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A REVIEW ON LOW THD PV INVERTER USING SWITCHED CAPACITOR

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ABSTRACT

The output of solar cell varies nonlinearly with temperature, shading, irradiance, hence to extract maximum power out of it a MPPT algorithm is required. To understand which algorithm suits best for one's requirement this paper presents a comparative study of two popular hill climbing MPPT algorithms perturb & observe and incremental conduction their performance is evaluated using MATLAB.

Key-Words: - Maximum power point (MPP), maximum power point tracking (MPPT), photovoltaic (PV), comparative study.

1. INTRODUCTION

The world is advancing its journey to face energy crises due to increased pressure on conventional fuels. Their prices are steeply rising and will continue to rise due to modern lifestyle and various geopolitical situations, so it is best for humankind to switch to non-conventional forms for ever growing energy requirements

One solution that seems promising is solar energy. Sun has always been used as a source of energy since ancient era as it is free, abundant in nature, and non-polluting. However, it suffers from atmospheric hindrance, weather, climate, time & place of operation.

In modern world various techniques are available to harness solar energy, out of which Photo voltaic (PV) implies direct conversion of Radiation to electricity by exciting electrons from lower energy level to higher energy levels and force them to pass through external circuit making them do useful work.

Despite aforementioned advantages, the conversion efficiency of PV modules is low and appreciable initial setup cost reduces their widespread use in industry or for household purposes. This is where MPPT (Maximum power point tracking) schemes comes into picture to increase efficiency of solar panels / arrays by increasing the extracted output power of PV modules or arrays.

There is only one MPP for each curve at given temperature and irradiance level. The scope of this paper is to have a comparative study of two of the famous hill climbing type MPPT algorithm P&O (perturb and observe) and IC (Incremental conductance) used in continuous conduction mode to supply the given load using a dc-dc buck boost converter.

Within this context this paper demonstrates the performance of the two above mentioned techniques of MPPT, which uses the MATLAB software to implement and simulate real time situation. The specific scope of this paper comprehends the following issues:

i. Configuration of PV modules.
ii. Implementation and simulation of MPPT techniques (PO & IC).
iii. Comparison among the above two discussed MPPT techniques.

2. CONFIGURATION OF PV MODULES

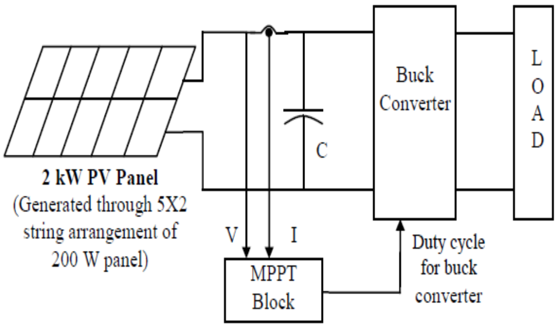

Figure 1. Block Diagram of system configuration

The block diagram of the system is shown in figure 1 wherein 10 PV panels KC200GT (Kyocera, 2013) each of 200watts are connected to form an array. These are arranged in a matrix of 5x2 (5rows and 2 columns) thus creating a maximum output of 2KW. The switching of buck converter is controlled using duty cycle output of MPPT block.

2.1 Modelling of PV panel

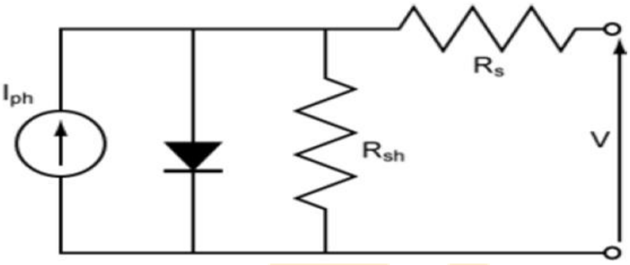

Figure 2. Single diode circuit of solar cell.

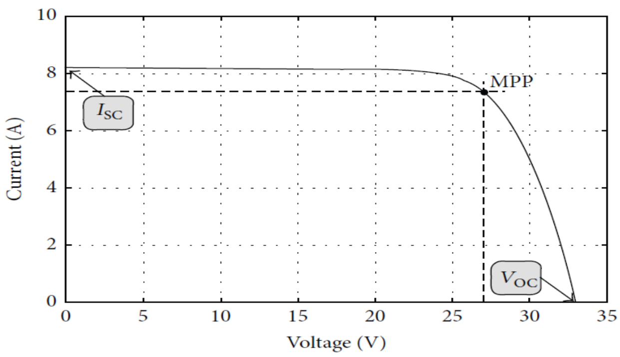

Figure 3. VI characteristic of solar cell.

The output power of the panel is given by $P_{max} = V_{max} \times I_{max}$. Thus there exist unique voltage and current corresponding to MPP.

MATLAB (Simulink environment) based mathematical model of PV panel has been made and the following equations were taken into account to find the variables.

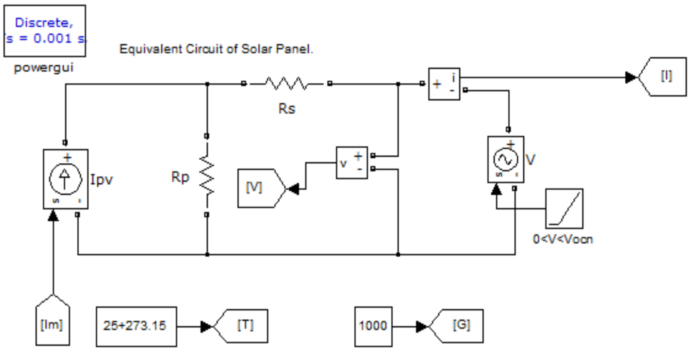

Figure 4. Model of solar panel.

$$Ipv = (Ipvn + Ki\Delta T)\frac{G}{Gn}$$

$$Io = \frac{Iscn + Ki\Delta T}{\exp(\frac{Vocn + Kv\Delta T}{aVt}) - 1}$$

$$\text{Im} = Ipv - Io\left[\exp\left(\frac{V + RsI}{aVt}\right) - 1\right] - \frac{V + RsI}{Rp}$$

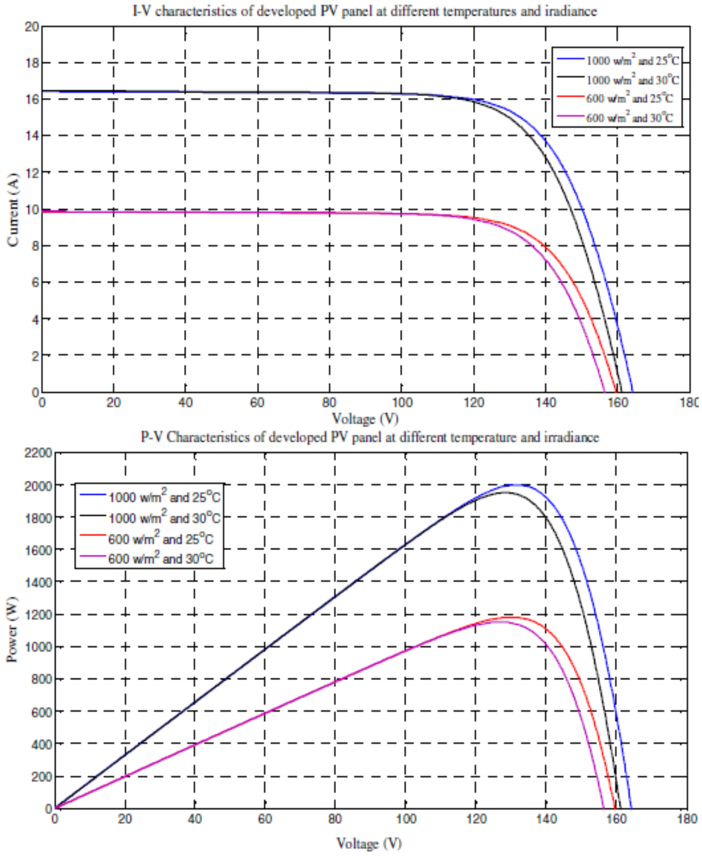

Figure 5. I-V and P-V characteristics of developed 2kW panel

3. MPPT ALGORITHMS

Maximum power point tracking scheme helps user to extract the maximum output power from solar panel by forcing it to operate on required voltage and current corresponding to MPP at a given Temperature/irradiance. In this paper two famous hill climbing type of MPPT algorithm PO & IC are taken for a comparative study.

3.1 Perturb and observe

This algorithm seems quite promising despite being simple to track maximum power. In this technique output power is sampled and then the PV module is forced to operate on different voltage if the extracted power is more than perturbation needs to be kept in same direction if the extracted power is less, then the perturbation needs to be reversed. However, this algorithm is sluggish and hovers around the MPP and can never reach it theoretically. The condition worsens if the characteristic curve changes due to change in atmospheric condition during perturbation steps.

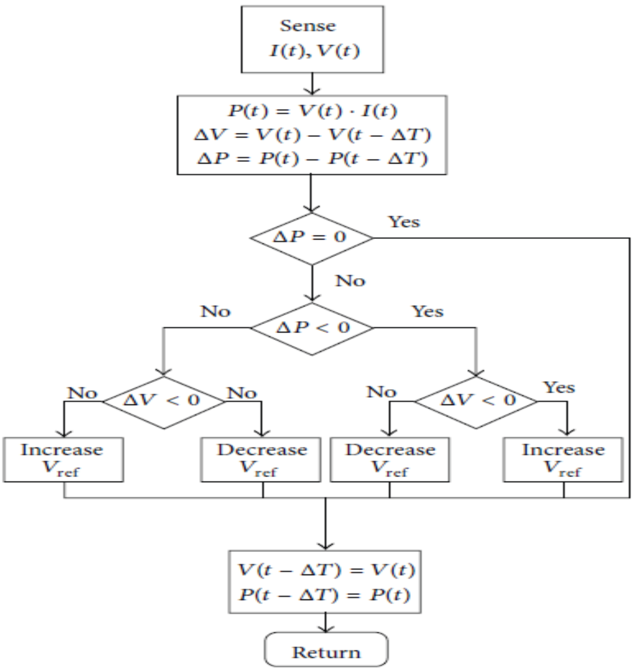

Figure 6. Flow chart of Perturb and Observe algorithm

3.2 Incremental conductance

IC method overcomes the limitation of convergence speed and steady state error faced in PO method. In this technique the derivative of the curve (slope) is measured and the algorithm exploits the fact that slope at MPP is zero.

$$\frac{dP}{dV} = \frac{d(V.I)}{dV} = V\frac{d(I)}{dV} + I\frac{d(V)}{dV} = I + V\frac{d(I)}{dV}$$

$$\frac{dP}{dI} = \frac{d(V.I)}{dI} = V\frac{d(I)}{dI} + I\frac{d(V)}{dI} = V + I\frac{d(V)}{dI}$$

Thus by comparing the instantaneous and incremental conductance the following inferences can be made.

(i) $\Delta I/\Delta V = -I/V$: the operating point lies exactly in the MPP;

(ii) $\Delta I/\Delta V > -I/V$: the operating point lies to the left of the MPP;

(iii) $\Delta I/\Delta V < -I/V$: the operating point lies to the right of the MPP.

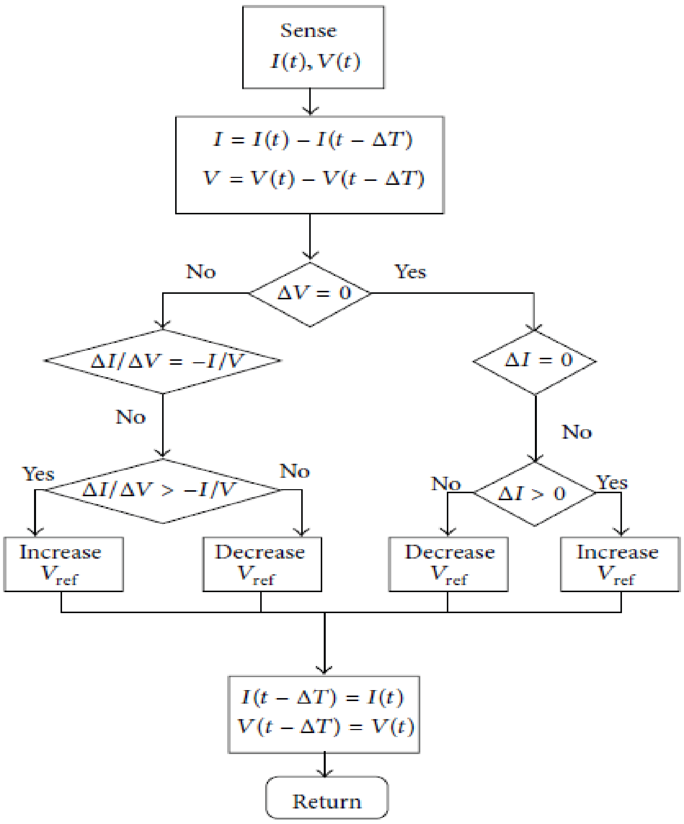

Figure 7. Flow chart of Incremental conductance algorithm

4. COMPARITIVE STUDY

4.1 Data sheets

Table 1. Design specification of buck-boost converter

Parameter	Value
Maximum power (P_{max})	2 kW
Output voltage (V_0)	100 V
Output voltage ripple (ΔV_0)	5% V_0
Inductor current ripple (ΔI_L)	5% I_0
Switching frequency (f_s)	70 kHz

Table 2. Characteristics of PV module KC200GT

(Kyocera, 2013)

Parameter	Value
Maximum power (P_{PVmax})	200 Wp
Maximum power voltage (V_{PVmax})	26.3 V
Maximum power current (I_{PVmax})	7.61 A
Open circuit voltage (V_{OC})	32.9 V
Short circuit current (I_{SC})	8.21 A
Temperature coefficient of V_{OC}	-1.23×10^{-1} V/°C
Temperature coefficient of I_{SC}	3.18×10^{-3} A/°C

Table 3. Power stage components for the designed buck-boost converter.

Parameter	Value
Load resistance	3.33 Ω
Filter inductance	1 mH
Output filter capacitance	37 μF
Maximum voltages across the switch and the diode	231.5 V
Average current through the switch	22.8 A
Rms current through the switch	34.7 A
Average current through the diode	30 A
Rms current through the diode	18 A

The temperature and irradiance may vary as per the following profile, which has been defined arbitrarily: 800W/m^2–32°C; 1000W/m^2–32°C; 700W/m^2–20°C; 500W/m^2–25°C; 200 W/m^2–32°C;

4.2 P&O Method

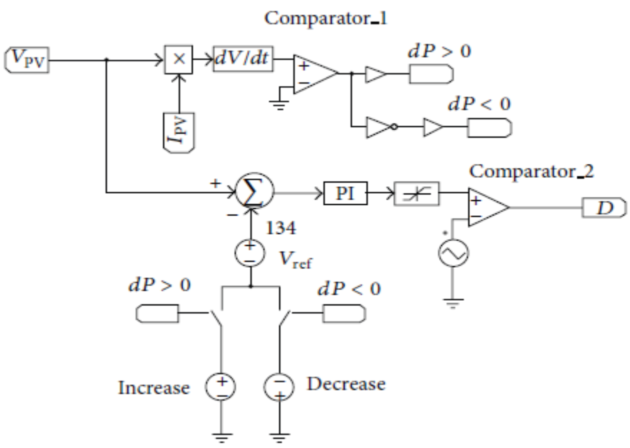

Figure 8. Implementation of P&O technique.

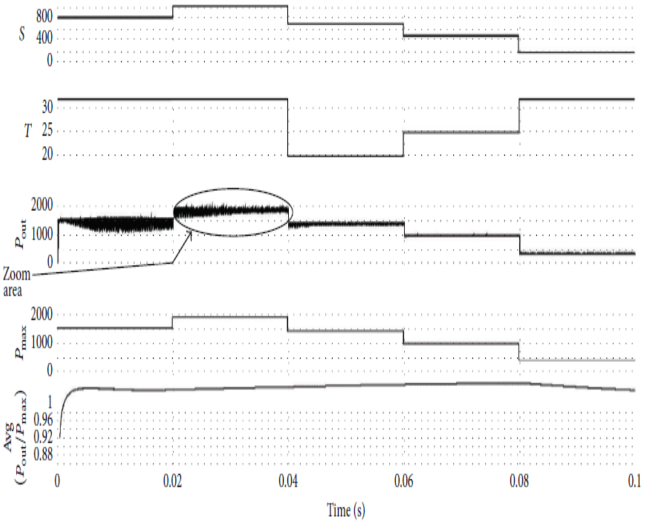

Figure 9. Irradiance profile (*S*), temperature profile (*T*), extracted power (*P*out), theoretical value of the maximum extracted power (*P*max), and average efficiency obtained with P&O technique.

Time (ms)	0–20	20–40	40–60	60–80	80–100
Temperature (°C)	32		20	25	32
Irradiance (W/m^2)	800	1000	700	500	200
Efficiency (%)	96.66	97.35	98.02	98.4	97.45

Table 4. Efficiency obtained for the P&O technique under distinct operating conditions.

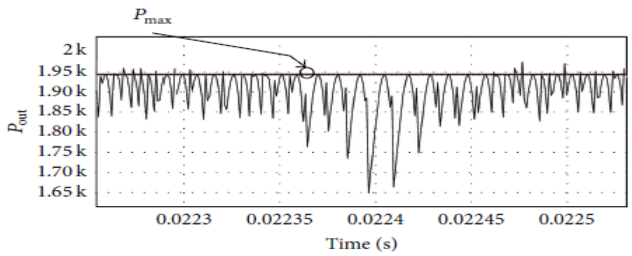

Figure 10. Detailed view of *P*out and *P*max when using P&O.

4.3 IC Method

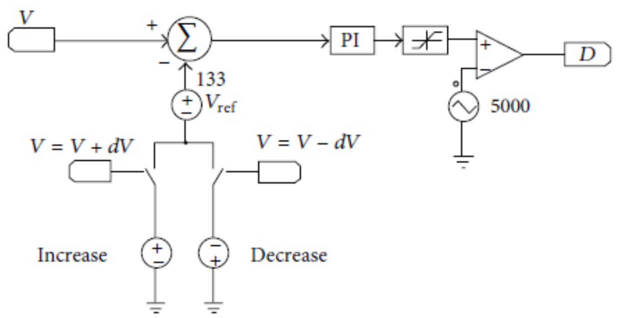

Figure 11. Implementation of IC technique.

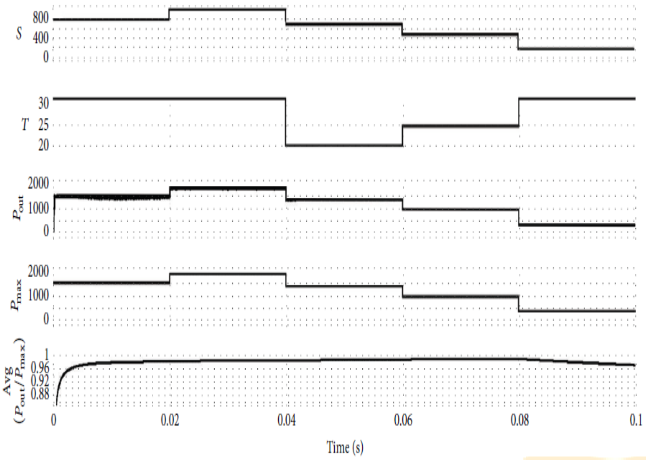

Figure 12. Irradiance profile (*S*), temperature profile (*T*), extracted power (*P*out), theoretical value of the maximum extracted power (*P*max), and average efficiency obtained with IC technique.

Time (ms)	0–20	20–40	40–60	60–80	80–100
Temperature (°C)	32		20	25	32
Irradiance (W/m^2)	800	1000	700	500	200
Efficiency (%)	98.42	98.66	98.87	99.11	97.59

Table 5. Efficiency obtained for the IC technique under distinct operating conditions.

4.4 Brief summary and conclusion

The methods described above hold their unique significance. P&O algorithm is quite simple and robust whereas IC can be chosen if accuracy and speed is of much concern however IC algorithm require more complex hardware implementations.

Table 6. Comparison of the global average efficiency for the MPPT techniques.

Technique	Average efficiency (P_{out}/P_{max})
P&O	97.58%
IC	98.53%

This paper presents the detailed comparative study of two famous hill climbing technique namely perturb and observe method and incremental conductance method. Out of which the incremental method is proved to be the best one due to its higher efficiency speed and reliability when large power is to be extracted.

5. REFERENCES

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