Comparitive Study of P&O and Incremental Conductance method for PV System

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Abstract— **The intension of this paper is to focus on efficient and optimized Photovoltaic system to obtain maximum power using power electronic devices. In general, Photovoltaic panel very rarely operates at maximum power point which results in poor efficiency. Optimization of Photovoltaic system is performed by using Maximum power point tracking (MPPT) algorithm for better efficiency. Generally, in MPPT, Perturb and Observe (P&O) algorithm is amply adopted. Though it tracks the peak power point accurately at constant irradiance and temperature it has some demerits like slow response and oscillations at different atmospheric conditions. To overcome this intricacy incremental conductance algorithm is preferred. The simulation is done to find out Current Voltage (I-V) and Power voltage(P-V) curves of PV module and PV panel under varying atmospheric conditions. The performances such as oscillations, tracking capability are compared for both incremental conductance algorithm and traditional P and O algorithm and superiority of incremental conductance over conventional Perturb and Observe MPPT algorithm are evaluated using the MATLAB/SIMULINK software.**

Keywords— ***Maximum power point tracking* (MPPT), *photovoltaic* (PV), *perturb and observe* (P&O), incremental conductance (InC).**

I. Introduction

With increasing bothering factors, such as global warming, damage to environment, fossil fuel deficit and sky rocketing oil prices renewable energy sources are gaining a lot of importance. Solar photovoltaic generators are most commonly used, as it is pollution free and maintenance free. A photovoltaic system inheres number of solar modules in cascade and shunted to reach output power requirements. The main hindrances that solar photovoltaic system facing are high installation cost and final electrical productivity is very low i.e. solar energy conversion to electrical energy is very low which ranges 9-17%, this indicates large space is inevitable to produce high electricity. Consequently, peak power point tracing indispensable to govern PV array at zenith point of power. There are several MPPT techniques, differ from each other in terms of algorithm complexity, implementation cost and sensors used. Depending on scheme of control variable as a) Duty cycle b) Current c) Voltage.

The operating voltage perturbation is observed in the P&O method that leads to changes in output power. These perturbations are continued till the peak power point is reached. In the Incremental conductance MPPT algorithm the inclination of power-voltage(P-V) curve in PV panel is observed to identify the maximum power point. Performance aspects such as convergence speed, number of sensors required, accurate tracking capabilities are compared. The organization of this paper is done as the block diagram explanation and outline of the project are explained in the first section. The mathematical modeling of PV module and panel in section two. In the third section perturb and observe (P&O) and incremental conductance algorithms are explained in detail. In section four delineation of parameters of the boost converter. Finally, simulation studies and analysis are executed and conclusions are summarized in the section five.

A. Schematic diagram of efficient photovoltaic system

boost converter to get peak power.

B. Outline of the work:

PV panel current and voltage are sensed and fed to MPPT controller. In MPPT controller depending on the type of algorithm used duty cycle is adjusted to reach the maximum power point. Therefore, by adjusting the duty cycle of the converter maximum power point is achieved.

II. MATHEMATICAL DESIGN OF PV MODULE

By photovoltaic effect, the solar cell converts sunlight into DC electricity. Solar cell Current-Voltage(I-V) and Power-Voltage(P-V) characteristics varies with solar irradiance and temperature.

A. Modeling of Photovoltaic cell

As equivalent circuit of PV cell, single diode model is used
in this paper as shown in fig.2a

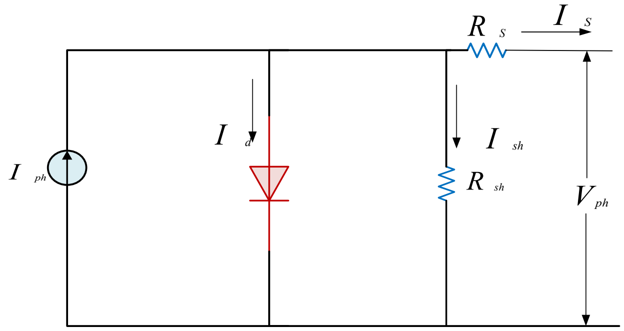


Fig.2.a. Equivalent circuit of PV cell

In the equivalent circuit, the elements are current source, uncontrolled switch, a cascade resistor and a shunt resistor.

Current of PV Panel:

$$I = I_{ph} - I_o\left[exp\left(\frac{V}{V_{ref}}\right) - 1\right] - \frac{V + IRs}{R_p} \; .... (1)$$

Where,

I_{ph} = Photo Current

I_o = Reverse Saturation or leakage current of the diode.

V is voltage inflict on the uncontrolled switch

$a = (N_s KT_c)/q = Ns.A.V_T$

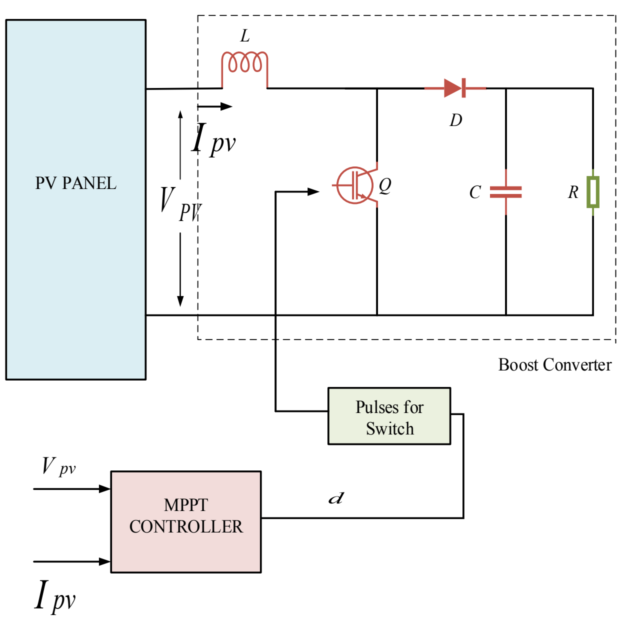
$$V_T = \frac{k.T_C}{q}$$

T_C is the actual cell temperature.

k is Boltzmann Constant = 1.368*10^ (-23) J/K

q is electron charge (1.602 * 10^ (-19)) coulombs

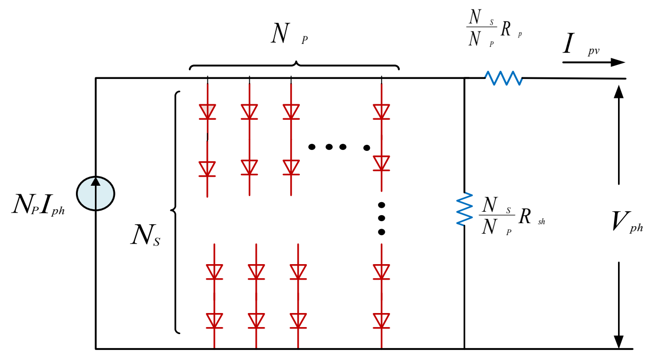
V_T is called the thermal voltage because of its exclusive dependence on temperature.



N_S is the number of PV cells cascaded.

A is the ideality factor.s

and other parameters are taken from [10], [2].



B. Modelling of PV Module

Fig. 2b Equivalent circuit of PV module.

N_p is number of solar cells connected in shunt. [3]

III. MPPT ALGORITHMS

In PV system MPPT tracking technique is used to maximize power extraction under all atmospheric conditions. P&O and Incremental conductance MPPT algorithms are executed. Both methods are explained briefly [5].

A. Perturb and Observe MPPT algorithm

By change in voltage (ΔV) the voltage is incremented or decremented in voltage based P and O MPPT algorithm [7],[9]. The differential change in power is calculated with respect to change voltage. The peak power is then reached when the change in power is zero. Normally change in the power may not be zero. If ΔV>0 leads to ΔP>0 then perturbation is in the same direction otherwise it is in the opposite such as

S. No	Perturbation	Change in Power	Next Perturbation
1.	Positive	Positive	Positive
2.	Positive	Negative	Negative
3.	Negative	Positive	Negative
4.	Negative	Negative	Positive

Table. 1 Implementation logic of P&O method

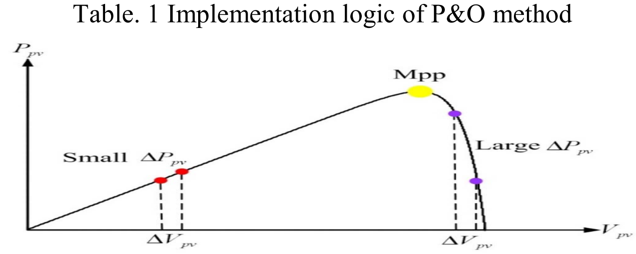


Fig. 3a Power Voltage(P-V) characteristics of PV panel indicating MPP

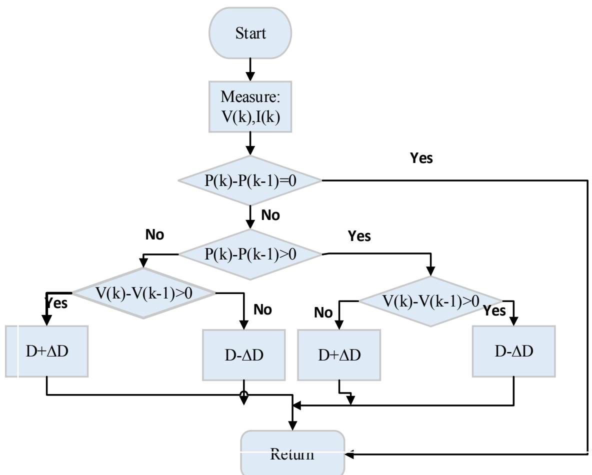


Fig. 3b Flowchart of P and O algorithm

B. Incremental Conductance MPPT algorithm

According to zenith point of power, the terminal voltage of PV panel is adjusted depending on the incremental and instantaneous conductance [11].

$P=VI$……………………………. (2)

By applying chain rule for derivative of products,

$\partial P/\partial V=[\partial(VI)]/\partial V$…………………. (3)

At maximum power point (MPP), as $\partial P/\partial V=0$, above equation can be inscribed in terms of panel voltage (V) and array current (I) as

$\partial P/\partial V=-I/V$…………………….. (4)

The MPPT regulates the PWM control signal of boost converter until the condition: $(\partial I/\partial V)+(I/V)=0$ is satisfied from equation (3). The peak power of the module lies at above 98 % of its incremental conductance in this method. The Flow chart of incremental conductance MPPT is shown in Fig. 3c

- When $\frac{dP}{dV}=I+\frac{dI}{dV}=0$, solar panel works at maximum power.
- When $\frac{dP}{dV}=I+\frac{dI}{dV}>0$, solar panel works in the left of maximum power. To reach the peak power point, changes are made to the right.
- When $\frac{dP}{dV}=I+\frac{dI}{dV}<0$, solar panel works in the right of maximum power. To reach the peak power point, changes are made to the left

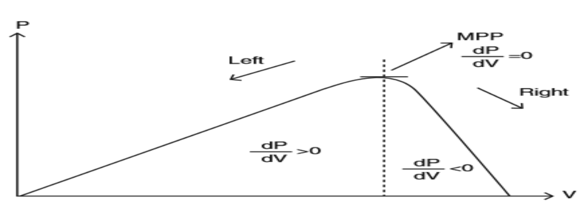
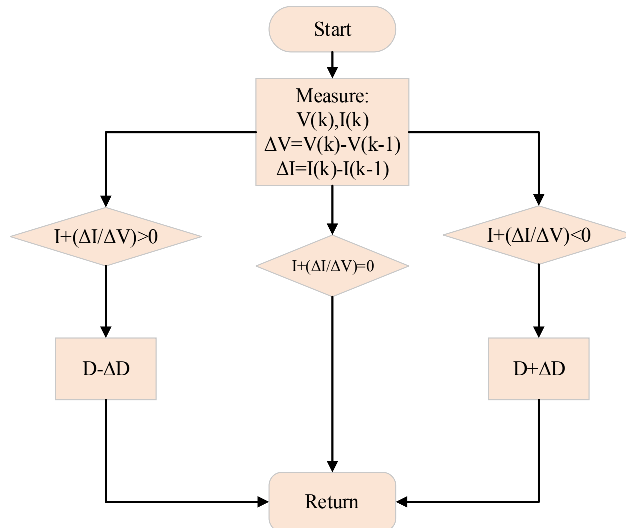


Fig. 3c Power Voltage characteristics of PV panel indicating



MPPT at $\frac{dP}{dV}=0$

Fig. 3c. Flowchart of Incremental conductance algorithm

IV. BOOST CONVERTER

Delineation of boost converter for MPPT application, at Standard Test Conditions of the PV panel [6]. The input parameters of the boost converter are taken from designation of PV panel tabulated in table no. 2 $V_{PV}=V_{MPP}$, $I_{PV}=I_{MPP}$ and $P_{PV}=P_{MPP}$. For load resistor R of 40Ω, the voltage output from converter is resolved. Assuming lossless converter.

$P_O=P_{PV}$ ……………………….. (5)

Therefore, the values of duty ratio (D) and V Power Voltage (P-V) characteristics of PV Panel with different irradiances (400W/ m^2, 600 W/ m^2 ,800 W//m^2,1000 W//m^2). o are derived as

$V_O=\sqrt{P_O R}=162$…………………… (6)

$D=\frac{V_{PV}}{V_O}=0.41$………………………. (9)

Values of inductor and capacitor,

The inductor value is depicted for 1% of the input current ripple ΔI_{PV} at switching frequency $f_{SW}=20$ KHz as the PV panel voltage also fluctuates with current. (6), (9)

$$L=\frac{V_{PV}D}{2\Delta\Delta_{PV}f_{SW}}=13.85\text{mH}$$

The voltage output of the capacitor is plotted for 1% output voltage ripple ΔV_O as

$$C = \frac{V_O D}{2\Delta\Delta_O R f_{SW}} = 25\mu F$$

In order to reduce Equivalent Series Resistor(ESR) effect two capacitors are affixed in shunt and value of capacitor is 440 µF

S. No	Parameters	Symbol	Value
1.	Zenith power	P_{MPP}	66.3
2.	Voltage at zenith point of power	V_{MPP}	22.8
3.	Current at zenith point of power	I_{MPP}	2.91
4.	Open circuit voltage	V_{OC}	26.8
5.	Short circuit current	I_{SC}	3.11
6.	Current temperature coefficient	$\alpha I_{SC}\left(\frac{\%}{°C}\right)$	0.013
7.	Voltage temperature coefficient	$\beta V_{OC}\left(\frac{\%}{°C}\right)$	-0.72

Table.2. Specifications of PV module at STC

S. No	Parameters	Symbol	Value
1.	Zenith power	P_{MPP}	1060.8
2.	Voltage at zenith point of power	V_{MPP}	91.2
3.	Current at maximum power	I_{MPP}	11.64
4.	Open circuit voltage	V_{OC}	107.2
5.	Short circuit current	I_{SC}	12.44
6.	Current temperature coefficient	$\alpha I_{SC}\left(\frac{\%}{°C}\right)$	0.013
7.	Voltage temperature coefficient	$\beta V_{OC}\left(\frac{\%}{°C}\right)$	-0.72

Table.3. Specifications of PV panel at STC

V. SIMULATION RESULTS AND ANALYSIS

Characteristics of the PV panel from equation (1), are obtained by using simulation with changes and without changes in atmospheric conditions

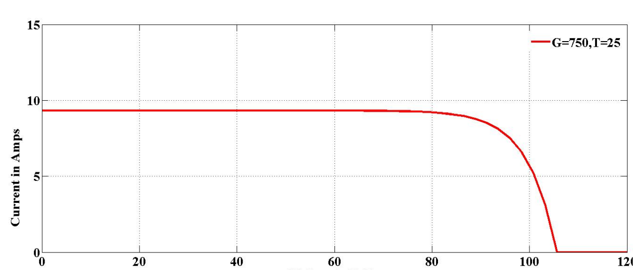


Fig.5.1 Current Voltage (I-V) characteristics of PV Panel with irradiance 750 W/, Temperature 25.

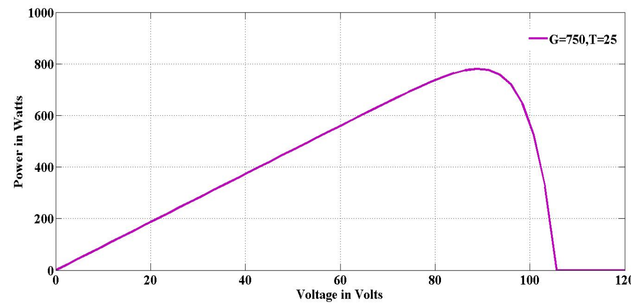


Fig.5.2. Power Current (P-V) characteristics of PV Panel with irradiance 750 W/ Temperature 25.

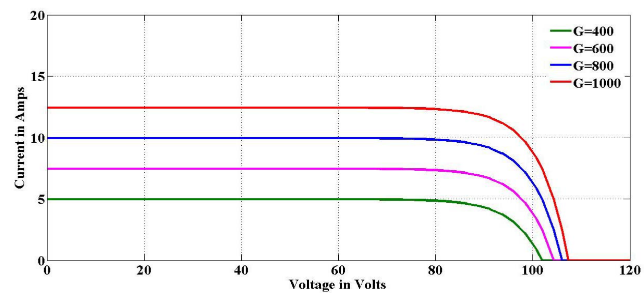


Fig.5.3. Current Voltage (I-V) characteristics of PV Panel with different irradiances (400W/m^2, 600 W/m^2,800 W//m^2,1000 W//m^2).

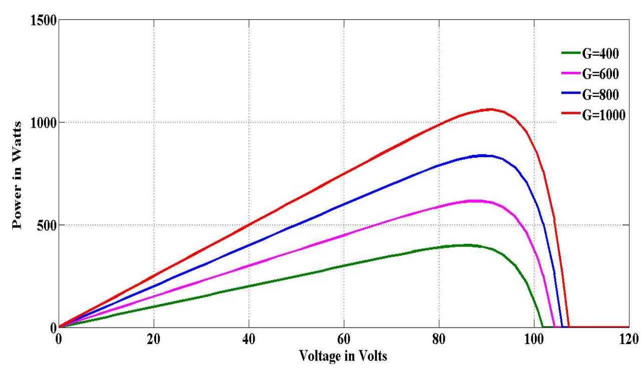


Fig.5.4 Power Voltage (P-V) characteristics of PV Panel with different irradiances (400W/m^2, 600 W/m^2,800 W//m^2,1000 W//m^2).

A. *Simulation results of Photovoltaic panel with and without MPPT*

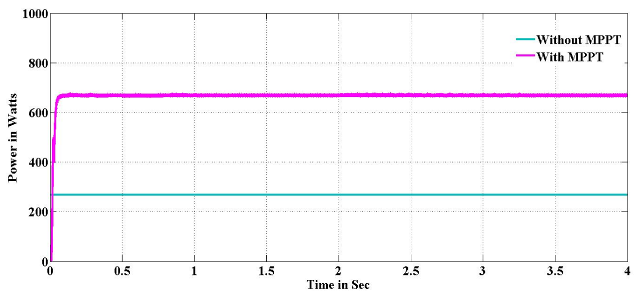


Fig. 5.5 Comparison of Power waveforms of converter with and without MPPT.

Analysis 1: From the results of simulation it can be seen that PV panel power ratings are less without MPPT therefore, power transfer capability is very less and efficiency decreases. PV panel with MPPT reaches the maximum power point.

B. *Simulation results of comparison of P&O algorithm and Incremental conductance algorithm*

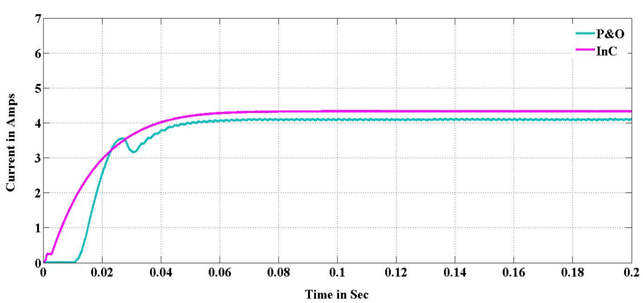


Fig. 5.6. Comparison of, Current waveform of P and O MPPT and Incremental Conductance MPPT with irradiance 750W/m^2, Temperature 25 °C

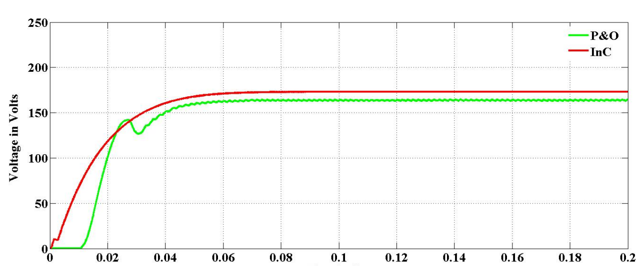


Fig. 5.7. Comparison of Output Voltage waveform of P and O MPPT and Incremental Conductance MPPT with irradiance 750 W/m^2, Temperature 25 °C .

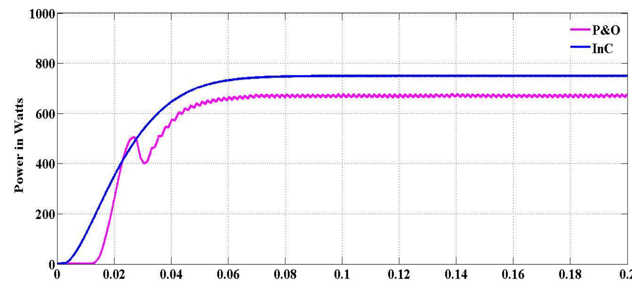


Fig. 5.8. Comparison of Output Power waveform of P and O MPPT and Incremental Conductance MPPT with irradiance 750 W/m^2, Temperature 25 °C .

Analysis 2: From the results, it can be inferred that Incremental conductance has smooth response and tracks the zenith point more accurately and quickly when compared to conventional the P&O method.

C. *Simulation results of perturb and observe algorithm and Incremental conductance algorithm with sudden change in the irradiance*

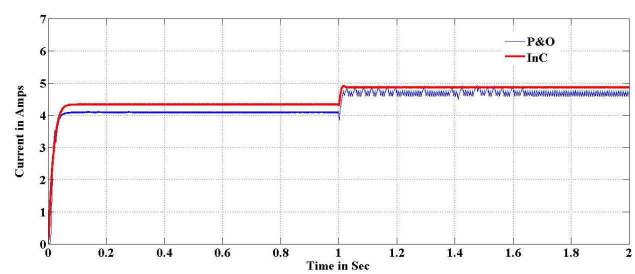


Fig. 5.9. Comparison of Output Current waveform of P and O MPPT and Incremental Conductance MPPT considering sudden change in the Irradiance (750 W/m^2 and 1000W/m^2).

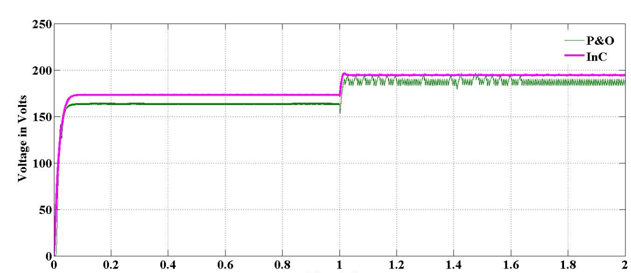


Fig. 5.10. Comparison of Output voltage waveform of P and O MPPT and Incremental Conductance MPPT considering sudden change in the Irradiance (750 W/m^2 and 1000W/m^2).

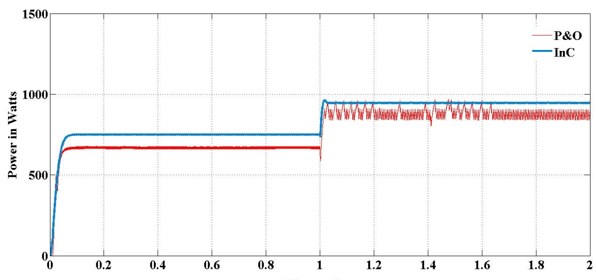


Fig. 5.11. Comparison of Output Power waveform of P and O MPPT and Incremental Conductance MPPT considering sudden change in the Irradiance (750 W/m^2 and 1000W/m^2).

Analysis 3: From the simulation results it is seen that with sudden changes in the irradiance, InC has very less oscillations with fast response and accurate tracking capability compared P and O method.

S. No	**At various atmospheric conditions**	**Output Power**		**Percentage increase in power**
		P&O	*InC*	
1.	At irradiance 750 W/m^2, Temperature 25°C	673.1	750.7	11.5%
2.	At irradiance 750 W/m^2, Temperature 30°C	655	722	10.2%
3.	At irradiance 750 W/m^2, Temperature 40°C	631	652.4	3.99%
4.	At Temperature 25°C, irradiance 800 W/m^2	733.6	806.9	9.99%
5.	At Temperature 25°C, irradiance 900 W/m^2	836.2	890.3	6.46%
6.	At Temperature 25°C, irradiance 1000 W/m^2	875	945.3	8.03%

Table 4 Output power of both P&O , InC methods and calculating percentage increase of power in proposed InC method

VI. CONCLUSION

In this paper, PV Panel is modelled and various characteristics like Current vs Voltage and Power vs Voltage are obtained under varying atmospheric conditions. The most adopted P&O MPPT algorithm and I&C algorithm are simulated. The performance of PV panel with and without MPPT algorithm are evaluated and results show, that PV panel without MPPT generates very less output power. A comparative study of both the MPPT algorithms for steady state and dynamic response has been made. The results show that I&C MPPT algorithm tracks the maximum power point better than the P&O algorithm. About 11.5% percentage increase in power is noticed at irradiance of 750W/m^2 at 25^o C., thereby increasing the efficiency of solar energy conversion. Though the I&C algorithm requires an additional sensor compared to the P&O algorithm, it has fast response with very less oscillations under steady and transient conditisons of sudden changes in the irradiance and temperature.

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