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Performance of Photovoltaic System's Maximum Power Point Tracking

Ahmed Ibrahim[1], M.M Sayed[2], Majid Esawi[3]

Professor, Dept. of EPME, Engineering College, Cairo University, Giza, Egypt [1]

Assistant Professor, Dept. of EPME, Engineering College, CairoUniversity, Giza, Egypt[2]

MSc Student, Dept. of EPME, Engineering College,CairoUniversity,Giza, Egypt[3]

ABSTRACT:The Maximum Power Point Tracking (MPPT) is an instrument which extracts the maximum power available from the PV array at any given moment. The power available from a PV module passes through a peak at a particular operating point and this peak also changes with atmospheric conditions. Hence the changing peak power needs to be continuously tracked.This paper explains the performance of two different MPPT used tosolar modules: perturb and observe (P&O) and incremental conductance (IC). It starts with a description of each method and then it compares them considering capability to follow irradiance variations in the required measurements.

KEYWORDS: Renewable energy, Photovoltaic, Perturb and Observe, DC-DC Converters, Maximum power point tracking (MPPT).

I.INTRODUCTION

Solar energy is one of the most important renewable energy sources. Against to the conventional not renewable sources such as gasoline, coal, etc. solar energy is clean, inexhaustible and free. The main applications of photovoltaic (PV) systems are in either stand-alone (water pumping, domestic and street lighting, electric vehicles, and military and space applications) or grid-connected configurations (hybrid systems, power plants) but PV systems have two problems: the first problem is that the conversion efficiency in electric power generation is low. The second is that the amount of the electric power generated by solar arrays changes continuously with weather conditions [1].

Egypt is country enjoying the advantageous position with solar energy , so Egypt is among the first countries to utilize the solar energy. Nowadays utilization of solar energy includes use of photovoltaic cells, solar water heating, and solar thermal power. Use of solar thermal technology may include both electricity and water desalination [2] and[3].

The PV cell has non–linear current–voltage qualities. The power delivered by an array increases to a point, as the current draw rises. The maximum power point is usually at the knee of the curve. The aim of the MPPT subsystem is to determine just where that point is, and to regulate current accordingly. The factors that make the location and tracking the maximum power point a bit more challenging are temperatures and the partial shading of an array. The rapid changes in irradiance or temperature may introduce multiple local maxima. Some MPPT techniques address the issue of phantom maxima better than others [4].

It is possible to track the MPPT that is one of the key functions that every PV should have to optimize the energy captured. The MPPT has been reported in different works. A comparison among many different MPPT techniques has been presented in [5], [6], and [7]. The perturb and observe (P&O) and incremental conductance (IC) methods receive the best rankings. From the studies conducted in [8], the best controller for MPPT is IC controller. The P&O method is able to improve the dynamic and steady state performance of the PV system simultaneously [3]. From [9], it is found that IC method has less oscillation in comparison to P&O method which results in higher efficiency. The IC method offers different advantages which are: good tracking efficiency, response is high and well control for the extracted power [10], [11], and [12].

This paper explains the performance and comparison of P&O and IC methods. It is organized as follows: Solar explorer kit is presented in Section II, the control of the system is given in Section III, the discussion of the results is presented in Section IV, and conclusions are finally drawn in Section V.

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II.SOLAREXPLORERKIT

Solar Explorer Kit is a low voltage platform to evaluate C2000 microcontroller family of devices for renewable energy applications such as PV inverter. The input to the solar explorer kit is a 20V DC power supply which powers the controller and the supporting circuitry. A 50W solar panel can be connected to the board (Typical values V_{mpp} 17V, P_{max} 50W). However for quick demonstration of the power processing, a PV emulator power stage is integrated on the board along with other stages that are needed to process power. The control of the PV panel is kept separate from the control of the other stages. PV is light dependent source; the PV panel emulator can be used to test PV inverter under changing lighting conditions. As the control of PV panel is executed on a separate controller a SPI link is added from the DIMM100 on the solar explorer to the PV Panel emulator controller. This simplifies the debug and demonstration. The Solar Explorer kit can be used to implement a PV inverter system by connecting the power stages as shown in Fig 1 [13] and[14].

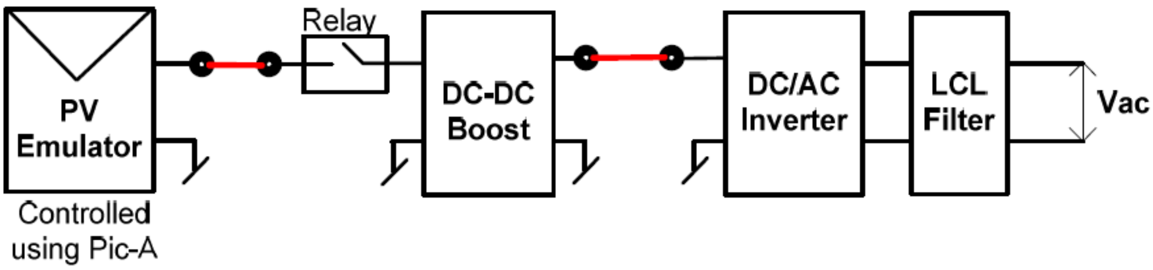

Fig. 1 PV Inverter using Solar Explorer Kit [13]

A. DCDC Boost with MPPT

Fig 2 shows the power stage circuit implemented on solar explorer kit for this stage. Inductor L1, MOSFET switch Q1 and diode D1, together form the boost circuit. The boost circuit operates at 100 KHz. Fig 3 illustrates the control scheme for the DC-DC Boost stage with MPPT.

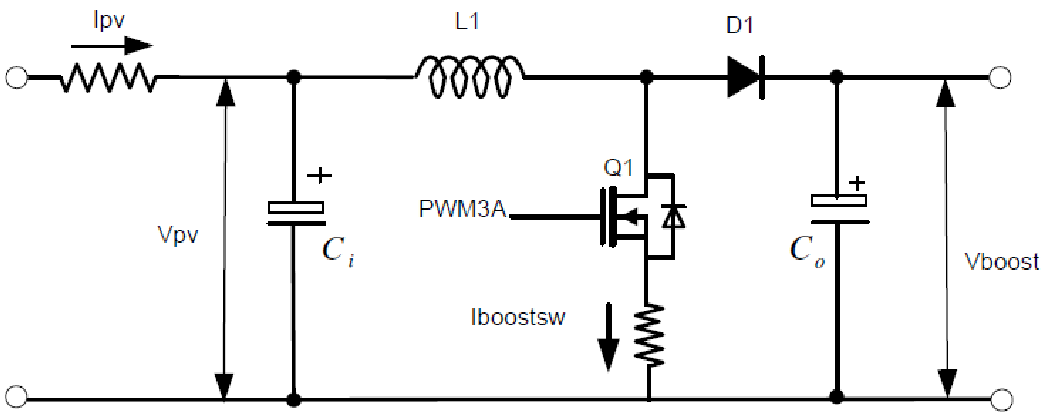

Fig. 2DC DC Boost stage power circuit [13]

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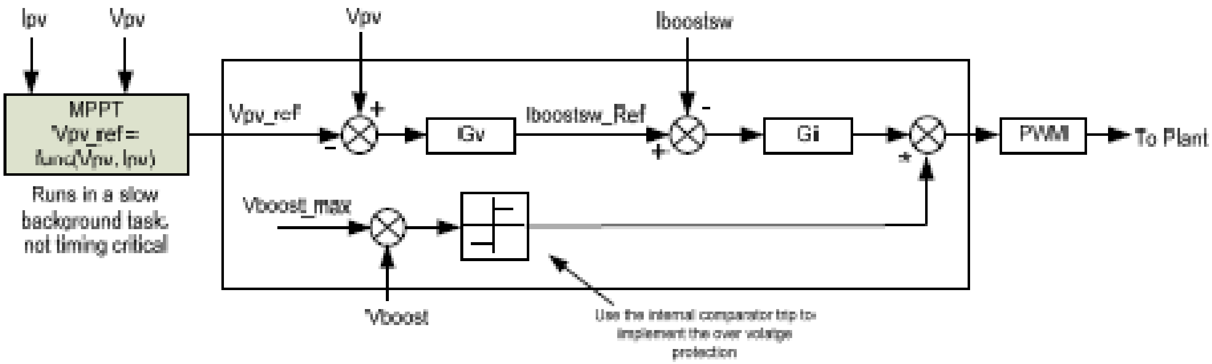

Fig. 3Control of DC-DC Boost with MPPT [13]

B. DC-AC Single Phase Inverter

A full bridge inverter, as shown in Fig 4, is used to generate single phase AC waveform. Input to this block is from DCDC Boost power stage. Inverter stage operates at 20Khz. Switches Q1, Q2, Q3, Q4 form the full bridge inverter. These, together with LCL filter, generate filtered single phase AC output.

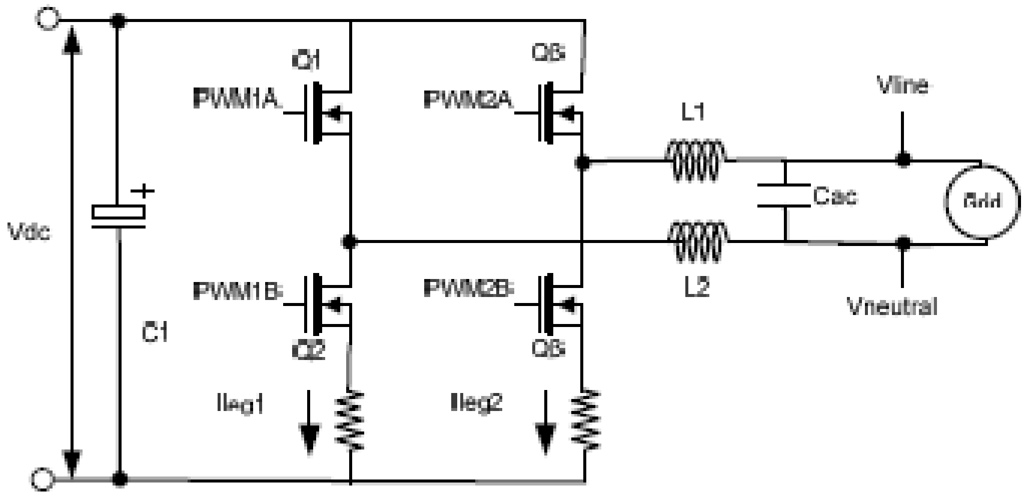

Fig. 4DCAC inverter stage power circuit [13]

III.CONTROLSYSTEM

The photovoltaic array is regulated at the optimum power point that it can provide to obtain best performance from the system.

A. Perturb and Observe

The primary and classical algorithm implemented in the MPPT is the P&O method which involves perturbing the point of operation and measuring the power delivered by the PV array. This process is followed by comparing the power values of two consecutive instants that leads to the decision on the direction of perturbation in the subsequent sampling cycle. Such a course of action leads to climbing of the hill-like P-V curve to ultimately reach the MPPT and oscillate around it until the P-V curve changes due to the next change in atmospheric condition. Several variants of the classical P&O exist and can be judiciously used according to the requirements of the specific PV system and its application. Fig 5 illustrates the flowchart of the P&O algorithm [8] and[15].

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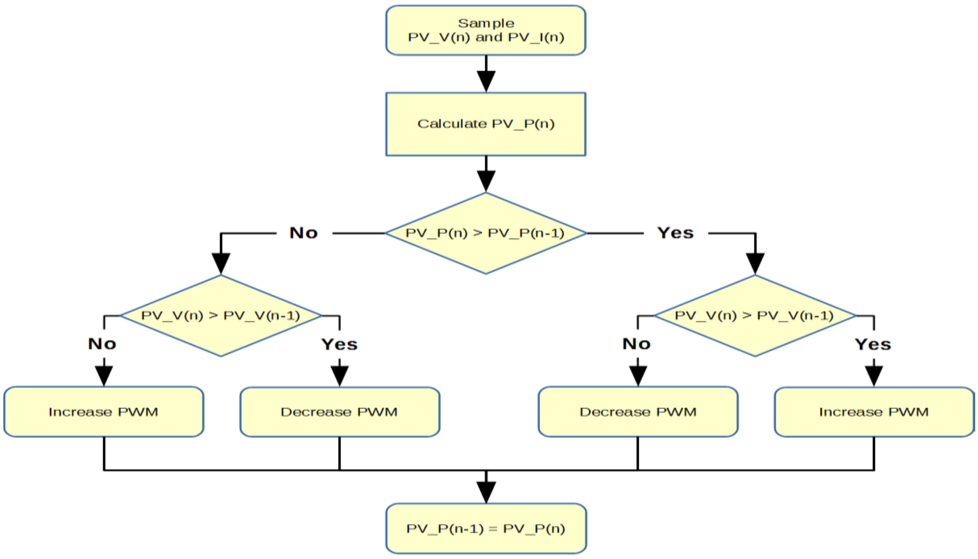

Fig. 5Flowchart of the P&O algorithm [8]

B. Incremental Conduction Algorithm

The P-V curve of solar module shows that the slop may be positive, negative and zero on the left, the right and the peak point respectively. This observation is utilized when devising the INCC algorithm (Fig 6) thus the operation point is said to reach the MPPT in the conditions as follows [10]:

$$dI/dV = -I\ V \qquad at\ MPP$$
$$dI/dV > -I\ V \qquad left\ of\ MPP$$
$$dI/dV < -I\ V \qquad right\ of\ MPP$$

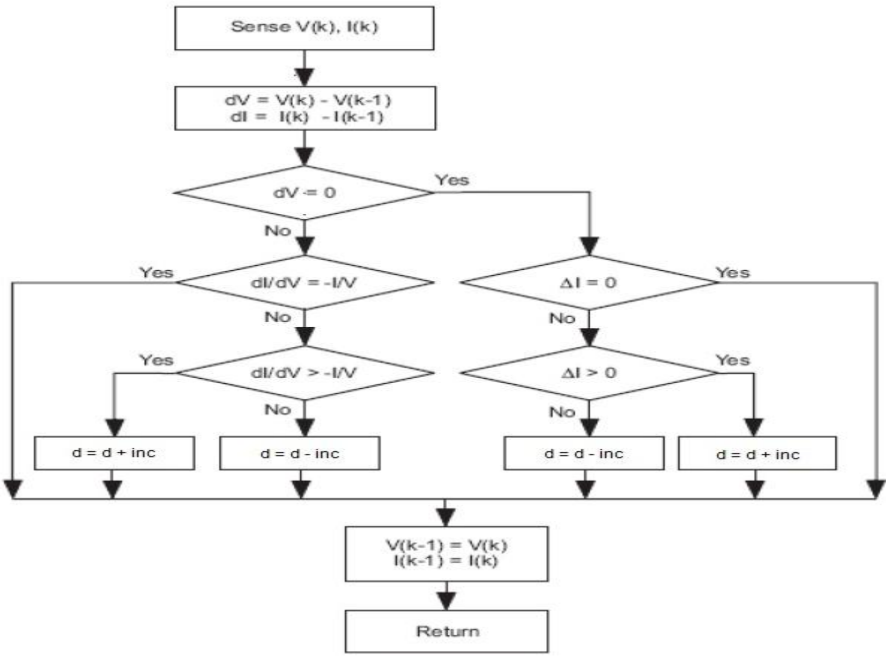

Fig. 6Flowchart of the IC algorithm [10]

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IV.RESULTS AND DISCUSSION

A. PV Panel with P&O Controller

The results obtained of the control technique applied to the photovoltaic system (Solar Kit) are the following. Fig 7 and Fig 8 present the evolution of power and current and voltage characteristic by P&O algorithm during a variation in solar radiation in a whole day, the irradiation varies from 0W/m² to 800w/m². It can be seen that the increase of the illumination explained by an increase of the maximum power available and the system track the new maximum power point tracking very quickly when the weather change suddenly. These oscillations would reduce the effectiveness of the photovoltaic power.

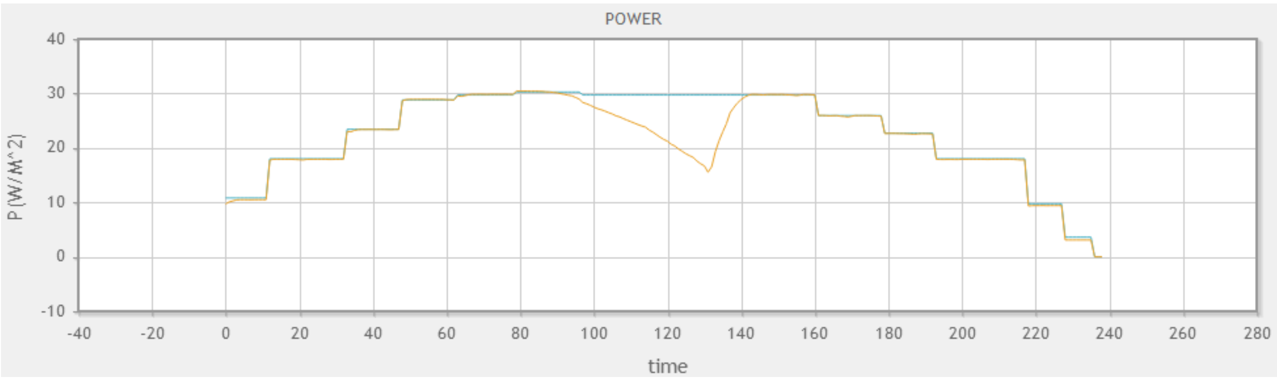

Fig. 7Power characteristics with P&O

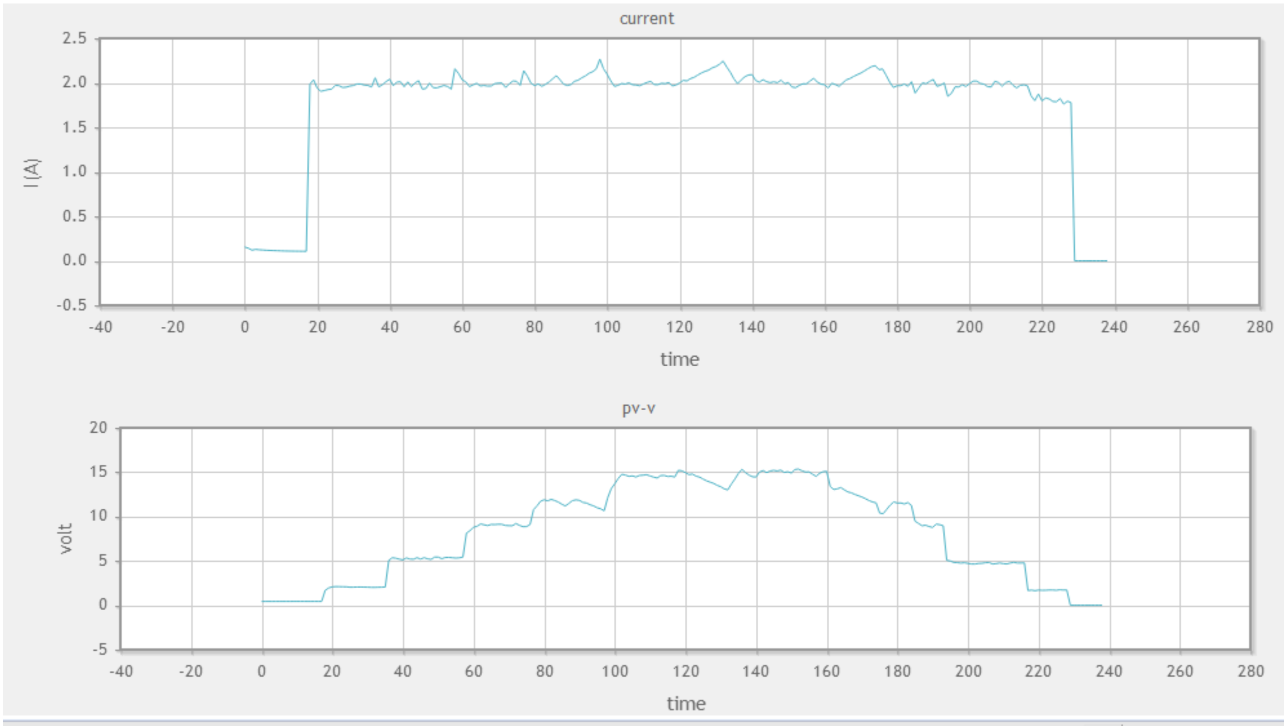

Fig. 8Current and voltage characteristics with P&O

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B. PV Panel with IC Controller

Since The IC algorithm efficiencies are presented in both Fig 9 and Fig 10. They present the evolution of Power and current and voltage characteristic in the same conditions of the previous technique (P&O algorithm).Comparison of P&O controller and IC proves that incremental conductance gives better results than perturb and observe, it improved stability and offered higher energy utilization efficiencies compared to P&O algorithm, The MPPT without oscillations is desirable.

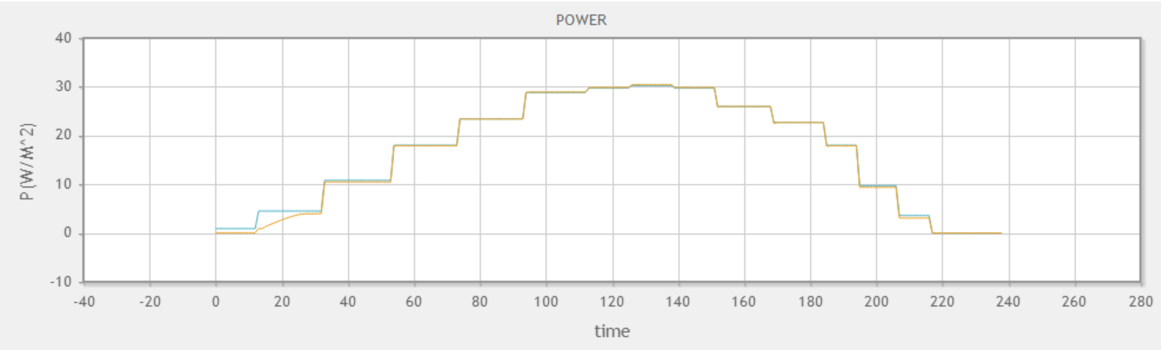

Fig. 9Power characteristics with IC

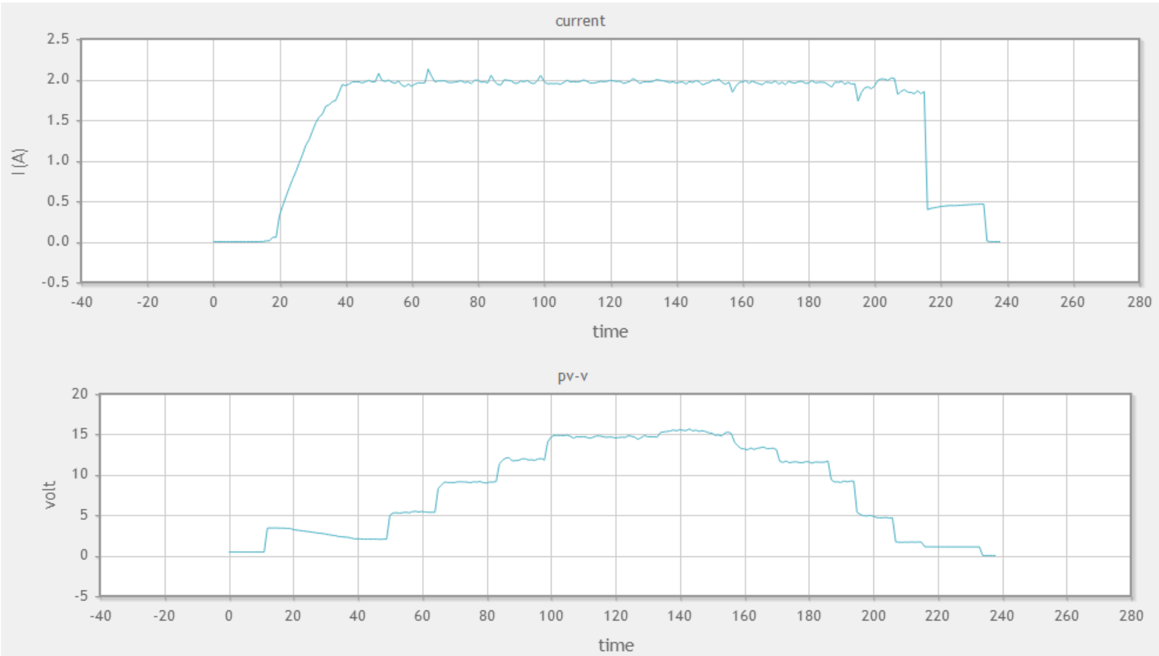

Fig. 10Current and voltage characteristics with IC

C. Comparison of PV Power with and without MPPT

The power extracted from the PV cell has been compared by using the MPPT technique(IC algorithm) and without this technique for the reason of proving the effectiveness of MPPT technique.As can be seen in Fig 11 and Fig 12, the MPPT technique maintains the PV cell's maximum output thus reducing the power losses and optimal utilization of solar energy.In order to test the continuation of the Pmax, the solar illumination value was chosen to be varied and to see its impact on the performances of the photovoltaic power.The results proves that the excellent performance of the PV control in response to serve the change in the solar intensity condition. The output power of the PV cell was substantially change with the weather condition.

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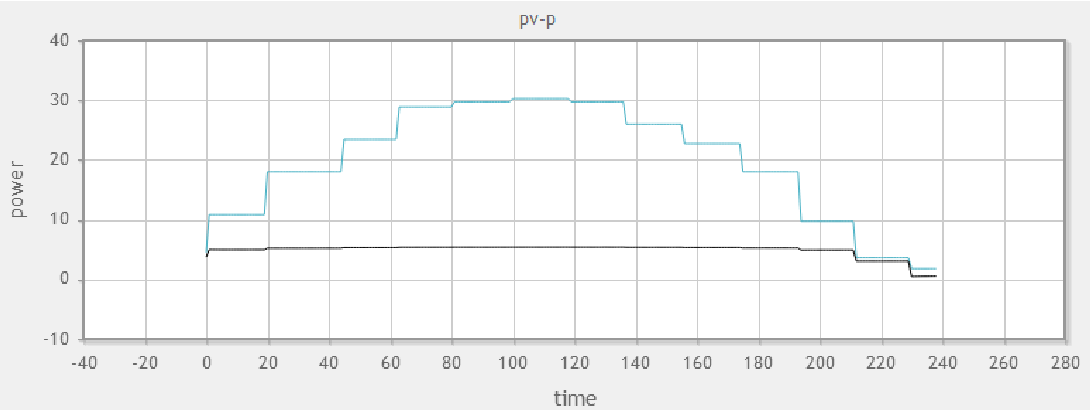

Fig. 11Power characteristics without MPPT

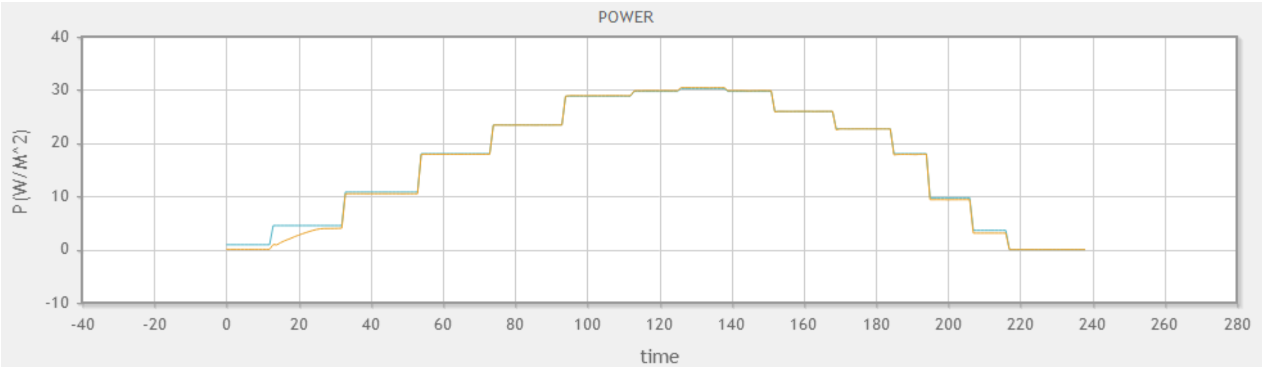

Fig. 12Power characteristics with IC

V. CONCLUSION

By using the Solar Explorer Kit measurement and comparison analysis of MPPT algorithm has been conducted.The results proved that the benefits of the MPPT algorithm increased significantly the efficiency of the energy production and assured better tracking performance under varied radiation conditions, meanwhile the PV system proved its fast response to irradiation.

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