follow by boost converter. All of this converter will be used in comparing two basic controller in MPPT.

**COMPARISON OF P&O CONTROLLER AND IC IN BUCK CONVERTER**

*B Buck Converter Simulation With Perturb and Observe Controller*

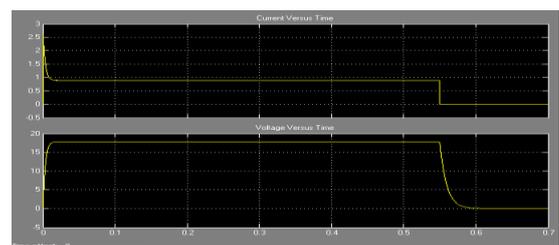




Fig 11: Output current and voltage for Buck and P&O Controller

IC	17.9	0.84	17.87	17.87	0.84	0.8391
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*C Buck Converter Simulation With Incremental Cond. Controller*

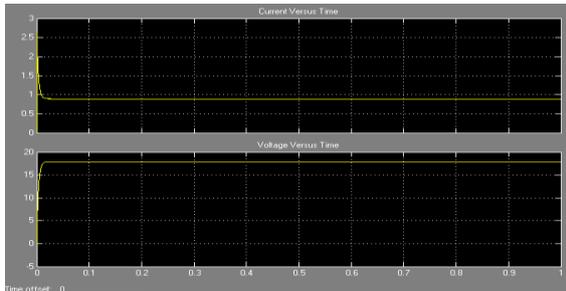


Fig 12: Output current and voltage for Buck and In Con Controller

Table 3 show the overall comparison for P&O and IC Controller. Once the converter injected the power from the solar panel and the controller start function, the value for of  $V_{in}$  to controller do not same value from output of the solar panel. This is because the controller function that varies the value of duty cycle will change the input value that sense by the controller. The input voltages of this controller show a different each other. Buck the connected with P&O give a value of 26.8 V therefore buck that connected with incremental conductance give value of 17.87V. In Incremental Conductance controller the output voltage and current is not change between input and output value. The Perturb and Observe Controller give a difference for input and output value. The output value behave as Buck converter behave. The voltage will drop from 26.8V to 16.8V and finally the voltage value is 534mV. In this system show that incremental conductance controller will work better with buck controller than perturb and observe controller. The incremental conductance controller will have the stable value from start to end of the simulation.

Table 3: Comparison Output Value Between Perturb & Observe and Incremental Conductance in Buck Converter

Controller	$V_{in}$ (V)	$I_{in}$ (A)	$V_{out1}$ (V)	$V_{out2}$ (V)	$I_{out1}$ (A)	$I_{out2}$ (A)
P&O	26.8	0.97	16.8	0.0534	0.97	0.007

COMPARISON OF P&O CONTROLLER AND IC IN BOOST CONVERTER

*D Boost Converter Simulation With P&O Controller*

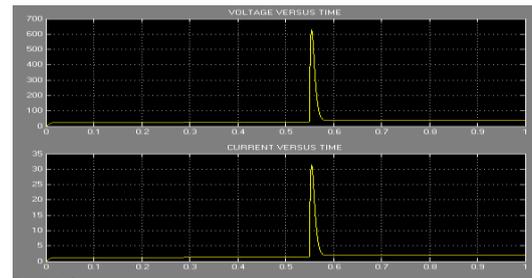


Fig 13: Output current and voltage for Boost and P&O Controller

*E Boost Converter Simulation With Incremental Cond Controller*

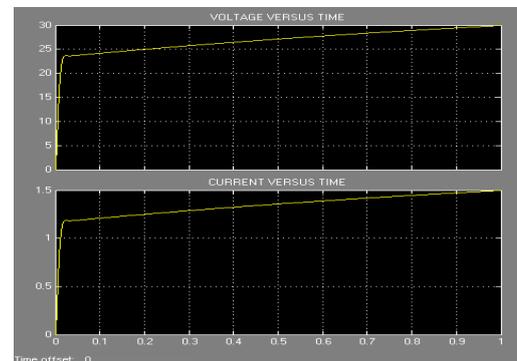


Fig 14: Output current and voltage for Boost and IC Controller

Table 4: Comparison Output Value Between Perturb & Observe and Incremental Conductance in Boost Converter

Controller	$V_{in}$ (V)	$I_{in}$ (A)	$V_{out1}$ (V)	$I_{out1}$ (A)
P&O	38.79	1.9	37.99	1.9
IC	38.62	175.3	29.92	1.496

From the simulation show that voltage input for both controller is almost the same. Perturb and Observe Controller shows a not stable condition. During the



simulation the current and voltage decrease rapidly and lastly came to same value at the initial stage. From the simulation result is shows that controller that connected with Boost converter which will give a stable output is the incremental conductance controller. Perturb and Observe controller can achieve maximum output value at 37.99 V that better than incremental conductance controller.

## VII. CONCLUSION

This paper has presented a comparison of two most popular MPPT controllers, Perturb and Observe Controller with Incremental Conductance Controller. This paper focus on comparison of two different converters which will connect with the controller. One simple solar panel that has standard value of insolation and temperature has been included in the simulation circuit. From all the cases, the best controller for MPPT is incremental conductance controller. This controller gives a better output value for buck and boost converter. Hence this controller will give different kind of curves for the entire converter. In simulation Buck converter show the best performance the controller work at the best condition using buck controller.

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