Performance Analysis of Perturb & Observe and Incremental Conductance Method of Maximum Power Point Tracking in Solar PV-Based Power Generation

Avdhesh Kumar

Abstract In this paper, study and performance analysis of perturb and observe (P&O) and incremental conductance (InC), method of maximum power point tracking (MPPT) control algorithms has been performed. It has been tested under different environmental conditions, viz. standard test condition, varying insolation and temperature in the MATLAB/Simulink 2018(a) environment. P&O and InC algorithm has been analyzed. It is found that performance using incremental conductance algorithm is efficient in terms of less perturbation in the duty cycle and slightly more power output, i.e. 100 W for developed 10.25 kW solar PV system in the MATLAB/Simulink.

Keywords Incremental conductance · Solar photovoltaic · Perturb and observe

1 Introduction

The integration of renewable energy sources, semiconductor devices and partial shading of SPV array results in several losses that are significant enough to be taken into account while designing the system for supplying a specific load. Thus, the efficiency still ranges between 14 and 16%, due to above aforementioned restrictions [1]. Figure 1 shows the schematic representation of the system consisting of a SPV system, boost converter embedded with maximum power tracking method and load [2].

Solar photovoltaic energy is suitable as one of the key options for supplying electricity to remote areas. Output power of solar PV is influenced by different environmental conditions. To achieve the optimal power output irrespective of dynamic nature of environmental conditions, MPPT is required. MPPT aims to achieve the

A. Kumar (✉)
Electrical Engineering Department, Delhi Technological University, Delhi, India
e-mail: avdhesh_phd2k17@dtu.ac.in

H. Malik et al. (eds.), *Renewable Power for Sustainable Growth*,
Lecture Notes in Electrical Engineering 1086,
https://doi.org/10.1007/978-981-99-6749-0_10

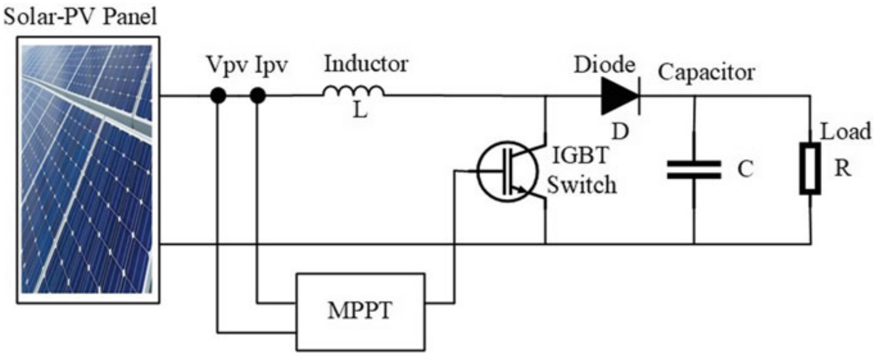


Fig. 1 Test system

optimal power output irrespective of environmental conditions [3]. The most popular techniques, namely P&O and InC algorithms have been used. P&O and InC technique evaluate the point of the MPP by shifting it back and forth and injecting a disturbance in the PV voltage/current based on the nonlinear properties of the PV [4].

In the literature [5], different MPPT have been thoroughly discussed in order to obtain maximum power like simple and efficient P&O and InC, grey wolf optimization (GWO) and particle swarm optimization (PSO). All of the MPPT techniques based on artificial intelligence show fast convergence speed, less oscillation under steady state and high performance. These methods are highly computational and expensive to develop. The problem associated with MPPT algorithm has been addressed in various literature, but P&O is the furthermost commonly used method due to, its comfort of implementation, particularly for low-cost implementations [6]. Further research is ongoing to enhance the existing MPPT techniques to handle temperature and varying irradiance conditions. Grid integration of PV system is realized using a VSC. The operation of the PV system requires switching pulses given to the VSC. The generation of switching pulses requires the reference current which helps in elimination of harmonics, compensation of reactive power and maintaining power balance at the PCC. The main aim of pulses given to VSC is to reduce the distortion level at grid side.

There are a number of techniques for the conventional MPPT [7], InC, hill climbing, P&O and improved P&O method. Because the algorithms for these strategies are less sophisticated, they are simple to implement. Since the PV will only produce one GMPP under uniform irradiation, these conditions will maximize their efficiency.

Fuzzy logic control and artificial neural network-based MPPT are examples of intelligent-based approaches [7]. These methods are designed to be extremely accurate under dynamic, ever-changing weather circumstances. Their tracking effectiveness and speed are really high. Complexity in control technique and enormous data processing for the system's initial training are additional drawbacks of these techniques.

Cuckoo search-based and artificial bee colony are examples of optimization methodologies [7–10]. These approaches also tend to hunt for real MPP in changing environmental situations. The PSO technique is a faster tracking method with less steady-state oscillations [10].

In the present studies, PV-based microgrid has been implemented using Perturb & Observe and incremental conductance MPPT control. Performance analysis and comparison of P&O and InC MPPT algorithms have been performed under standard test condition, varying insolation and temperature in the MATLAB/Simulink 2018(a) environment.

2 System Configuration

Figure 1 shows that test set-up consists of a 10.25 kW SPV system, as well as a boost converter and a consumer load(R). SPV power is not constant and fluctuates with environmental situations, P&O and InC algorithms have been modelled and simulated to achieve optimum efficiency of the SPV array.

3 Solar PV Configuration

Output of PV array are constantly changing owing to environmental variations, it is essential to track the optimum power using algorithm. In this study, the MPP is tracked using the P&O and InC control method. Using the maximum power transfer theory, the MPPT algorithm maintains the solar PV operating point corresponding to maximum power by varying the duty ratio. Characteristics of the SPV array varied solar insolation and temperature are depicted in Figs. 2 and 3, respectively.

4 MPPT Control Technique

The output of a PV array is not continuous and varies, depending on the environment. In order to monitor the optimum power, P&O and InC MPPT algorithm has been implemented in MATLAB/Simulink (2018) environment.

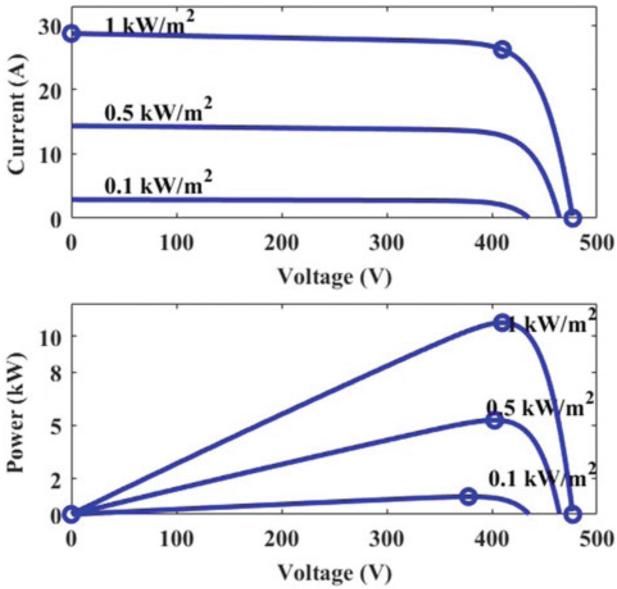


Fig. 2 *I–V* and *P–V* curve of PV array at variable insolation

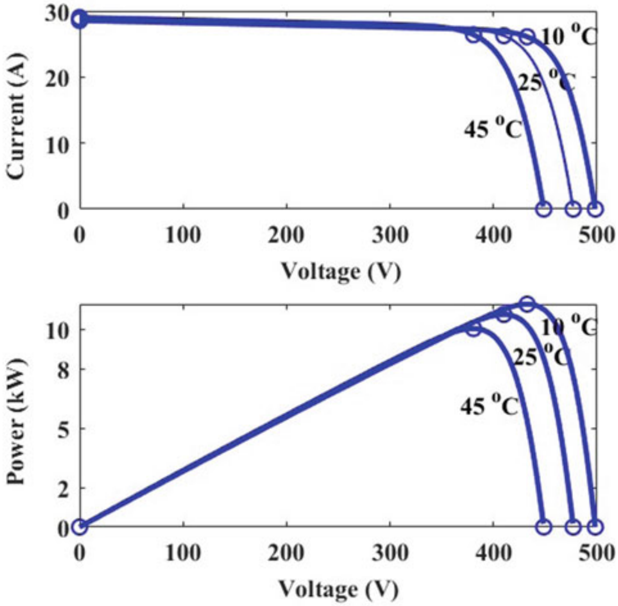


Fig. 3 *I–V* and *P–V* curve of PV array at variable temperature

4.1 P&O

This P&O MPPT is user-friendly, has the simplest algorithm and is simple to implement on any microcontroller, making it ideal for most authors to utilize in their applications. P&O calculations compare the voltage position after comparing, with obtained power at two places on a *P–V* curve. The voltage is then changed appropriately to follow the MPP (either to the left or right of the *P–V* curve).

Flowchart of P&O has been depicted in Fig. 4. Fundamentally, this method first looks for a (ΔP), then it looks for a sign of (ΔV). Fundamentally, this method first looks for a change in (d*P*), then it looks for a sign of (d*V*). To examine the actual movement of the operational point, *P–V* curve data is used. Furthermore, procedure continues until ($dP = dV$) equals zero. Furthermore, algorithm comprises an adjustment in converter's duty cycle as well as an adjustment in the output voltage. The changes in the PV array voltage, maximum power point tracking algorithm of the SPV system, varies the duty cycle of the DC–DC converter.

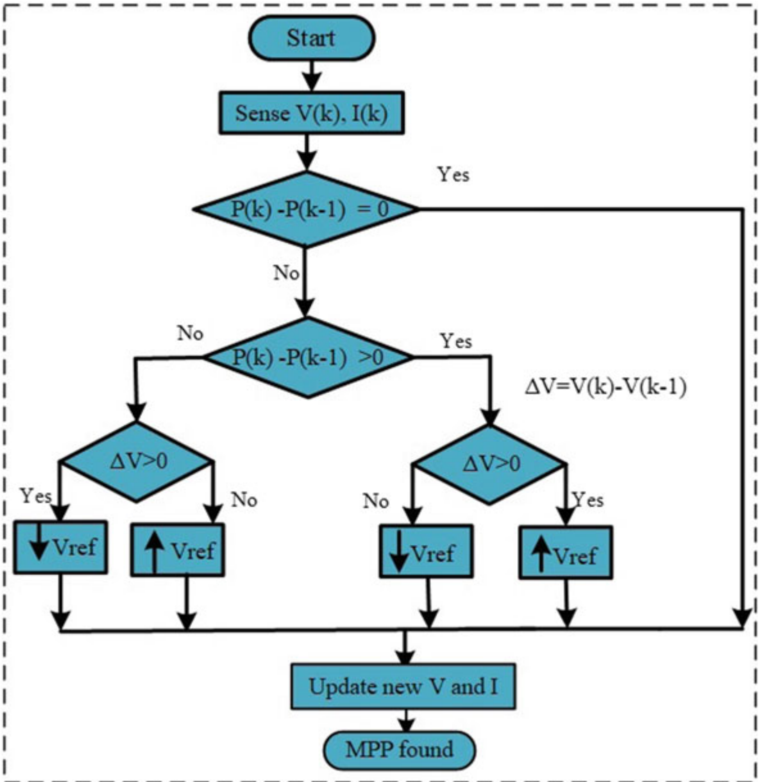


Fig. 4 P&O: flowchart

4.2 InC

Flowchart of InC has been depicted in Fig. 5, this approach largely follows the same path from P&O to MPP, but makes use of the special relationship between the *I–V* curve. This calculation measures the PV cell current and voltage. Furthermore, InC algorithm, estimates derivative of current (d*I*) and voltage (d*V*) of PV cells. The InC method, requires ($dP/dP = 0$) at MPP. The *P–V* curve will be used as the basis for all data in this approach, which uses that data to track the MPP. Only the tracking procedure is completed if either the PV array power's derivative ($dP = dV$) or the *P–V* curve's slope are both zero.

P–V curve has a zero slope at MPP, increasing to the left of MPP and decreasing to right. Following are fundamental equations for this technique:

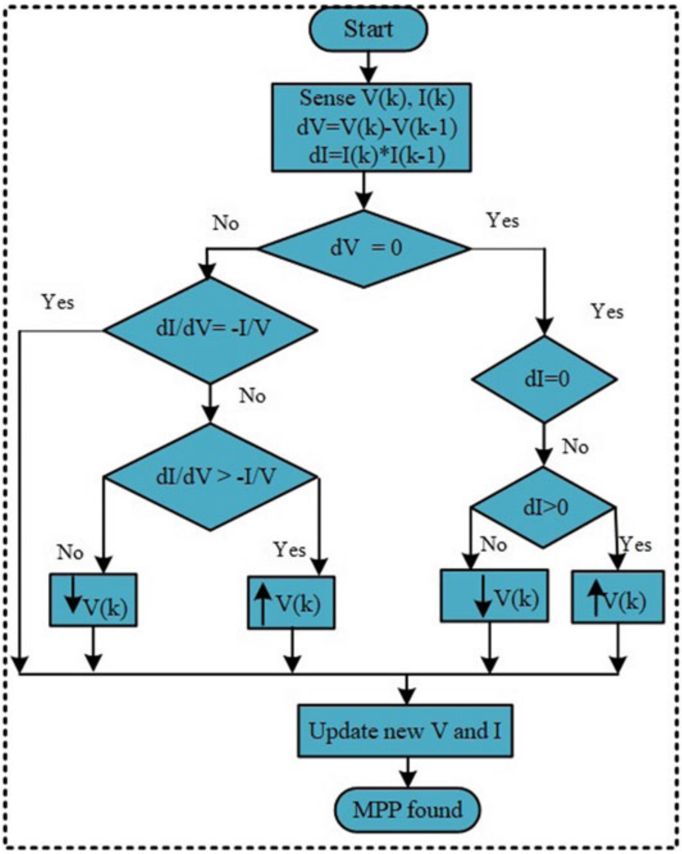


Fig. 5 InC: flowchart

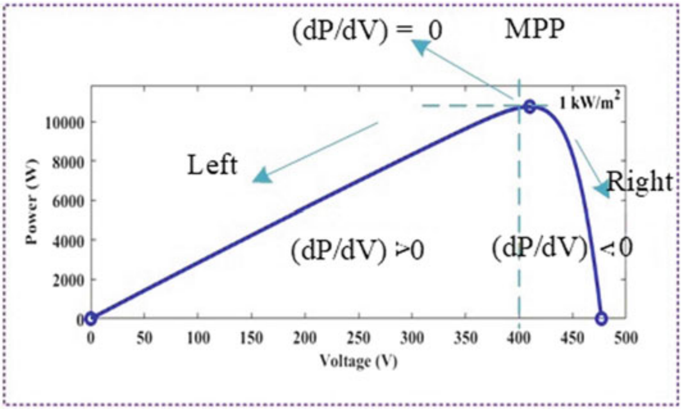


Fig. 6 *P–V* curve

$$\text{At MPP, } \frac{dI}{dV} = -\frac{I}{V}$$

$$\text{Left of MPP, } \frac{dI}{dV} > -\frac{I}{V}$$

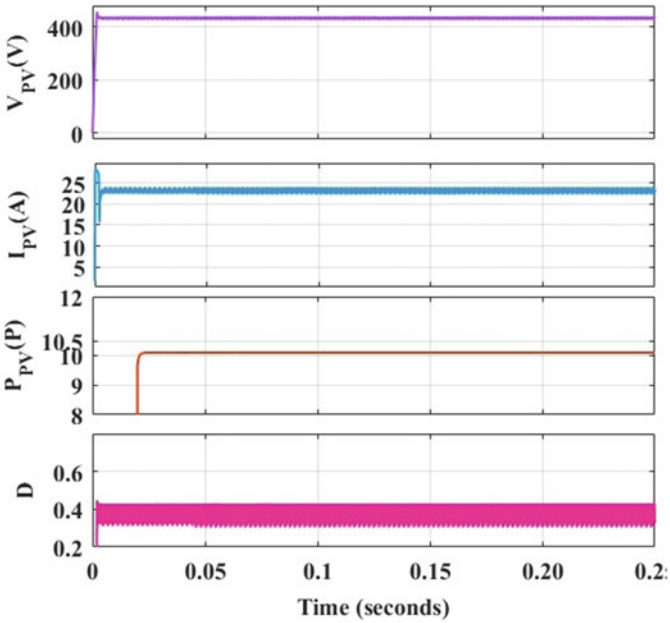
$$\text{Right of MPP, } \frac{dI}{dV} < -\frac{I}{V}.$$

Equations’ left side signifies the InC of the *P–V* module and their right side signifies its instantaneous conductance. In the case when the ratio of output conductance change equals the negative output conductance, SPV operates at its MPP that can be seen from *P–V* curve of the SPV system as depicted in the Fig. 6.

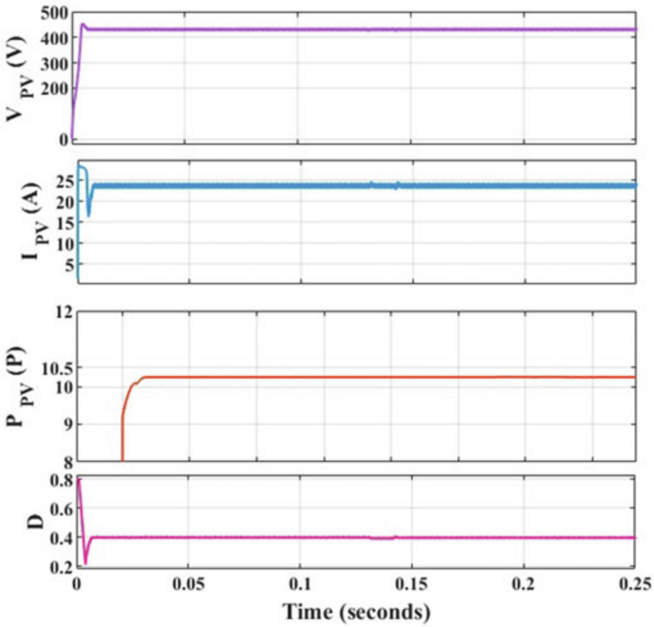
5 Results and Discussions

Performance under different environmental conditions have been analyzed and compared. Microgrid system is modelled in MATLAB/Simulink. The performance of P&O and InC at standard test condition (STC), variable insolation and variable temperature has been analyzed and presented. Various parameter of the system, viz. voltage, current and power are depicted in Figs. 7, 8, and 9, respectively. It has been observed from Fig. 7b that in the developed system, incremental conductance is efficient and has less perturbation in the duty cycle when compared with P&O at STC [1000 W/m^2 and 25 °C] and extracting slightly more power, i.e.100 W for the developed solar PV system (10.25 kW).

The system’s performance is evaluated by varying the external circumstances, such as insolation and temperature to further validate the efficacy of the two control

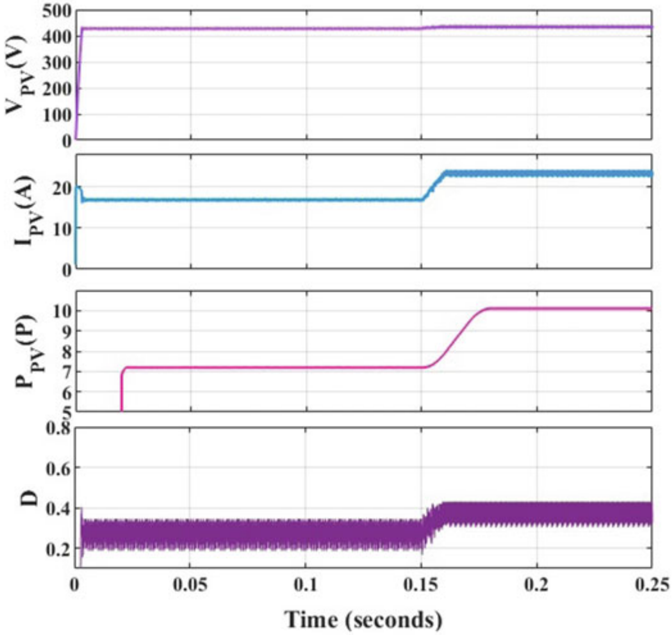


(a)



(b)

Fig. 7 Simulation result at STC [1000 W/m^2 and 25 °C] using: **a** P and O, **b** InC



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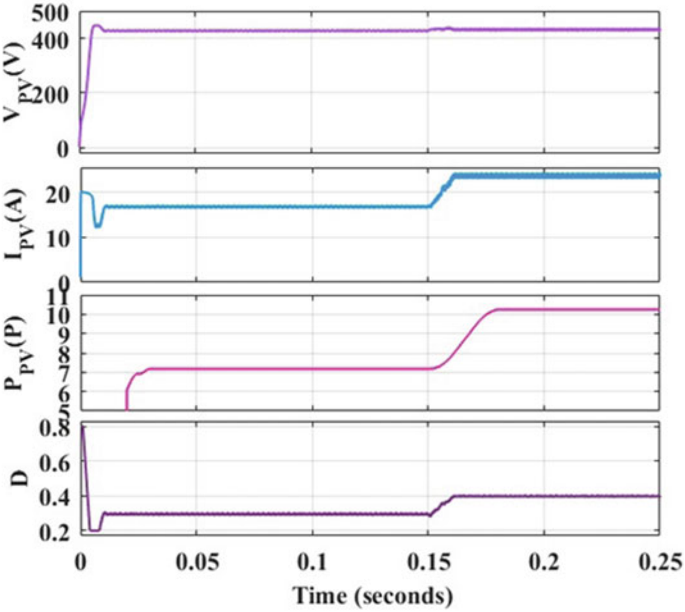
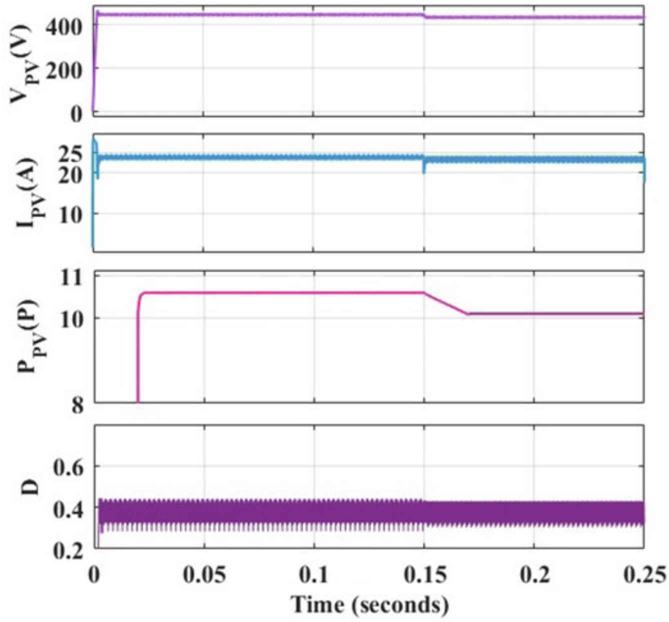
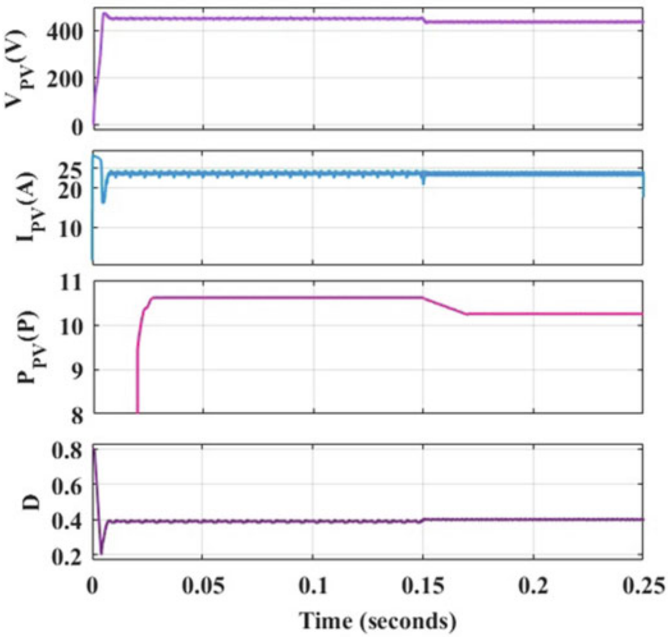


(b)

Fig. 8 Simulation result variable insolation using: **a** P&O, **b** InC



(a)



(b)

Fig. 9 Simulation result variable temperature from 15 to 25 [°C], using: **a** P&O, **b** InC algorithms. At 0.15 s, the solar insolation intensity has been changed from 700 to 1000 W/m^2 and performance is depicted in the Fig. 8. It has been observed from Fig. 8b that incremental conductance is efficient and has less perturbation in the duty cycle when compared with P&O at variable insolation and extracting slightly more power, i.e.100 W for the developed solar PV system (10.25 kW).

The system's performance is evaluated by changing external circumstances such as temperature to further validate the efficacy of the two control algorithms; at 0.15 s, the temperature has been changed from 15 to 25 [°C], performance is depicted in the Fig. 9. It can be seen from the Fig. 9b that InC has less perturbation/oscillations in the duty cycle when compared with P&O at variable temperature and also extracting slightly more power, i.e. 100 W for the developed solar PV system (10.25 kW).

6 Conclusions

In this paper, PV-based standalone microgrid has been developed and implemented in the MATLAB/Simulink 2018(a). P&O and InC method of the MPPT control algorithm have been used as MPPT. It has been tested under different environmental conditions, viz. standard test condition, varying insolation and temperature. Performance of the implemented method has been analyzed. It is found that performance using incremental conductance algorithm is efficient in terms of less perturbation in the duty cycle and slightly more power output, i.e. 100 W for developed 10.25 kW solar PV system in the MATLAB/Simulink.

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