WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Incremental Conductance Algorithm for PV System

Prashant N. Donge [a], Gaurav Karlekar [b]

[a] PG Scholar, Department of Electrical engg., Ballarpur Institute of Technology, Bamni, Tah-Ballarpur Dist- Chandrapur 442701, India,

[b] Assistant professor, Department of Electrical engg., Ballarpur Institute of Technology, Bamni, Tah-Ballarpur Dist- Chandrapur 442701, India,

A B S T R A C T

Maximum power point tracking (MPPT) techniques are used in photovoltaic (PV) systems to extract maximum power from the PV module. Incremental conductance (INC) method is widely used because of its low-cost and ease of implementation. The INC method oscillates close to maximum power point (MPP), when atmospheric conditions are constant or slowly varying. However, when irradiance and temperature are changing rapidly, this method fails to track MPP with rapid speed. This paper presents characteristics of the PV device, which are affected by the atmospheric factors like irradiation and temperature etc. Basic Incremental conductance MPPT algorithm to track the maximum power available in the solar panel. The MPPT method Incremental conductance is implemented in MATLAB/M-files.

Keywords: Solar Photovoltaic (PV); Modeling; Maximum power point tracking (MPPT); Incremental Conductance (INC).

1. Introduction

Growing demand for energy and the increasing concern about the environmental impact from excessive use of fossil Fuels have progressively increased the interest in renewable Energy research. Among the alternative sources, solar power generation is currently considered as a natural energy source that is more useful, as it is pollution free, maintenance free, distributed over the earth, fast technological progress and Continuous cost reduction. The fundamental element in solar power generation system is the solar cell or photovoltaic (PV) cell that converts sunlight into direct current (DC) electricity. The basic device of a PV system is the PV cell. Cells may be grouped to form panels or arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors. Applications that are more sophisticated require electronic converters to process the electricity from the PV device. In general, the larger the area of a module or array, the more electricity that it can produce [1]. The biggest disadvantage of solar energy production revolves around the fact that power Generation is not constant throughout the day; it is always changing with weather conditions, i.e., irradiation and temperature. Furthermore, the efficiency of solar energy conversion to electrical energy is very low which is only in the range of 9-17% [2]. Therefore, it is important to track maximum power point of solar photovoltaic system. There are many MPP tracking methods have been developed and implemented. The MPPT methods vary in complexity, sensors required, convergence speed, cost, range of effectiveness and in other aspects. Among the different MPPT methods perturb and observe (Hill climbing method), Incremental conductance, fractional short circuit current, fractional open circuit voltage and Ripple correlation control these are some well-known methods. Maximum power point can be tracked by comparing the instantaneous conductance to the incremental conductance. Incremental conductance method overcomes the drawback of Perturb and Observe method by using PV arrays incremental conductance to compute the sign of (dp/dv) without perturbation. Incremental conductance method is effective while working with long time partial shading condition by varying duty ratios of boost converter. Ripple correlation control uses ripple that exists in all switching power converters to extract information about the operating point of the solar panel [3].

2. Solar PV Modeling

Solar Photovoltaic (PV) system studies need a reliable and accurate mathematical model to predict energy production from the PV resource under various irradiance and temperature conditions. In order to study the electronic converters for PV systems, it is necessary to know how to model the PV device, which is attached to the converters. The Mathematical model of the PV device useful in the study of the dynamic analysis of converters, especially in the study of maximum power point tracking algorithms. Modeling of the PV models can be categorized into two main types, single diode models and double diode models. The double diode model is characterized by its high accuracy; however, it is relatively complex and suffers from low computational speed. The second type, single diode model, is the most commonly used model in power electronics simulation studies, because it offers a reasonable tradeoff between simplicity and accuracy. Another advantage of using single diode model is the possibility to parameterize it based only on provided information by datasheet of solar PV panel. PV manufacturing datasheets provide only four information about the output electrical characteristics of their PV modules at standard test conditions (STC), which are short-circuit current I_{sc}, open circuit voltage V_{oc}, operating voltage and current at maximum power point(V_m,I_m), and the implicit information that the peak of P–V curve occurs at the voltage point(V_m). Thus, only four equations can be written accurately relying on datasheet information. However, single diode PV models have five unknown parameters, which need to be estimated. To compensate, the parameterization in starts with one predefined parameter, the ideality factor, and then derives the rest four parameters accordingly. [4].

There are more than sixteen equations available for the modeling of the PV device. Out of which some important equations are as follows, From equivalent circuit, Output current of the PV device (I) in ampere is given as,

$$I = Ip - Is\left(\exp\left(\frac{V + I\,Rs}{aVt}\right) - 1\right) \quad (1)$$

Where, Ip is the photocurrent; Is is the reverse saturation current which is affected by the temperature of the PV cell; V is the voltage applied on the diode; a is the ideality factor, which normally varies from 1 to 2 depending on the diode itself, and in this case, it is assumed to be approximately equal to 1.82; Vt is the thermal voltage ($Vt = \frac{kBT}{q}$) with the Boltzmann constant k_B=1.38 × 10−23 J/K; T is the absolute temperature of the diode in Kelvin; and q = 1.6 × 10−19 C is the charge represented by an electron. Finally, R_s is the equivalent series resistance of the PV array [5-6].

Output voltage of the PV device (V) in volts is given as,

$$V = \frac{akTr}{q}\ln\left[\frac{Ip + Is - I}{Is}\right] - IRs \quad (2)$$

The photocurrent generated by the light depends linearly on Irradiation of the sun and the temperature of the cell expressed as follows influences it: Photocurrent (I_P) generated when light incident in ampere is given as,

$$Ip = Ipr + ki(T - Tr) \quad (3)$$

Reverse saturation current (I_s) in ampere is given as,

$$Is = Isr\left(\frac{T}{Tr}\right)^{\frac{3}{a}} exp\left(\frac{-qVg}{ak}\left(\frac{1}{T} - \frac{1}{Tr}\right)\right) \quad (4)$$

Where, Reference Reverse saturation current (I_{sr}) in ampere is given as,

$$Isr = \frac{Iscr}{\exp\left(\frac{qVocr}{akTr}\right)} \quad (5)$$

Where, Vg is the band gap voltage of the semi-conductor. It is set at 1.12V in this paper. The series resistance can be determined by, Series resistance (R_s) of the PV device in Ohm and given as,

$$RS = \frac{-dV}{dIVoc} - \frac{1}{Xv} \quad (6)$$

$$Xv = Iscr\frac{q}{kBTr}\exp\left(\frac{qVocr}{akBTr}\right) \quad (7)$$

Where, $\frac{dV}{dIVoc}$ can be generated from manufacturers' data.

Table I: KEY SPECIFICATIONS OF KC200 GHT PV Module

Dimensions	**Specifications**
Length	1425(±2.5)mm
Width	990(±2.5)mm

Parameters At 1000 W/m^2 **(STC)**	**Ratings**
Maximum power (P_m)	200W
Maximum Power Voltage (V_{mp})	26.3V
Maximum Power Current (I_{mp})	7.61A
Open Circuit Voltage (V_{oc})	32.9V
Short Circuit Current (I_{sc})	8.21A
Parameters At 800 W/m^2 **(NOCT)**	**Ratings**
Maximum power (P_m)	142.21W
Maximum Power Voltage (V_{mpp})	23.2V
Maximum Power Current (I_{mpp})	6.13A
Open Circuit Voltage (V_{oc})	29.9V
Short Circuit Current (I_{sc})	6.62A

3. Characteristic of PV System

The characteristics of Solar PV panel describes the effective performance of solar PV panel under different environmental conditions such as irradiation, temperature etc. these atmospheric factors affect the output power of the PV panel. To analyze the characteristics of the PV panel the specific solar panel

Kyocera KC200 GHT PV module is utilized. Each PV module consists of 54 series connected cells. The key specifications for the PV module from the manufacturers' data sheet are listed in Table I. A model of the PV array is created in MATLAB with M-files.

The characteristics of the PV device is mainly affected by the atmospheric conditions such as,

3.1 Effect of different Irradiation levels

The effect of different Irradiation level can be analysed by keeping the other environmental factors constant. Such as temperature, shading effect of PV panel etc. The effect of different Irradiation levels directly affects the output current of PV device. As the higher the value of Irradiation level higher will be the output current of the PV device and vice-versa. Output voltage of the PV panel is less affected by the variation of irradiation level.

3.2. Effect of different Temperature levels

The effect of different Temperature level (difference between ambient temperature and Nominal temperature) can be analysed by keeping the other environmental factors constant. Such as Irradiation, shading effect of PV panel etc. The effect of different Temperature levels directly affects the output current of PV device. As the higher, the value of Temperature level lower will be the output voltage of the PV device and vice-versa. Output current of the PV panel is less affected by the variation of Temperature level.[7].

4. Incremental conductance (INC) MPPT method

The Incremental conductance (INC) method is based on the fact that the slope of the PV array power curve is zero at the MPP, positive on the left of the MPP, and negative on the right, as given by,

$$\frac{dP}{dV} \geq 0 \quad \text{At Left of MPP}$$

$$\frac{dP}{dV} \leq 0 \quad \text{At Right of MPP}$$

$$\frac{dP}{dV} = 0 \quad \text{At MPP} \qquad (4.9)$$

$$\frac{dP}{dV} = \frac{d(IV)}{dV} = I + V\frac{dI}{dV} \cong I + V\frac{\Delta I}{\Delta V} \qquad (4.10)$$

Equation (4.9) can be rewritten as,

$$\frac{\Delta I}{\Delta V} \geq \frac{-I}{V} \quad \text{At Right of MPP}$$

$$\frac{\Delta I}{\Delta V} \leq \frac{-I}{V} \quad \text{At Left of MPP}$$

$$\frac{\Delta I}{\Delta V} = \frac{-I}{V} \quad \text{At MPP} \qquad (4.11)$$

This method based on the whether the array voltage is greater than or less than peak power point voltage. Equation (4.10) shows that maximum power point can be tracked by comparing the instantaneous conductance to the incremental conductance. Incremental conductance method overcomes the drawback of Perturb and Observe method by using PV arrays incremental conductance to compute the sign of $\left(\frac{dP}{dV}\right)$ without perturbation. This helps to determine the Maximum power point technique has reached the maximum power point and stop perturbing the operating point. Although this method has the drawback is that it increases the complexity compared to Perturb & Observe method, requires more time for computation.

Fig.4.6 showing a typical PV curves with relationship between instantaneous conductance and incremental conductance. Equation (4.10) showing that at maximum power point both instantaneous and incremental conductance has same value. Thus maximum power point can be tracked. This method has the advantage over the Perturb & Observe of not oscillating around the maximum power point under rapidly varying environmental conditions. Fig.4.7 showing the flowchart of Incremental conductance, in which incremental conductance is compared with instantaneous conductance and thus maximum power point is tracked. Increment size determines the how fast maximum power point is tracked. Fast tracking can be achieved with bigger increments but the system might not operate exactly at the maximum power point and oscillate about instead. This method has complex circuitry; accuracy of the method depends on the iteration size, which is usually fixed for the conventional incremental conductance method. The increment size determines how fast the MPP is tracked. In some of the modified Incremental conductance method variable step size is implemented. The step size is automatically tuned according to the inherent PV array characteristics. If the operating point is far from MPP, it increases the step size which enables a fast tracking ability. If the operating point is near to the MPP, the step size becomes very small that the oscillation is well reduced contributing to a higher efficiency. But generally, The INC MPTT algorithm usually uses a fixed iteration step size, which is determined by the accuracy and tracking speed requirement. Thus, the corresponding design should satisfactorily address the trade-off between the dynamics and steady state oscillation. Fast tracking can be achieved with bigger increments but the system might not operate exactly at the MPP and oscillate about it instead; so there is a trade-off. A method is proposed that brings the operating point of the PV array close to the MPP in a first stage and then uses Incremental Conductance to exactly track the MPP in a second stage.

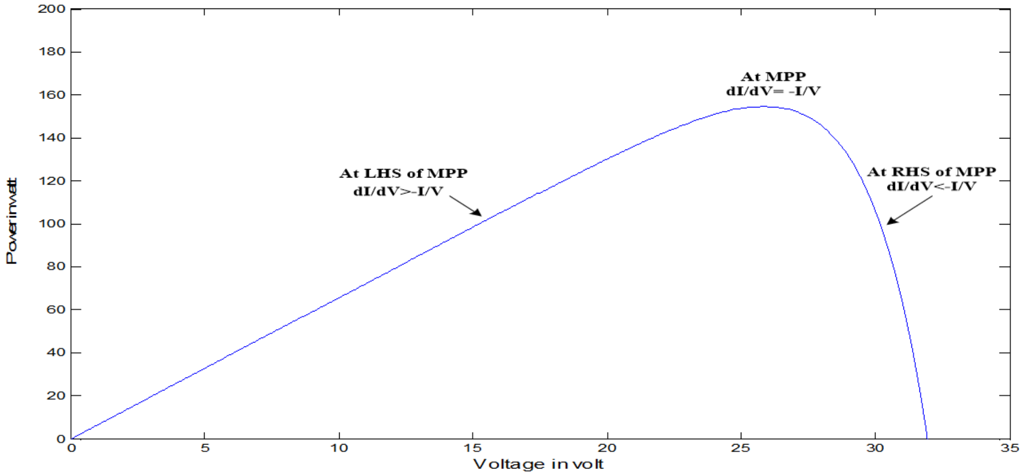

Fig. 4.6 Conductance showing Typical P-V curve

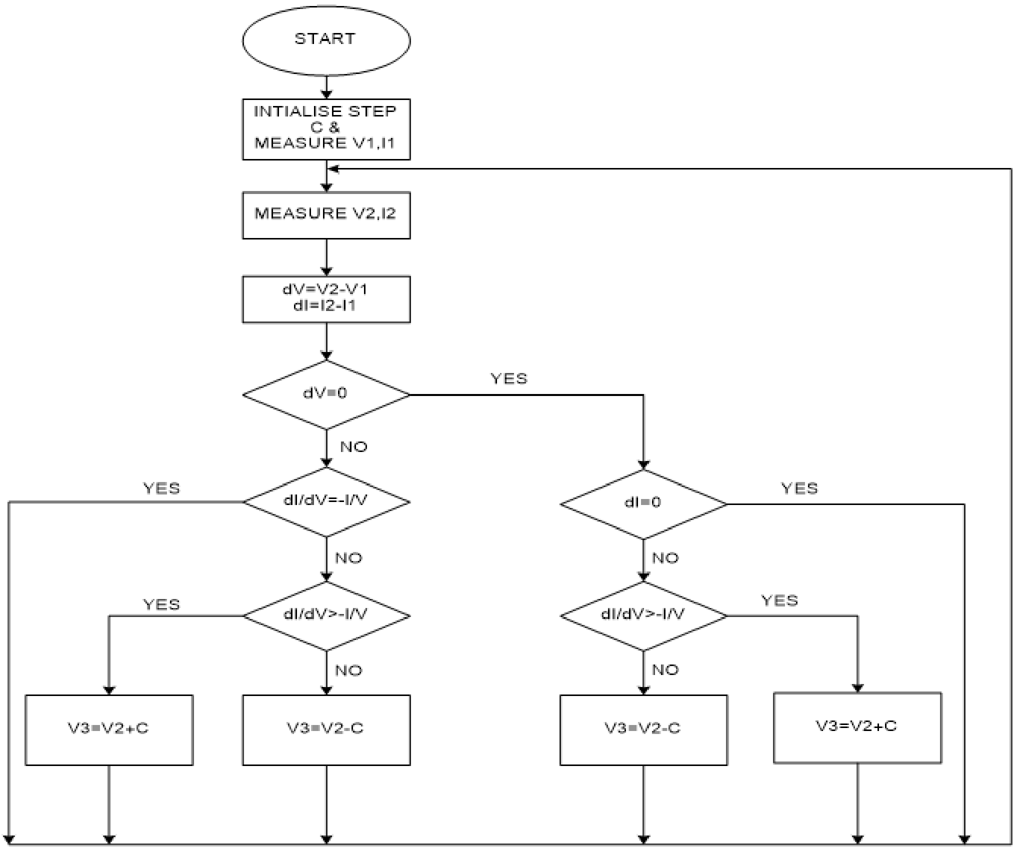

Fig. 4.7 Flowchart of Incremental Conductance

Fig.3 shows the flowchart of P&O MPPT algorithm [10]. This algorithm continuously compares the previous voltage sample with present voltage sample. If this change in voltage is greater than zero (dV>0) in that case P&O algorithm continuously perturbs the voltage in the same direction until Maximum power point is reached. If change in voltage is less than zero (dV<0) in that case this algorithm perturbs the voltage in reverse direction so that it reaches back to Maximum power point.

This algorithm has the drawback that after reaching the maximum power point its starts deviating on the maximum power point continuously all the time results in the substantial amount of power loss at maximum power point. Although this algorithm is quite simple to implement and it requires only one voltage sensor so, the cost of implementation of this algorithm is low [11].

5. Result and Discussion

5.1. Characteristics of PV device

Fig.4 shows V-I and Fig.5 shows V-P Characteristics of solar PV module with different Irradiation levels such as 1000 w/m^2,800 w/m^2 and 600 w/m^2 keeping the temperature level constant. It clearly shows that at low irradiation level the output current of PV device is more affected compared to output voltage.

Fig.6 shows V-I and Fig.7 shows V-P Characteristics of solar PV module with different temperature levels such as 25 deg., 50 deg. and 75 deg. keeping the irradiation constant. It also shows that as the temperature increases the output voltage of the PV device is reduces and vice-versa.

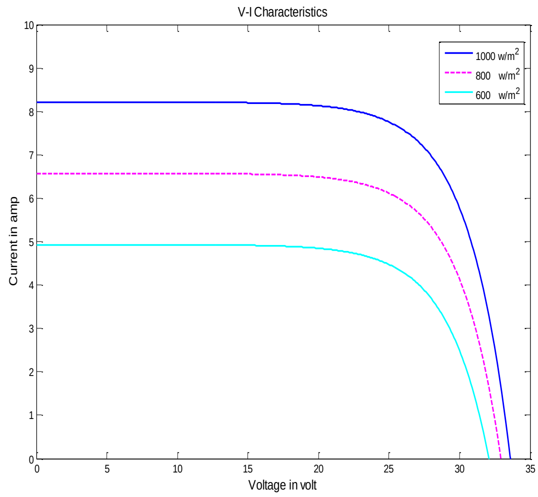

Fig.4 *V-I Characteristics of solar panel with different Irradiation*

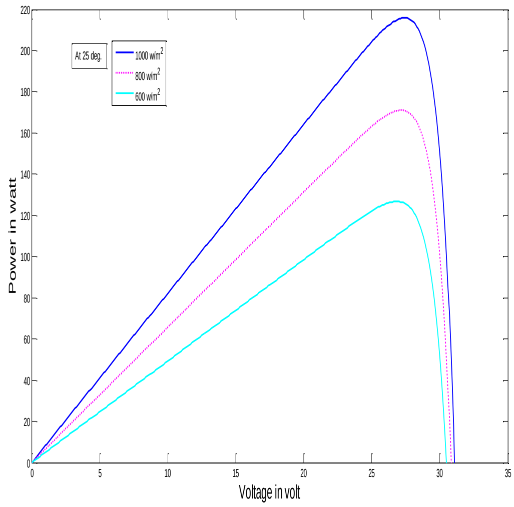

Fig.5 *V-P Characteristics of solar panel with different Irradiation*

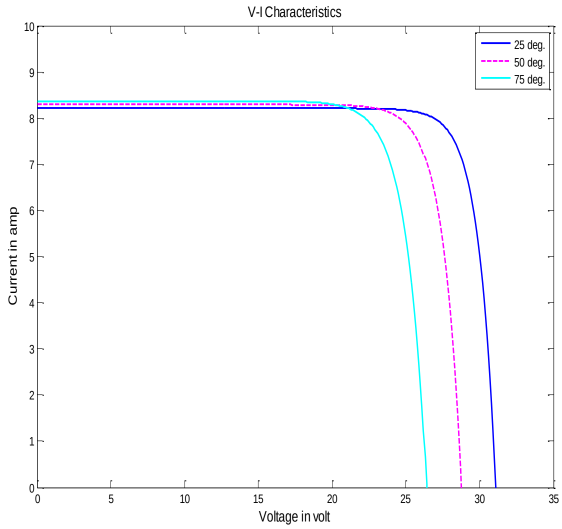

Fig.6 *V-I Characteristics of solar panel with different Temperature*

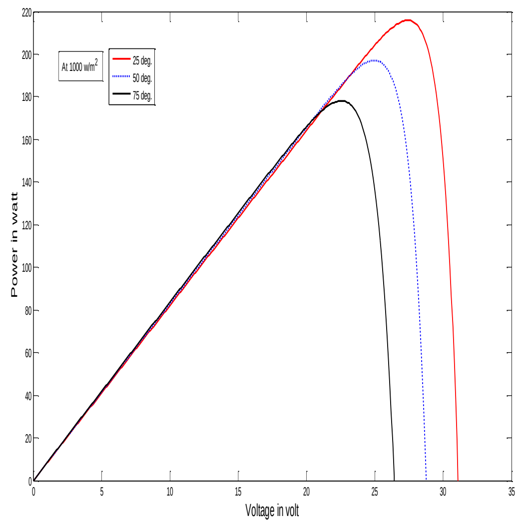

Fig.7 *V-P Characteristics of solar panel with different Temperature*

5.2. MPPT Results- Incremental Conductance Method

In this algorithm by comparing the incremental conductance $(\frac{\Delta I}{\Delta V})$ with instantaneous Conductance $(\frac{I}{V})$ the Maximum power point is achieved.

At 900 w/m^2 **On LHS of MPP** **on RHS of MPP**

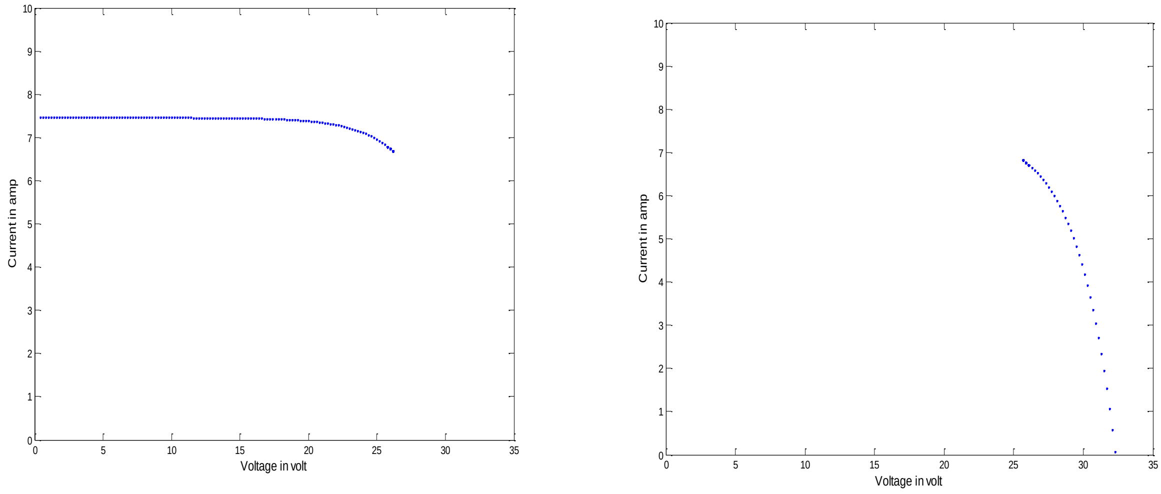

Fig. 5.7 V-I Characteristics of solar panel

At 900 w/m^2 **On LHS of MPP** **on RHS of MPP**

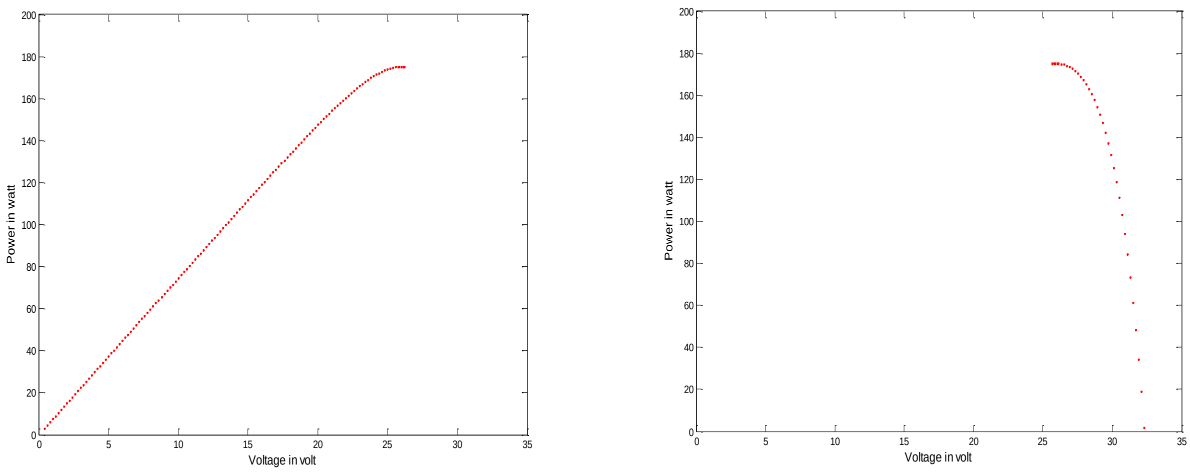

Fig. 5.8 V-P Characteristics of solar panel

Fig. 5.7 represents V-I Characteristics. the tracking of maximum power point i.e. At 179.42 watt corresponding to left hand side i.e. LHS and right hand side i.e. RHS. Fig. 5.8 represents V-P Characteristics. The tracking of maximum power point i.e. At 179.42 watt corresponding to left hand side i.e. LHS and right hand side i.e. RHS. It clearly shows that Incremental conductance MPPT method tracks the maximum power point at voltage 25.4 volts i.e. V_{mpp} and at current 7.32 ampere i.e. I_{mpp} for 900 w/m^2. From Fig. 5.7 shows that the Maximum power is tracked by comparing the Instantaneous conductance and incremental conductance. The power tracked by this method is faster as compared to P&O method. Initially in this method, voltage is perturbed by suitable perturbation size. In project work, it is taken as C=0.3 V and C=0.5 V. Hence in Fig. 5.8, the voltage is increased from zero when $V<V_{mp}$ and corresponding power is tracked. When, $V>V_{mp}$ i.e. RHS, in such case, Voltage will starts decreasing from open circuit voltage reaches to Maximum power point.

6. Conclusion

Results demonstrate that Solar PV device characteristics have been greatly affected by the atmospheric factors like different irradiation and temperature levels. Variation in Irradiation has great influence on output current in solar PV panel whereas variation in temperature has adversely affected the output voltage of the PV panel. The conventional Incremental conductance MPPT method compares the Instantaneous and Incremental conductance, starts the power from initial zero value of voltage. This method has faster tracking speed compared to P&O.

References

Fan Zhang, Kary Thanapalan, Andrew Procter, Stephen Carr, and Jon Maddy, "Adaptive Hybrid Maximum Power Point Tracking Method for a Photovoltaic System" IEEE Trans. Energy Convers.(DOI,-10.1109/TEC.), pp. 1-7,March 2013

S.K. Kollimalla and M.K. Mishra, "Adaptive Perturb and Observe MPPT Algorithm for PV system", IEEE Conf., 2013, pp. 1-6.

T. Esram and P. Chapman, "Comparison of photovoltaic array maximum power point tracking techniques," IEEE Trans Energy Convers., vol. 22, no. 2, pp. 439–449, Jun. 2007.

G. Walker, "Evaluating MPPT converter topologies using a MATLAB PV model," J. Electr. Electron. Eng. Australia, vol. 21, no. 1, pp. 49–55, 2001.

Y. Mahmoud. Xiao "A Parameterization Approach for enhancing PV model accuracy" IEEE Trans Ind. Electronics., vol. 60, Dec. 2013, pp. 5708–5715.

Marcelo Gradella Villava, Jonas Rafel Gazoli, and Ernesto Ruppert Filho,"Comprensive approach to modelling and Simulation of PV arrays",IEEE Trans Energy Convers, vol. No. 25,no. 5, pp.1198-1208,May 2009.

'Non-Conventional energy sources' by B.H. Khan.

D. Hohm and M. Ropp, "Comparative study of MPPT algorithms using an experimental, programmable, MPPT test bed," in Proc. 28th IEEE conf. Rec. Photovolt. Spec. Conf. 2000, pp 1699-1702.

Marcelo G. Villalva, Ernesto Ruppert F., "Analysis and Simulation of the P&O MPPT Algorithm Using a Linearized PV Array Model", IEEE Conf., 2009, pp. 231-237.

Thesis by Arjav Harjai, Abhishek Bhardwaj,Mrutyunjaya Sandhibigraha on "Study of Maximum Power Point Tracking (MPPT) Techniques in A Solar photovoltaic array" NIT Rourkela, pp. 1-42,May 2011.

Nicola Femia, Giovanni Petrone, Giovanni Spagnuolo and Massimo Vitelli, ''Optimization of Perturb and Observe Maximum Power Point Tracking Method", IEEE Trans on power electronics, vol. 20, no.4, pp. 963-973, July2005