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Research Paper

Experimental Comparative Study to Achieve the Maximum Power Point Tracking of a PV System

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This paper presents a comparison study in different techniques of maximum power point tracking (MPPT), which have been experimented and validated by simulation in the proposed PV system. The main aim of each MPPT technique is to enhance and optimize the output of photovoltaic (PV) array in dynamic weather conditions through an examination algorithm. Nevertheless, an optimized MPPT technique is described in many sides like achievement, software, precision, convergence velocity, and hardware naturalness. The gained experimental results for the MPPT techniques are compared using the Perturbation and Observation (P&O), Incremental Conductance (IncCond), Short Circuit Current (SCC), Open Circuit Voltage (OCV), and Constant Voltage (CV) at weather conditions variations. These methods were analyzed and their performance was estimated through using the Matlab/Simulink under different types of atmospheric conditions. These results show that the IncCond technique gives larger efficiency, at rapidly changing conditions than the other techniques.

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1. Introduction

The sustainable development target aims to promise the access to sustainable energy [1-2]. The solar power is the dominant renewable energy and the peoples need to understand the significance of cleaner energy technology and how it is affected through climate variation in the aspects of power generation. The overall output of PV is reduced up to 3% due to increase in temperature and cannot be compensated by increase in irradiation. [3-4]. The parameters involved with PV cell are the indicators of how the solar cell can convert the sunlight to electricity efficiently. The MPPT working principles is based on the maximum power transfer controller that is needful to impose a PV panel to operate on its MPP. Many MPPT techniques have been studied in the literature [5-10] such as the Perturb and Observe (P&O), the Incremental Conductance (IncCond), the Short Circuit Current (SCC), the Open Circuit Voltage (OCV), and the Constant Voltage (CV) techniques. These techniques could be compared by several characteristics: their implementation ease, effective cost, and convergence performance [10-12]. This paper contributes experimental results to determine power performance in real atmospheric conditions and other efficiency parameters (different MPPT techniques) around 1 kW solar PV. The performances are estimated and founded for a one-day (24 h) irradiance and temperature measurements. The MPPT techniques are performed on a buck-boost converter, it was shown that in all the tests, the MPPT achievement of the proposed (IncCond/P&O) is enhanced by approximately 1.5% points. Thus, we shall show how the five MPPTs performs under the atmospheric condition subjected to a one-day of continuous temperature and the irradiance.

2. MPP tracking

2.1 Incremental Conductance (IncCond)

IncCond presents the advantage to overcome the rapidly changing weather conditions. The technique is done through estimating the dP/dV sign, by different sensors: the voltage sensor/current sensor is desired in order to calculate the PV panel output as shown in Fig. 1 [13-14]. The output voltage and power are given by:

$$\begin{aligned}
&\frac{dP}{dV} = 0, at\,(MPP) \\
&\frac{dP}{dV} \succ 0, Left\,(MPP) \\
&\frac{dP}{dV} \prec 0, Right\,(MPP)
\end{aligned} \qquad (1)$$

$$\frac{dP}{dV} = I + V\frac{dI}{dV} \cong I + V\frac{\Delta I}{\Delta V} \tag{2}$$

$$\begin{aligned} &\frac{dI}{dV} = -\frac{I}{V}, at\,(MPP) \\ &\frac{dI}{dV} > -\frac{I}{V}, Left\,(MPP) \\ &\frac{dI}{dV} < -\frac{I}{V}, \mathrm{R}ight\,(MPP) \end{aligned} \tag{3}$$

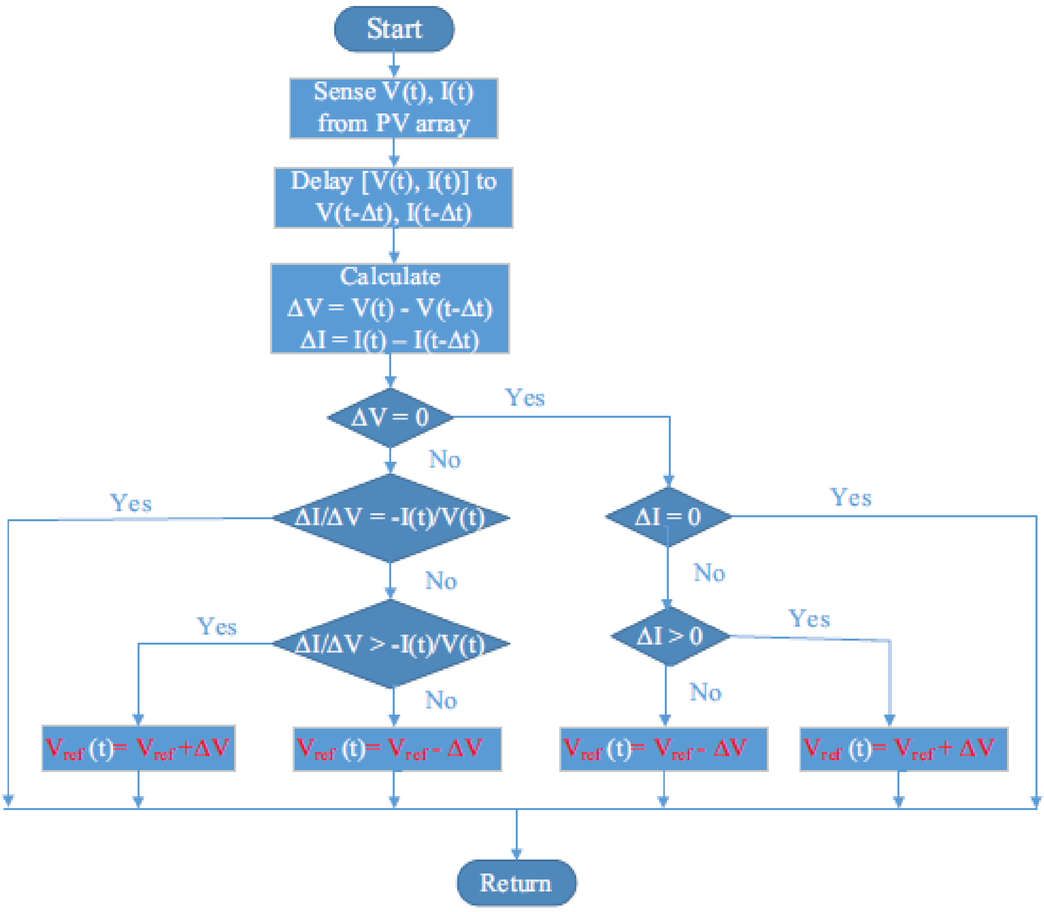

Fig 1. IncCond algorithm.

2.2 Perturbation and Observation algorithm (P&O)

P&O algorithm is the most widely used mechanism because of its unpretentious composition and small measured parameters. P&O technique in the solar system is founded on investigating the relation between PV panel output voltage and its power as it appears in Fig. 2 [15-17].

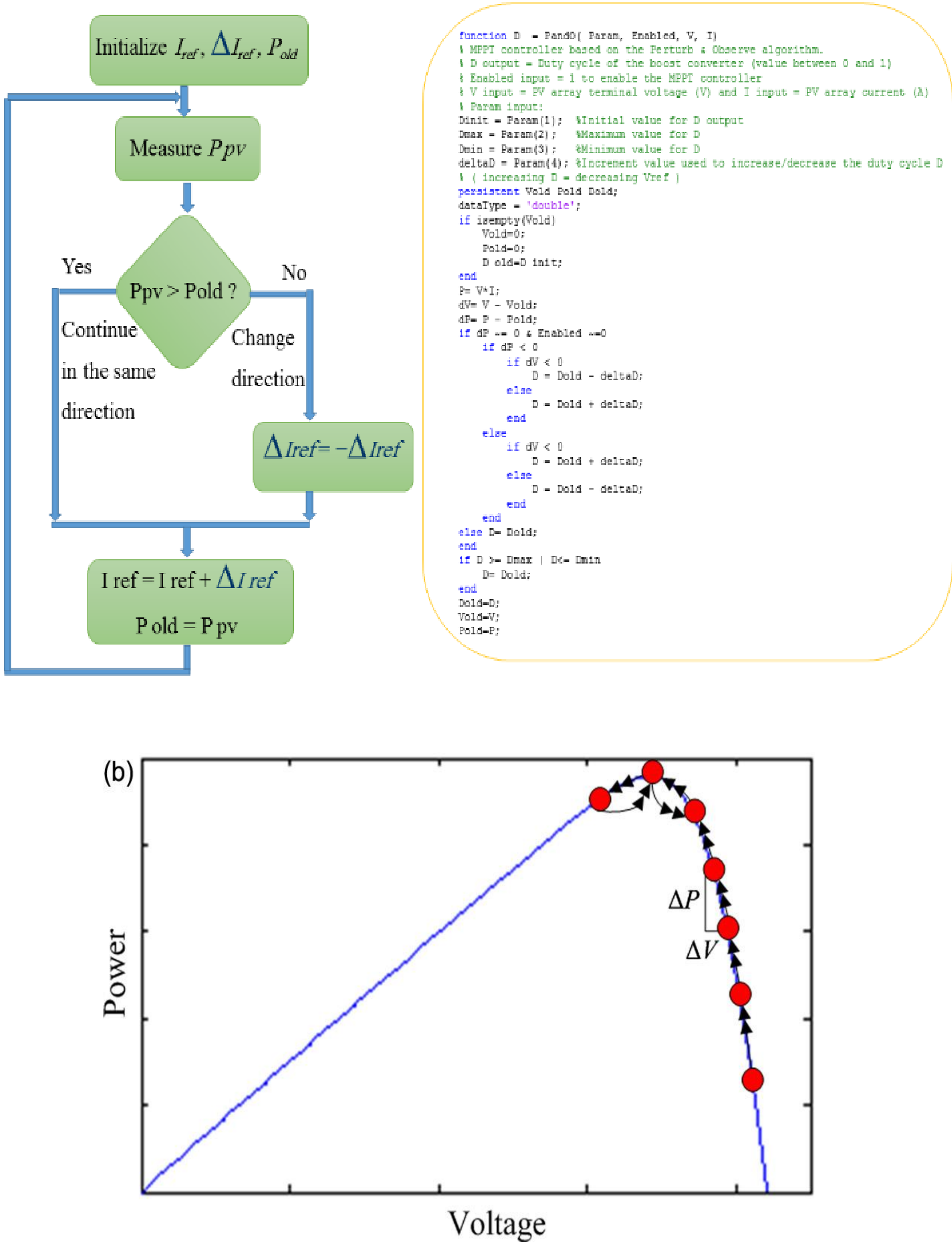

Fig 2. P&O algorithm.

2.3 Constant Voltage (CV)

CV technical algorithm (Fig. 3) is the easiest MPPT controller, and has a speedy response. The CV technical demands a PI controller to regulate the duty cycle of the converter order to preserve the measurement of the voltage Vpv about the MPP [18-19].

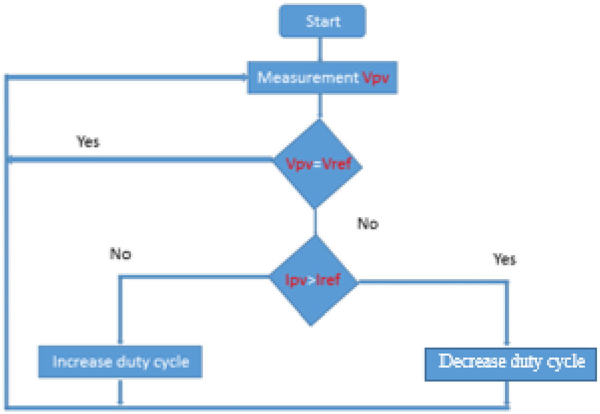

Fig 3. Flowchart of CV method.

2.4 Open Circuit Voltage (OCV)

The OCV technique (Fig. 4) is another well known MPPT method based on the reality that, the rate between the open circuit voltage and its PV panel maximum output voltage is equal to constant K [20-21].

$$\frac{V_{OC}}{V_{mpp}} \approx K1 \approx 0.7 \tag{4}$$

With

V_{mpp} is the PV panel maximum output voltage.

V_{oc} is the PV panel open circuit voltage and $K1$ is a constant.

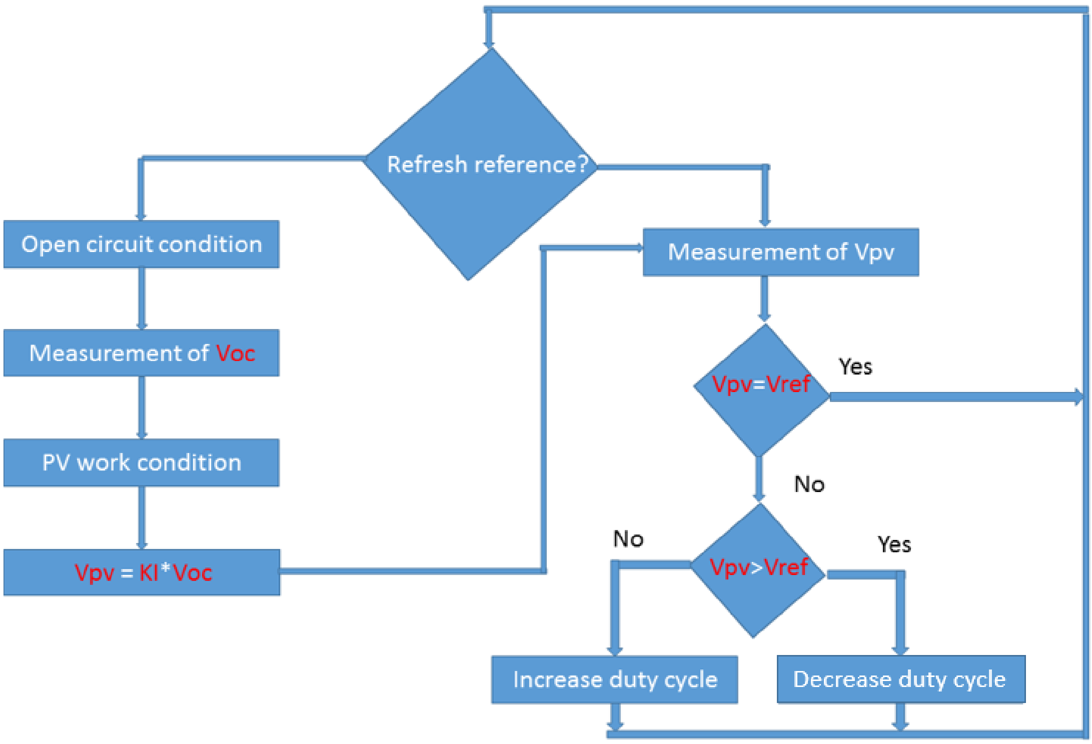

Fig 4. Flowchart of OCV method

2.5 Short Circuit Current (SCC)

SCC method is found at the measurement of the PV panel SCC when its output voltage is near to zero, and the PV panel maximum output current at MPP is linearly relative to its short circuit current as shown in Fig. 5 [22-23]. The PV panel output current and SCC at MPP could be expressed as

$$I_{mpp} \approx K2 \times I_{SC} \qquad (5)$$

With

K2 is a constant near to 1, and *Impp* represents the PV panel maximum output current.

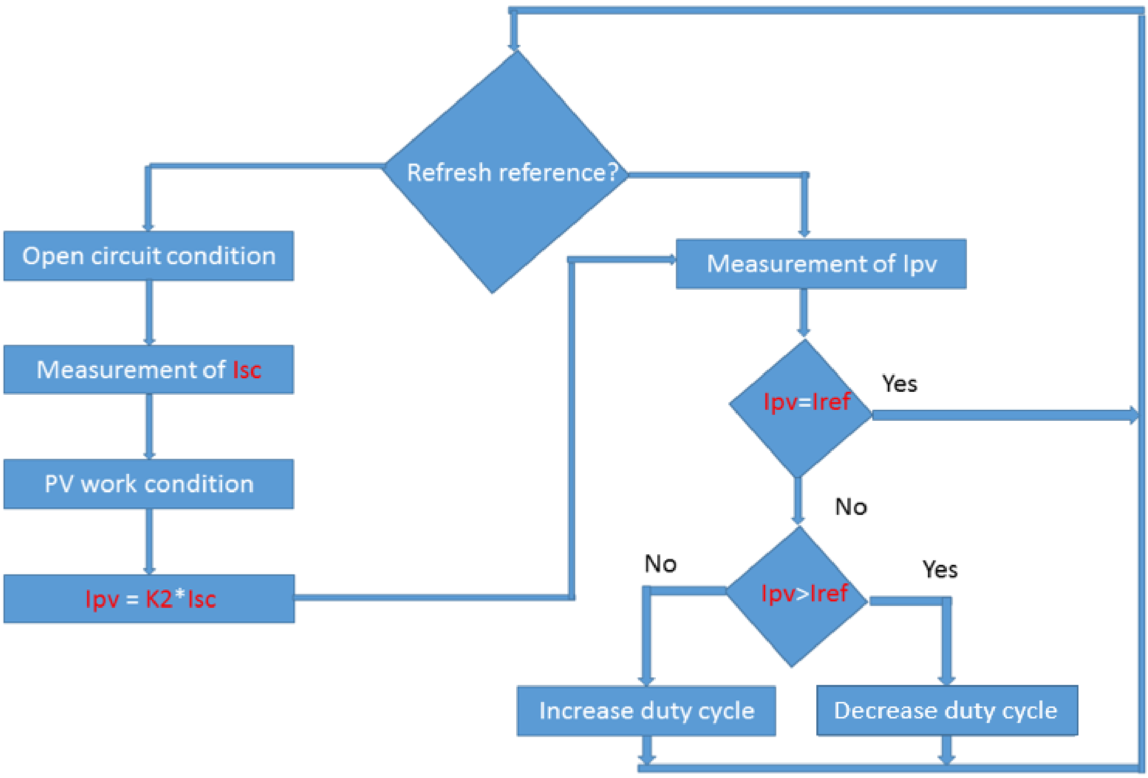

Fig 5. Flowchart of SCC method.

3. Experimental

In this part, the proceeded experimental work to compare the achievements of the proposed MPPT technique through IncCond, P&O, SCC, OCV and CV methods are carried out. The data applied to implement the current research have been registered at the used Research Unit for Renewable Energies (URAER) existing in the south of Algeria, with the latitude (+32.37°), longitude (+32.37°), and altitude (+3.77°), Fig. 6 and 7. They are registered every 5 min and consist of data information of comprehensive solar irradiance. Figure 8 displays a global schema of the grid-connected PV system through data acquisition. The characterizations of the applied PV panel in this article are presented in Table 1 [24-25].

Fig 6. Instrumentations position for the measuring overall solar irradiance in per day.

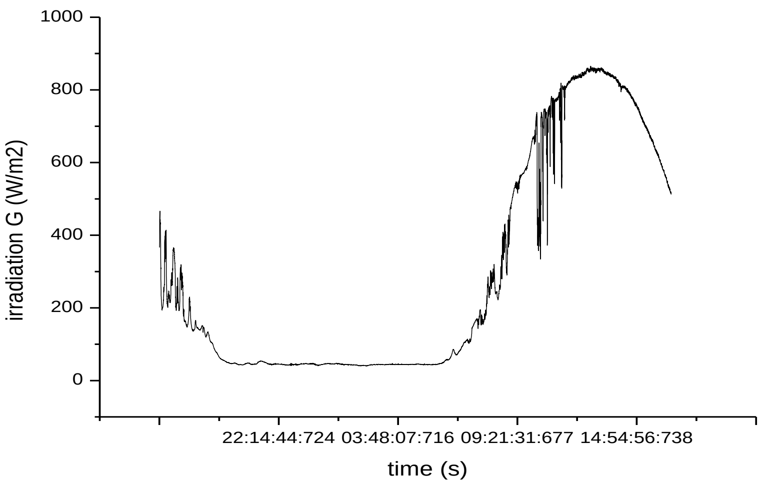

Fig 7. Result of the total measuring solar irradiance in per day in Ghardaïa town.

Fig 8. (a) PVG array used in the presents study, (b) Battery bank used in the present study (BERGAN-SOL 100Ah-12V) and (c) Experimental setup for the proposed system.

Table 1. PV array characterization.

Parameters	Variable	Value	Unit
Short circuit current	I_{SC}	3.5	A
Open circuit voltage V_{OC}	V_{OC}	22.2	V
Current at peak power	I_{MPP}	3.2	A
Voltage at peak power	V_{MPP}	17.5	V
Typical peak power	P_{MAX}	55	W
Minimum power	P_{MIN}	50	W

4. Results and discussion

The issue considered via MPPT algorithms is to find the PV voltage or PV current in which a PV module delivers high power under a given irradiance/temperature. Figure 9 and 10 show the current, voltage and power transferred by the PVG array during one day in spring. It could be observed that the current, voltage and power are close to the highest value at noon (about 26 A, 32V, and 700W) for a solar irradiation G = 900 W/m². Figure 11 and 12 show the current, voltage and power transferred through the Battery bank during one day in spring.

Both IncCond and P&O are examples of "mound climbing" thechniques that could find the local MPP for the array's operating case, and so provide a real MPP. P&O produces power output oscillations around the MPP. IncCond it could determine the MPP without oscillating. It could implement MPPT under rapidly varying weather conditions with higher precision than P&O. However, this technique could create oscillations and can implement erratically under rapidly changing weather conditions.

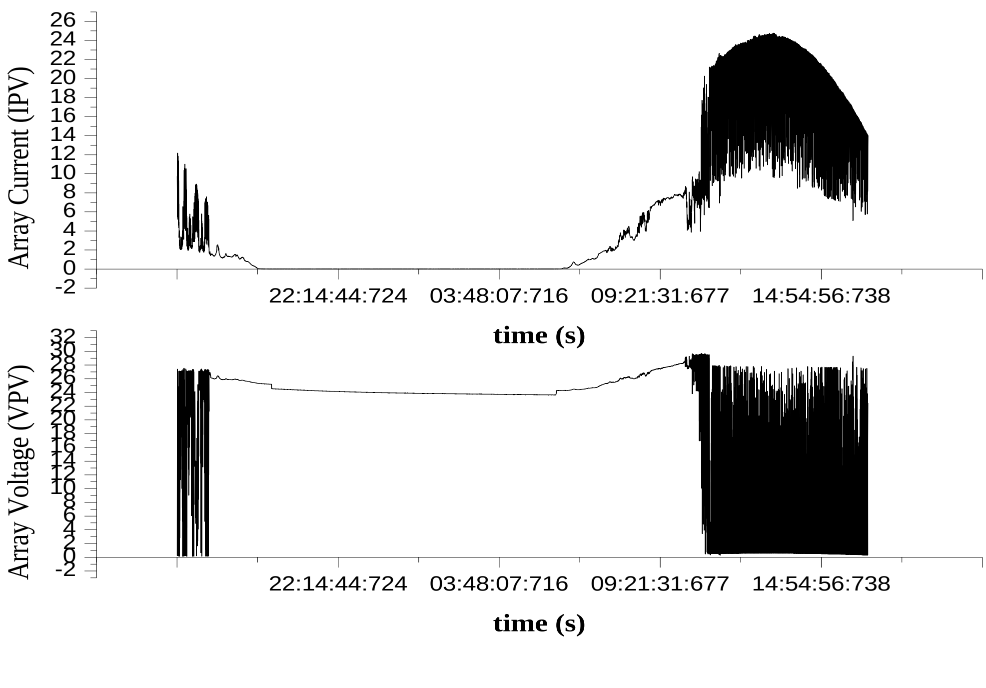

Fig 9. Current and Voltage transferred through the PVG array.

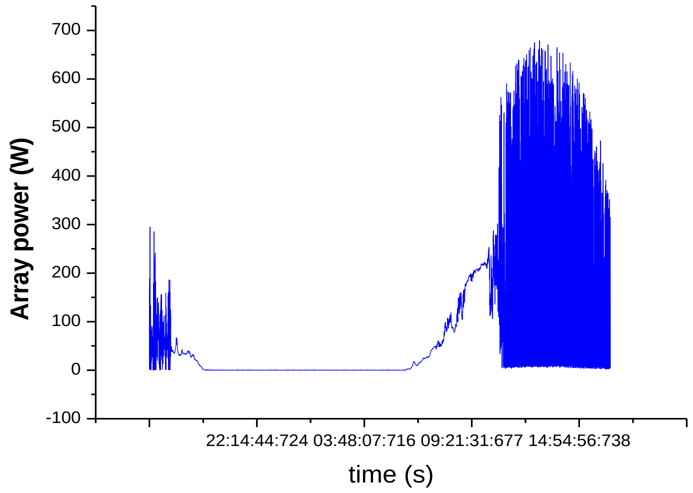

Fig 10. Power transfer through the PVG array

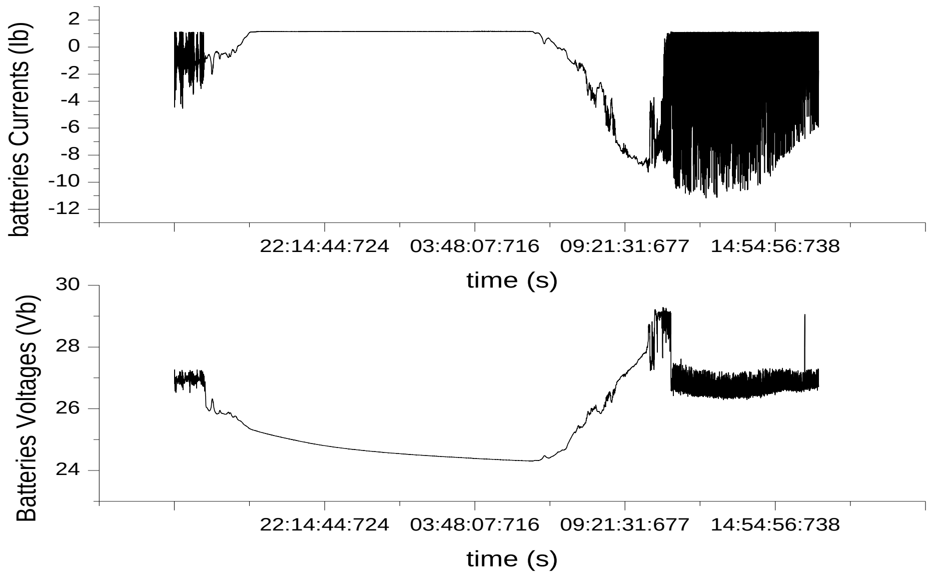

Fig 11. Current and Voltage transferred through the Battery bank.

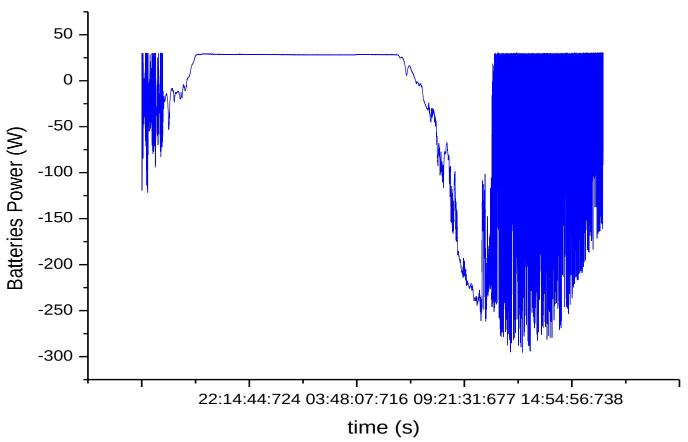

Fig 12. The transmitted power through the battery bank.

5. Simulation results

In the current simulation PV circuit, the PVG is connected with (IncCond, P&O, SCC, OCV and CV) MPPT control strategies in MATLAB/SIMULINK system as depicted in Fig. 13.
The modelling system is applied to highlight the difference among IncCond, P&O, SCC, OCV and CV algorithms which are used in current research.
The MPPT algorithms are applied for comparison of: IncCond, P&O, SCC, OCV and CV. Each MPPT algorithm achievement was estimated when the steady state situation was reached.
Fig. 14, 15, and 16 exhibit the PVG output voltage, current, and power respectively using various MPPT techniques at G=900W/m^2.
The PVG operating voltage values when the IncCond, P&O, SCC, OCV, and CV methods were performed at G=900 W/m2 are as follows: 28.5V, 28.59V, 28.9 V, 28.6V, and 28.9 V, whereas the current values are: 24.1A, 22.1A, 21.75A, 21.25A, and 19.8A, whilst, the power values are: 680W, 672W, 640W, 630W, and 520W respectively under the same condition.
Different MPPTs algorithms have been compared in terms of strategies and variable step size as presented in Table 2. The results show that approximately all MPPTs algorithms were able to work under STC condition. Meanwhile, only the IncCond algorithm has succeeded to track the global MPP during variable weather conditions.

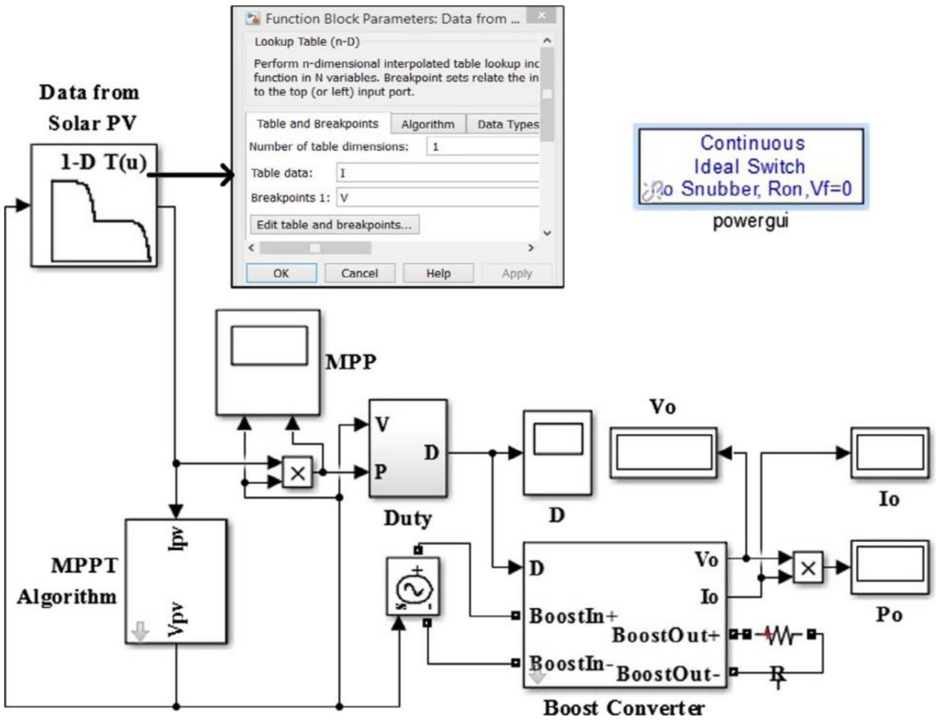

Fig 13. Detailed simulation PV circuit connected (InCcond, P&O, SCC, OCV and CV) MPPT Control Strategies in MATLAB/SIMULINK

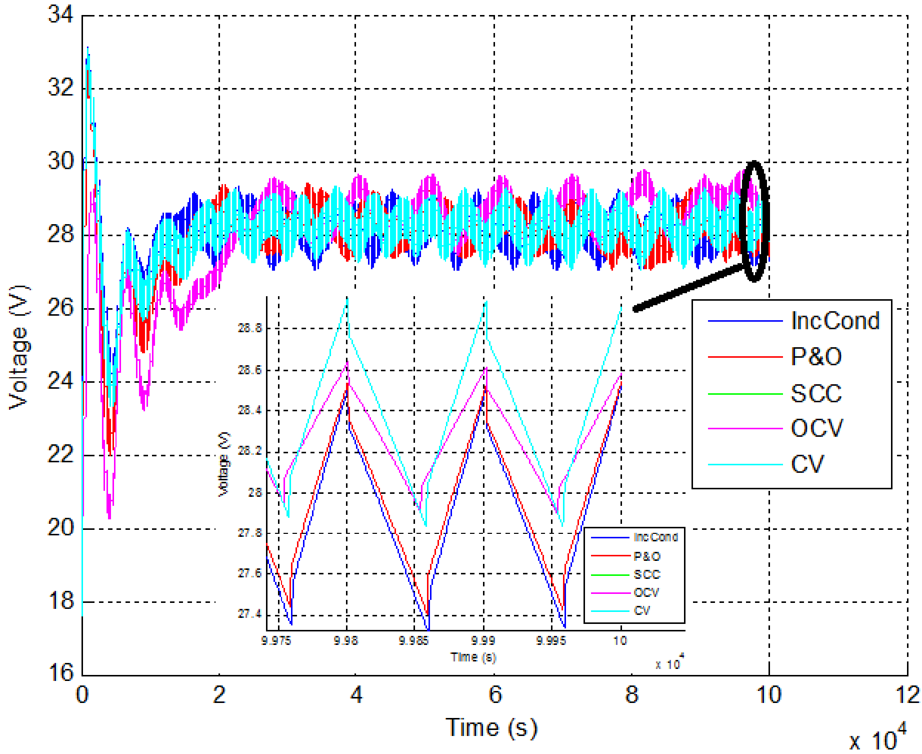

Fig 14. Simulation results of voltage PV side with various MPPT techniques

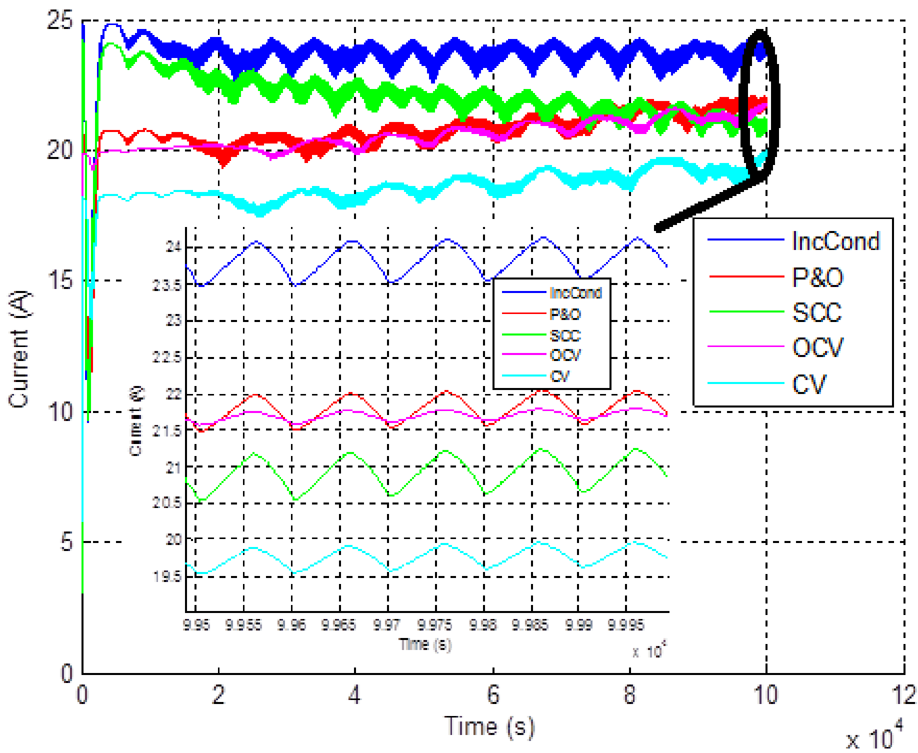

Fig 15**.** Simulation results of current PV side with various MPPT techniques.

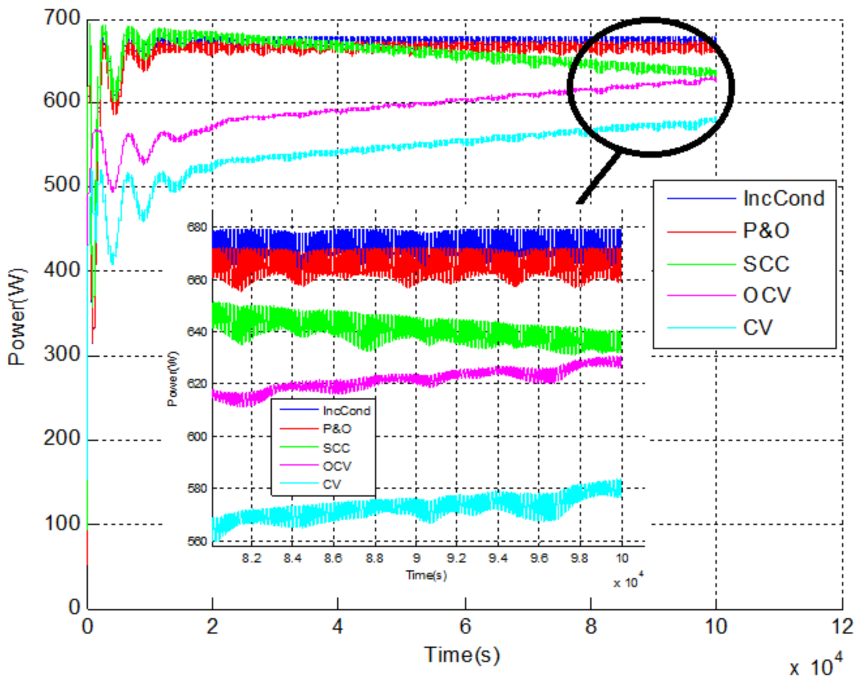

Fig 16. Simulation results of power PV side with various MPPT techniques.

Table 2. Comparison between various MPPT strategies, variable step size of MPPT algorithms.

Characteristics	Type of MPPT strategies Algorithms				
	IncCond,	P&O	SCC	OCV	CV
Precision	High	Good	Simple	Low	Low
Convergence Velocity	Varies	Varies	Medium	Slow	Slow
Tracking Efficiency	High	Good	Simple	Low	Low

6. Conclusions

A scheme to compare the efficiency and performance of five widely used MPPTs in terms of their speed has been carried out. The obtained results for the five MPPTs methods are compared under the same atmospheric conditions. The simulation results display that the good achievement was acquired from the IncCond technique as it provided the highest performance. Also, it was observed that the IncCond technique outperforms P&O, OCV, SCC, and CV methods under the same atmospheric conditions. While the P&O technique presents a reasonable performance, it reduces the constant state pulse and removes the prospect of divergence form the MPP position. Thus, the MPP tracking is carefully accomplished and the system energy quality is suitably improved.

7. Acknowledgements

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