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Performance of MPPT Under Irradiation Changes on PV Systems

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Abstract: As an intention to meet the growing energy demand and to change from all costly fossil fuel sources, many countries have promoted renewable energy source. PV costs are dropping and a lot of attractive projects have resulted throughout the world. Furthermore, the easy and quick implementation of Solar PV gives it a competitive advantage over other renewable energy sources. A MPPT technique is implemented to the system to track the maximum power point of PV. This paper presents a comparative study of seven conventional Maximum Power Point Tracking (MPPT) algorithms. Their performance is evaluated using the simulation tool called Simulink. In particular, this study compares the behaviors of each technique in the presence of solar irradiance. The Results show that Hill Climb, Perturb and Observe and Incremental Conductance generate much more energy under constant condition. And also that the MPPT Constant Current does not vary under the change of irradiation and has a fast response to reach a steady state compared to the other ones.

Keywords: Comparative Study, Maximum Power Point Tracking (MPPT), Simulink, Perturb and Observe, Incremental Conductance (IC)

I. INTRODUCTION

Alternative clean sources appeared, called Renewable Energy Resources (RES). One of the most important is the solar energy which has proved its worth for power plants of multiple MW proportions, as well as smaller applications such as rural electrifications [1], [2], [3], [4].Converting solar energy into electrical energy by Photovoltaic (PV) installations is the most recognized way to used solar energy. Photovoltaic cells are mainly made by crystalline silicon as semiconductor. Typical Photovoltaic (PV) cell efficiency is about 15% which means it can convert 1/6 of solar energy into electricity [5], [6], [7], [8],[9].One of the advantages of using PV is that the system has no moving rotating parts, it requires low maintenance costs and it is environmentally friendly. However, photovoltaic generation systems have two major problems. (1): The low conversion efficiency of electric power generation (9% to 17%). (2): The amount of electric power generated by the solar arrays changes continuously according to the weather conditions and daytime. Moreover the solar cell characteristic is nonlinear and varies according to the irradiation (G) and the temperature (T). In addition there is a unique point on current-voltage (I-V) or power-voltage (P-V) curve where the output of the PV has a maximum power point (MPP) [10], [11], [12]. Therefore it must be determined either through calculations models or by search algorithm. The PV Array is connected to a grid via a Voltage source converter (VSC) and a 260V/25kV three-phase coupling transformer. This paper focuses on the use of MPPT techniques, under solar irradiance variations. This work aims to show that Hill Climb, Perturb and Observe and Incremental Conductance generate much more energy under constant condition comparing to the others methods. And also that the MPPT Constant Current does not vary under the change of irradiation and has a fast response to reach a steady state compared to the other ones.

II. PV AND BOOST CONVERTER

A photovoltaic Array can be described by an equivalent circuit shown in Figure1. A solar panel cell essential is a p-n semiconductor junction. When exposed to the light, a Direct Current is generated. However It changed linearly with the solar irradiance (G) and the temperature (T), I= f (V, G, T).

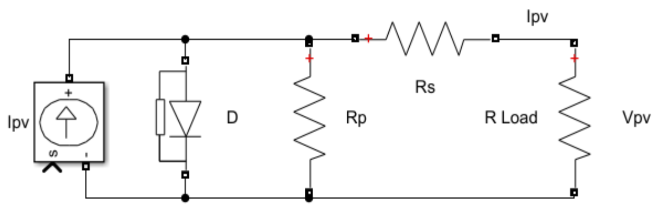

Fig. 1 Equivalent circuit of PV Array

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For the circuit above, the output current is given by the following equations:

$$I = I_{ph} - I_d - I_{sh} \tag{1}$$

$$I_d = I_{ds}\left[\exp\left(\frac{q(V+IR_s)}{nk\,N_s T}\right) - 1\right] \tag{2}$$

$$I_{sh} = \frac{V+IR_s}{R_{sh}} \tag{3}$$

Where:
I: Solar cell current (A)
Iph: Photoelectric current (A)
Id: Diode saturation current (A)
Ids: Reverse saturation current (A)
Ish: Current through shunt resistor (A)
q : Electron charge (1.6×10^{-19}C)
K : Boltzmann constant (1.38×10^{-23} J/K)
T : Cell temperature in Kelvin (K)
V : solar cell output voltage (V)
Rs: Solar cell series resistance (Ω)
Rsh: Solar cell shunt resistance (Ω)

To adjust the duty cycle to match the load a boost Converter is used, Figure 2. This type of converter is called a step up regulator since the output voltage is greater than the input voltage. This paper uses an average model of Boost converter. The Photovoltaic Array considered is SunPower SPR-300E-WHT-D; the electrical characteristics are given in the Table 1. They PV Array is composed of 72 strings of PV module connected in parallels. The power of one PV module is 300.303W. Each string consists of 4 modules connected in series. The total power delivered by the Photovoltaic Array is 87,351.264W.

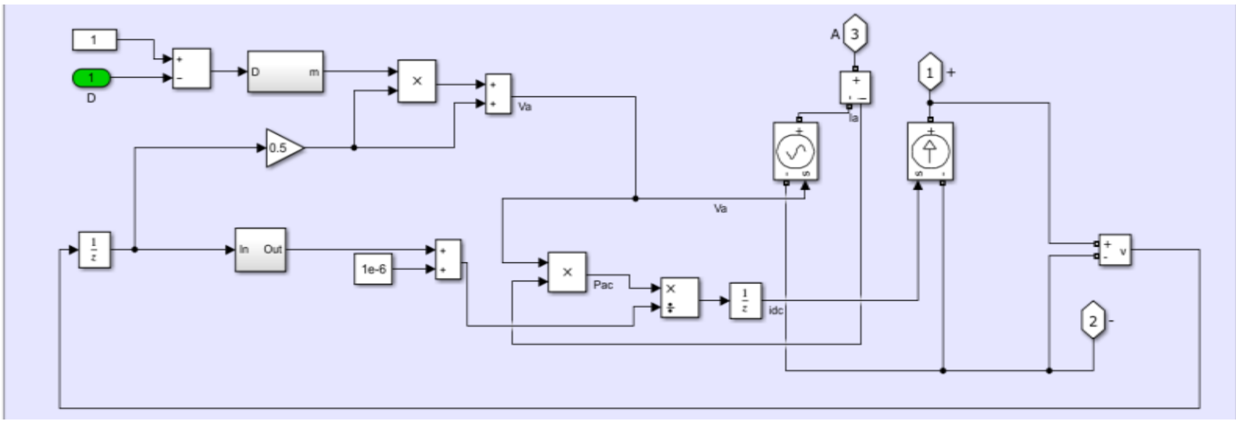

Fig. 2 Average model of Boost converter

Table 1: PV Array SunPower SPR-315E-WHT-D Electrical Characteristics

Parameters	Designation	Values
Pmp	Maximum Power (W)	300.303
Vmp	Voltage at maximum power point (V)	54.7
Imp	Current at maximum power point (A)	5.49
Voc	Open circuit voltage (V)	64
Isc	Short-circuit current (A)	5.87
Ncell	Cells per module	96
TempVoc	Temperature coefficient of Voc (%/deg.C)	-0.2727
TempIsc	Temperature coefficient of Isc (%/deg.C)	0.61738

III. MPPT ALGORITHMS

Many MPPT techniques have been proposed in the literature in order to improve the performance of PV system to track the MPP [13], [14], and [15]. In general Maximum power point tracking algorithms are classified according to the type of algorithm used. This classification makes difference between Conventional methods, Artificial Intelligence (AI), Swarm optimized methods, and bio-Inspired methods. A list of some algorithms methods, classify by the four groups cited before is given in Table 2. A model-based maximum power point tracking method was presented and compared with a Perturb and Observe algorithm [16]. Since the solar irradiation sensors are expensive, the novelty of the proposed model-based method is that there is no need to measure the solar irradiation. In the suggested technique, the voltage of maximum power point can be determined using output voltage and current of solar panel and the voltage of a point on the maximum power point locus with the same current, in three steps. On the other hand, a model-based method calculates the maximum power point rapidly based on the equations of the model and needs far fewer times to do this process. So, a model-based method is faster than a model-free one. A. Mehaouchi [17], analyze the modelisation and the simulation of the electric operation of a PV system adapted with a numerical control P&O. The simulation results is obtained with Matlab/Simulink and shown the control performance and dynamic behavior of photovoltaic system with a MPPT and without it. Mehaouchi used the panel MSX60, this panel gives under the test standard conditions (CST), a power of 60W, an optimal current of 3.5A and an optimal voltage of 17.1V.

Kannabiran K. [18], implements a Cuk converter as power conditioning circuit and Hybrid Maximum power point tracking technique to track maximum power point. The influence of algorithm and the various advantages of the technique are identified for different weather conditions. Kannabiran uses Solartech SPMO85P PV modules and connect it to a RL load through Hybrid MPPT controller for results. A.H [19] used a power simulation (PSIM) software to simulate a modified Maximum power point tracking scheme based on a conventional Perturb and Observe method. The author implemented the proposed MPPT modified method in the control circuit of a DC–DC converter. A prototype unit is tested with artificial light setup on a solar PV panel to simulate the changed solar irradiation condition. The results of the modified Maximum power point tracking scheme are compared with existing schemes. The modified Maximum power point tracking scheme works fast and gives improved results under change of solar irradiation. Furthermore, the steady state oscillations are also reduced. It can be applied in fast-changing solar irradiation areas where solar PV is used. The limitation of the proposed method is that it is not evaluated under partial shading conditions. In the works based on the generality of Photovoltaic [20], Perturb and Observe and Incremental Conductance are used to show the need of a Maximum power point tracking in a Photovoltaic system. The performance of the PV generator is evaluated from the conditions standards (CST): irradiation 1000W / m2, T=25°C and prove that the performance of the PV generator degrades with the increase of the temperature, the irradiation and the variations of the load. In addition, the MPPT adapts the PV generator to the load and transfer the maximum power provided by the PV generator. [21] On Yasser E. works, the method is based on a genetic neural algorithm in order to predict the closest point to the maximum power point (MPP), which will be the kickoff point of the search process. Not only does the new technique start the search process from the nearest point to the maximum power point, but also the developed search algorithm is very fast. Simulation results show that the new technique reaches the MPP in less than 100 sample times compared to tens of thousands of samples for conventional methods such as perturb and Observe. Furthermore, the new technique reaches directly the target maximum power point with small deviation from the intended values.

A comparison results with recently published work are provide to show the validity under fast changing conditions and partial shading. In 2016, A new Flower Pollination Algorithm (FPA) is investigated, the proposed method has dual mode search ability which creates required randomness in all iteration is the key reason to suit FPA for Maximum power point tracking. Further performance of Flower Pollination Algorithm is verified with Particle swarm Optimization method and conventional P&O method [22]. A.kheldoum compared the Golden Section method-based, with P&O and two hybrids: Hill Climb –Fuzzy Logic Control and Perturb and Observe-Fuzzy Logic Control. The results show that the PV systems converge rapidly to the maximum power point, thereby lower energy waste [23]. Ahmed Fathy presents the application of two novel meta-heuristic optimization algorithms to extract the global maximum power point from the PV system under partial shading conditions: The mine blast algorithm (MBA) and the teaching learning based optimization algorithm (TLBO). A comparison with fuzzy logic and adaptive Neuro-fuzzy logic trained by PSO has been done for the non-uniform shadow patterns and the results ensure the reliability of the MBA in extracting the global maximum power from the partially shaded PV array [24]. In 2017, Improved pattern search method (IPSM) is compared with other techniques such as perturb & observe and Particle Swarm optimization, after which IPSM presents lower energy losses in comparison with the other two algorithms, with the advantage of ensuring the location of the optimal power point in all cases [25].

Table 2: List of some algorithms methods

Conventional Methods	Artificial Intelligence (AI)	Swarm Optimized Methods	Bio-Inspired methods	Hybrid (Not study)
Perturb and Observe	Genetic Algorithm	Particle Swarm Optimization	Ant Colony Optimization	PSO- P&O
Incremental Conductance	Artificial Neural Network	Improved PSO	Cuckoo Search	Ant Colony optimization-P&O
Constant Current	Fuzzy Logic Control	Modified PSO	Firefly Algorithms	HC-FLC
Hill Climbing	Adaptive Neuro-Fuzzy Interference System	Deterministic PSO	Flower Pollination Algorithm	P&O-FLC

- **Perturb and Observe**

The Perturb and Observe method consist firstly of changing the voltage reference. Secondly, measure the power converted from the PV. The main problem is that it fails to give the maximum power point, when it is under fast changing atmospheric conditions. If this power and the new voltage are greater than the previous ones, the voltage reference is increased and if not it is decreased. The process is repeated to find the optimum maximum power point tracking. The Perturb and Observe Algorithm is shown in table3.

Table 3: P&O Algorithm

N°	ΔPpv	ΔVpv	Vpv(Vref)	D(Duty Cycle)
(1)	>0	>0	Increase Vref=Vref+ΔV	Decrease D=Dold-ΔD
(2)	>0	<0	Decrease Vref=Vref-ΔV	Increase D=Dold+ΔD
(3)	<0	>0	Decrease Vref=Vref-ΔV	Increase D=Dold+ΔD
(4)	<0	<0	Increase Vref=Vref+ΔV	Decrease D=Dold-ΔD

- **HILL Climb**

Hill Climb and Perturb and Observe are quite similar. The difference is that HC achieve the maximum power by perturbing the Duty Cycle (D) of the DC-DC converter. In the opposite, P&O perturbation is done by using the reference voltage (Vref) or reference current (Iref) of the solar photovoltaic. Thus if we increase Vref, we decrease D and if we decrease Vref, we increase D. The algorithm of HC is shown in table 4.

Table 4: Hill Climb Algorithm

N°	ΔPpv	D(Duty Cycle)
(1)	>0	Increase D=Dold+ΔD
(2)	<0	Decrease D=Dold-ΔD

- **Incremental Conductance**

The Incremental Conductance method consists also of increasing or decreasing the reference voltage. Its can determine that the maximum power point tracking has reached the maximum power of the photovoltaic, by comparing two values, the variation of the voltage and the variation of the current (**ΔV** and ΔI) and then stop the perturbation. The Incremental Conductance Algorithm is shown in table 5.

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Table 5: IC Algorithm

N°	ΔV	ΔI	I+ΔI/ΔV	Vpv(Vref)	D(Duty Cycle)
(1)	= 0	>0		Increase	Decrease
				Vref=Vref+ΔV	D=Dold-ΔD
(2)	= 0	<0		Decrease	Increase
				Vref=Vref-ΔV	D=Dold+ΔD
(3)	≠ 0		>0	Decrease	Increase
				Vref=Vref-ΔV	D=Dold+ΔD
(4)	≠ 0		<0	Increase	Decrease
				Vref=Vref+ΔV	D=Dold-ΔD

- **Constant Voltage**

The Constant Voltage (CV) method requires a fixed reference voltage. In this article, it is assumed that: Vref=V_{MPP}. V_{MPP} is the maximum voltage our PV, during every operation. The algorithm of Constant Voltage is given in table 7.

- **Constant Current**

The Constant current (CC) method required also a fixed reference. In this work, it is assumed that the reference voltage is equal to the current at maximum power point: Iref= I_{MPP}. The algorithms of Constant Current are given in table 8.Those two constants (CC and CV) stay in adequate approximation of the maximum power point, whenever the temperature or the irradiation varies. Thus the two methods assume that the external variation on the PV Array is insignificant.

Table 6: CV Algorithm

N°	ΔI	Vpv(Vref)	D(Duty Cycle)
(1)	>0	V_{MPP}	Increase
			D=Dold+ΔD
(2)	<0	V_{MPP}	Decrease
			D=Dold-ΔD

Table 7: CC Algorithm

N°	ΔI	Ipv(Iref)	D(Duty Cycle)
(1)	>0	I_{MPP}	Increase
			Vref=Vref+ΔV
(2)	<0	I_{MPP}	Decrease
			Vref=Vref-ΔV

IV. RESULTS AND DISCUSSION

The PV array SunPower SPR-300E-WHT-D has been simulated in MATLAB-SIMULINK. The modeling of the PV Array associate with Boost converter, Constant Current MPPT and the Grid is shown in figure 3. The results are obtained under three tests conditions: constant conditions, increase and decrease of the irradiance. One builder block, two switches and one constant value are put inside the model. These elements helps to permute from one test to another, thus simplify the work in this paper. Figure 4 shows the signal builder for the irradiance. Figure 5, shows the I-V curves and P-V curves of The PV Array under Standard Test condition (STC): T=25 deg.C and Ir 1000 w/m2.

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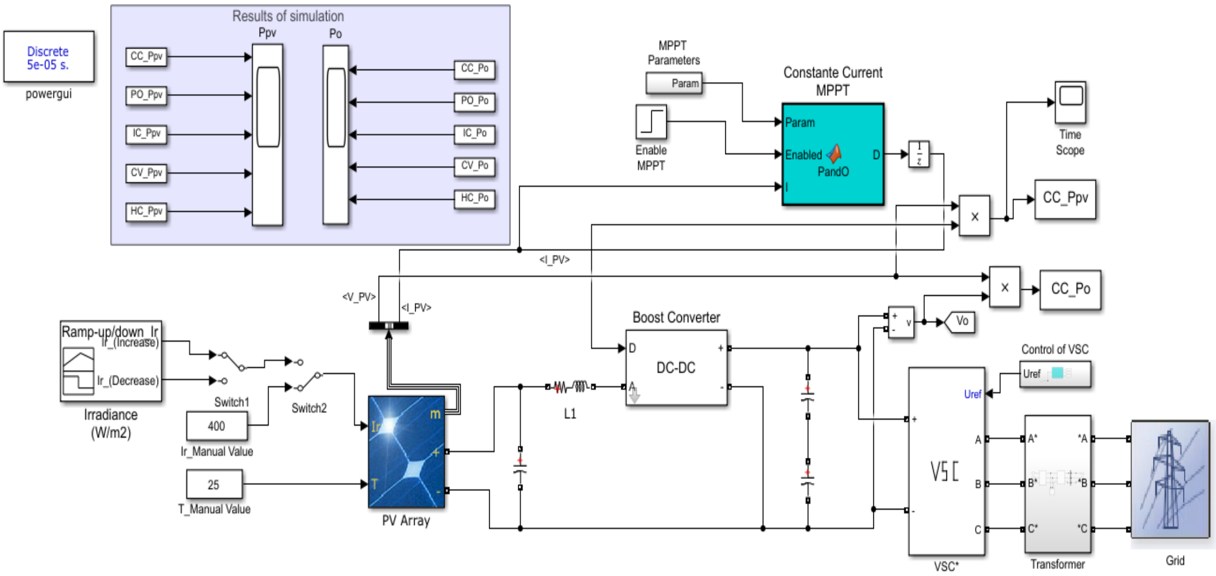

Fig. 3 PV Array + BOOST + CC MPPT + Grid

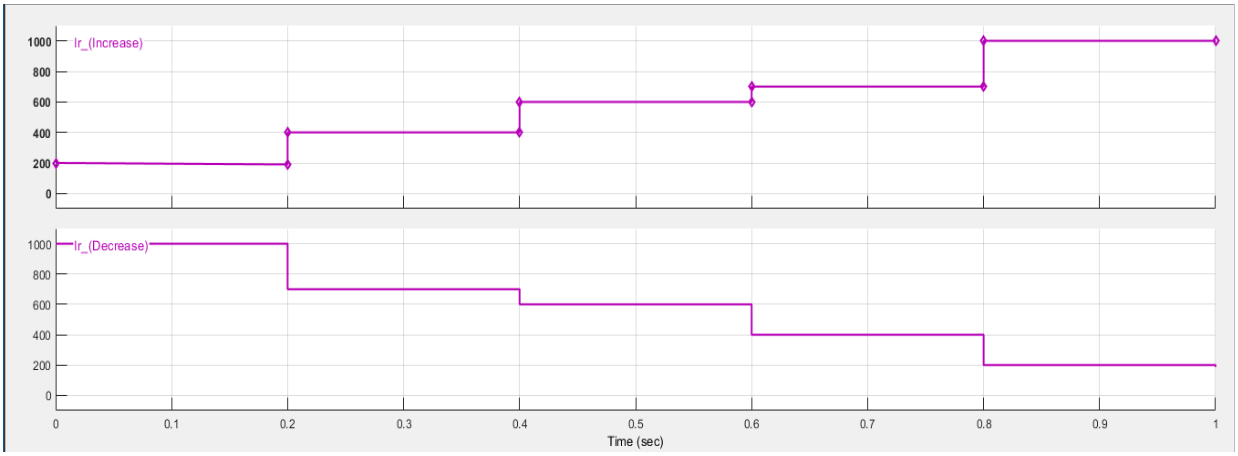

Fig. 4 Signal builder for the irradiance

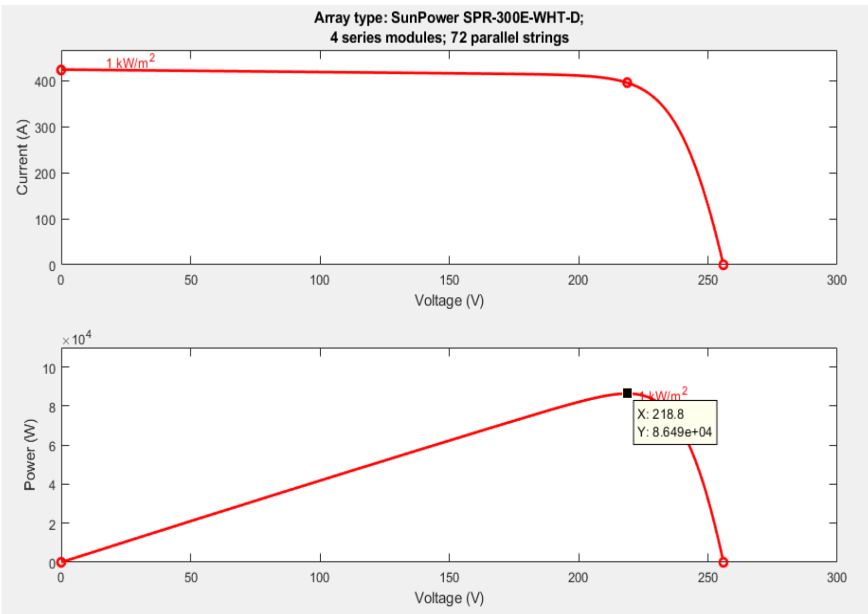

Fig. 5 Curves and P-V curves of The PV Array under STC

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Vol. 7, Issue 6, June 2019

- **Constant Condition**

According to the shape of the curves HC, PO and CV are quite similar and can be confound in the graphic. Figure 6 to figure11, show the curves of different MPPT under STC. Under Standard Test Conditions: HC, PO and IC generate much more energy comparing to CC and CV. However, CC presents less time to reach a steady state (0.147s for Ir=1000w/m2); HC and CV need more time, than the others to reach a steady state .It is important to observe that in every constant condition of irradiation, CC and CV technique reach quickly the min peak (0.015s and 0.020s), then make a fast response to a steady state, than either the P&O method or the IC method. Table 8 and table 9 give respectively the comparison of energy generated by different MPPT during constant condition and the time that all methods reach the minimum peak.

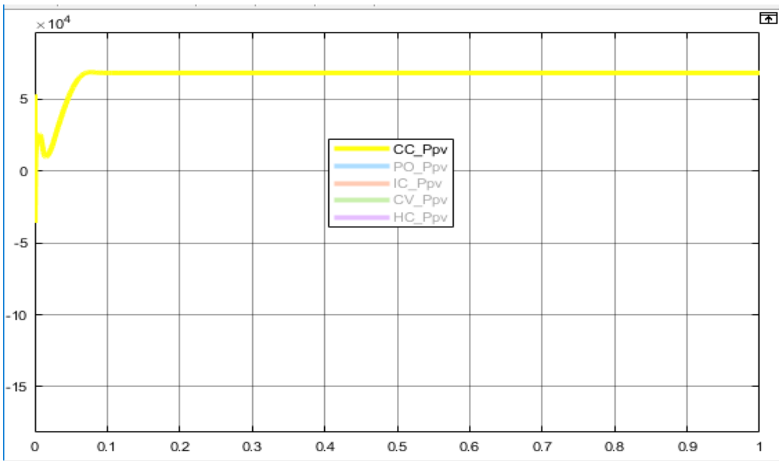

Fig. 6 Curve of CC under STC

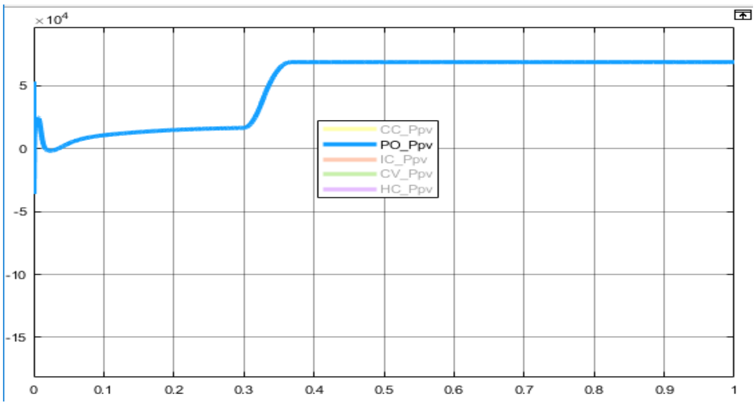

Fig. 7 Curve of PO under STC

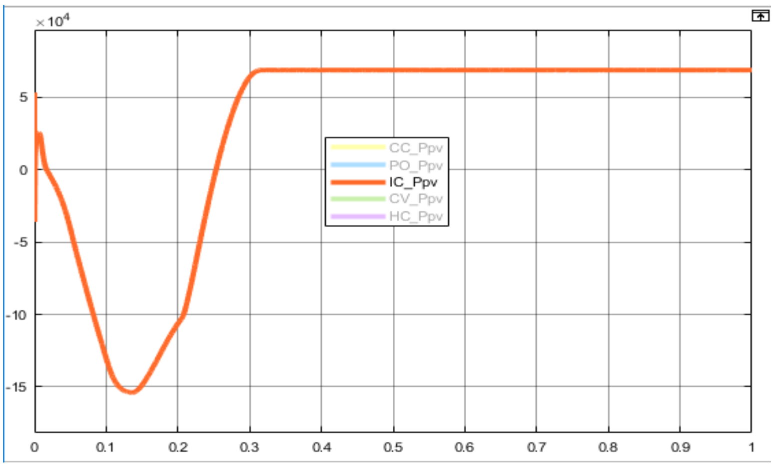

Fig. 8 Curve of IC under STC

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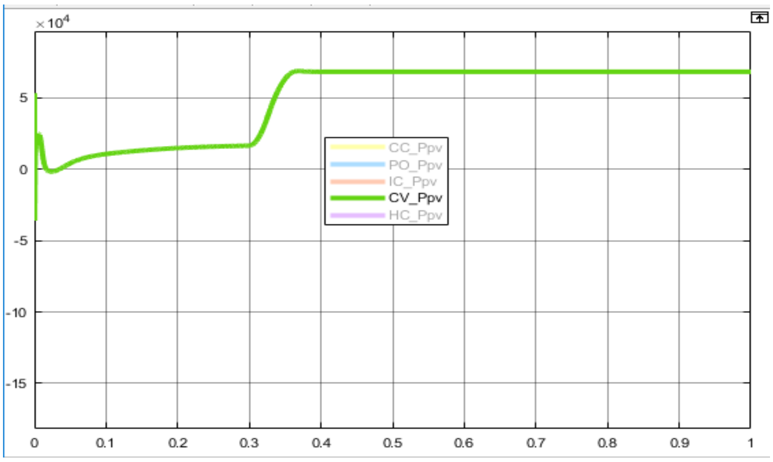

Fig. 9 Curve of CV under STC

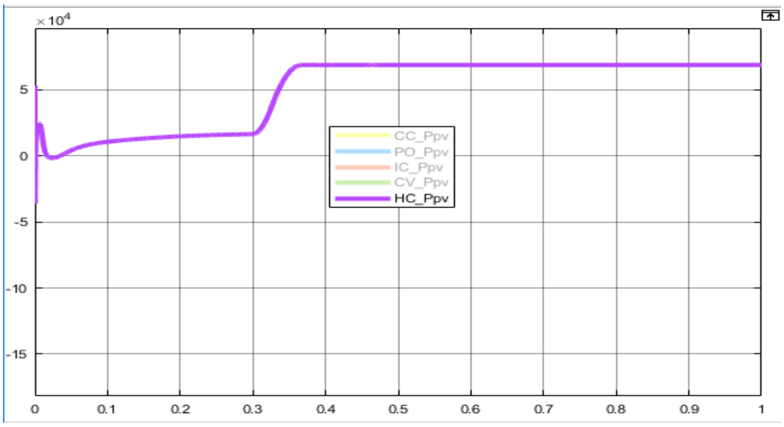

Fig. 10 Curve of HC under STC

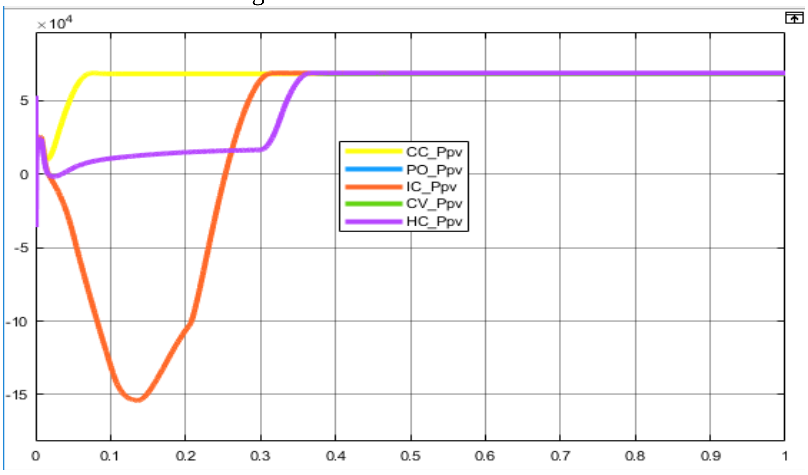

Fig. 11 Curves of five MPPT under STC

Table 8: Constant Condition Energy Generated (Watt)

Ir (w/m2)	Theory values	P&O	IC	HC	CC	CV
1000	8.649 e+04	8.642 e+04	8.642 e+04	8.640 e+04	8.565 e+04	8.594 e+04
800	6.897 e+04	6.897 e+04	6.897 e+04	6.896 e+04	6.839 e+04	6.858 e+04
600	5.147 e+04	5.146 e+04	5.146 e+04	5.146 e+04	5.112 e+04	5.117 e+04
400	3.397 e+04	3.397 e+04	3.397 e+04	3.468 e+04	3.386 e+04	3.386 e+04
Total	**2.409 e+05**	**2.408 e+05**	**2.408 e+05**	**2.415 e+05**	**2.390 e+05**	**2.396 e+05**

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Table 9: Steady state and Min peak

Steady State (Second)					
Ir (w/m2)	P&O	IC	HC	CC	CV
1000	0.384	0.339	0.575	0.147	0.389
800	0.371	0.325	0.362	0.143	0.380
600	0.364	0.331	0.366	0.081	0.379
400	0.364	0.287	0.376	0.101	0.386
Min peak (Second)					
Ir (w/m2)	P&O	IC	HC	CC	CV
1000	0.022	0.139	0.415	0.015	0.020
800	0.022	0.137	0.025	0.015	0.026
600	0.029	0.132	0.025	0.015	0.026
400	0.029	0.126	0.025	0.016	0.028

- **Increase and Decrease of the irradiance**

The two others test are simulated to experiment the behavior of the conventional groups MPPT during the rising of the sun, or when it is going down or else when there is shading reducing the irradiation on the PV Array. It's observed that the PO and CV curve have the same shape either on increase or decrease of the irradiation. When the irradiation increase or decrease, the behavior of CC remain the same as when it's on constant condition. In addition HC when changing to 400W/m2 and CV to 1000 w/m2 cannot reach a steady state. They stay on a variation state during the increase of variation. Also the same variation state is observed with PO, IC and HC during the decrease of irradiation (1000 w/m2 for PO and IC; 1000 w/m2 and 800 w/m2 for HC). This phenomenon is due to their peak min and the time to reach the steady state that is low. Table10 and table 11 give respectively the comparison of energy generated by different MPPT during the increase or decrease of the irradiation.

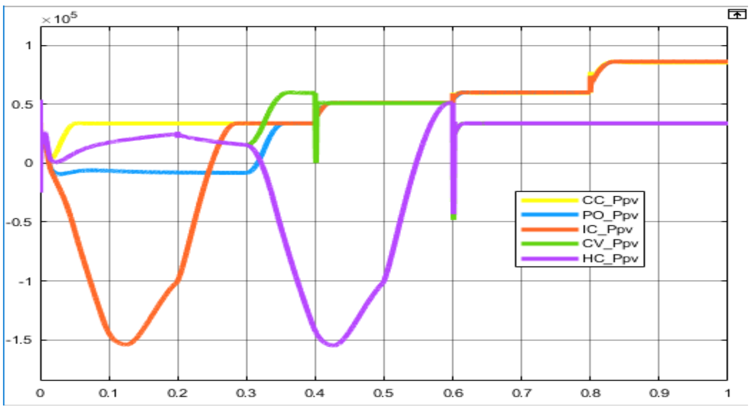

Fig. 12 Curves of MPPT increase of Ir

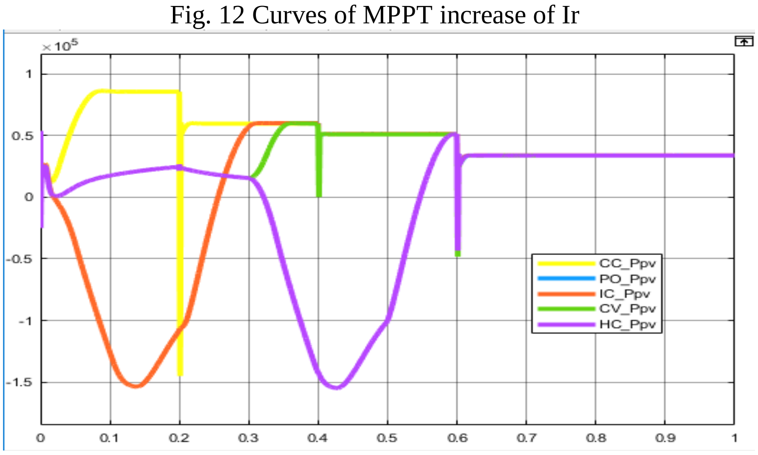

Fig. 13 Curves of MPPT Decrease of Ir

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Table 10: Power during Increase of Ir (Watt)

Ir (w/m2)	Theory Values	P&O	IC	HC	CC	CV
1000	8.649 e+04	8.642 e+04	8.642 e+04	8.638 e+04	8.565 e+04	-
800	6.897 e+04	6.023 e+04	6.022 e+04	6.016 e+04	6.839 e+04	5.982 e+04
600	5.147 e+04	5.146 e+04	5.146 e+04	5.145 e+04	5.112 e+04	5.112 e+04
400	3.397 e+04	3.397 e+04	3.397 e+04	-	3.386 e+04	3.386 e+04
Total	**2.409e+05**	**2.321 e+05**	**2.321 e+05**	**1.980 e+05**	**2.390 e+05**	**1.148 e+05**

Table 11: Power during Decrease of Ir (Watt)

Ir (w/m2)	Theory values	P&O	IC	HC	CC	CV
1000	8.649 e+04	-	-	-	8.565 e+04	8.565 e+04
800	6.897 e+04	6.022 e+04	6.022 e+04	-	6.839 e+04	5.976 e+04
600	5.147 e+04	5.146 e+04	5.146 e+04	5.146 e+04	5.112 e+04	5.117 e+04
400	3.397 e+04	3.397 e+04	3.397 e+04	3.396 e+04	3.386 e+04	3.386 e+04
Total	**2.409 e+05**	**1.457 e+05**	**1.457e+05**	**8.542e+04**	**2.390 e+05**	**2.304 e+05**

V. CONCLUSION

This paper purpose was to analyse by a comparative study of five conventional maximum power point tracking (MPPT) algorithms, the reaction of MPPT under the variation of irradiation. The PV Array SunPower SPR-300E-WHT-D, MPPT, DC-DC Boost converter and Grid was simulated on SIMULINK/MATLAB. The research has shown that, under constant condition: HC, PO and IC generate much more energy comparing to CC and CV. Also that, CC and CV technique reach quickly the min peak, then make a fast response to a steady state, than either the P&O method or the IC method, in every constant condition of irradiation. From the results, the conclusion is that CC doesn't vary under the three tests. Due to his fast response to reach a steady state CC method doesn't lose energy, thus produce 2.390e+05W like as his constant condition.

REFERENCES

[1]. J. Zhang and L. Zhao, “A critical review of the models used to estimate solar radiation”, 2017, paper 70, p. 314-329.
[2]. Africa’s Renewable Future the Path to Sustainable Growth, IRENA, United Arab Emirates.
[3]. A.Tekea, H.Başak, Ö.Çelik, “Evaluation & performance comparison of diff model for the estimate of solar radiation”,2015,pap50, p.1097-1107
[4]. K. Jordan, Facts & Figures SOLAR Energy, 2016.
[5]. M. Sameeullah. (2014) homepage on SlideShare. [Online]. Available:https://www.slideshare.net/maliksameeullah/solar-tracking3-31223734?qid=c70045e8-e29a-451e-bf26-69a3fcc0c771&v=&b=&from_search=1.
[6]. A. Hercules. (2011) homepage on SlideShare. [Online]. Available: https://www.slideshare.net/anish_hercules/solar-photovoltaic-systems.
[7]. Homepage on Alter Energy Tutorials CTAN. http://www.alternative-energy-tutorials.com/energy-articles/solar-cell-i-v-characteristic.html.
[8]. Solar Cell Characteristics, Applied Science Department NITTTR, Sector-26, Chandigarh.
[9]. M.Azzouzi, D.Popescu, & M.Bouchahdane, “Modeling of Ele Character of Photovoltaic Cell Considering Single-Diode Model”, 2016, pap 4.6
[10]. A. Čotar, “Photovoltaic systems”, REA Kvarner d.o.o., IRENA, 2012.
[11]. S. Aissou, “Photovoltaic Panels Characteristics Methods”, Jan. 2013.
[12]. K. Azizi, & A. Ghaffar, “Parameter estimation of photovoltaic panels & a model-based maximum power point tracking algorithm”,2016, Pap. 8
[13]. M.Haili & F.Mechergui, “Comparison of different mppt algthms with a proposed one using a power estimator for grid connect PV systems”, 2016, p 1-10.
[14]. M. Junaid, P. Shukla, and R. Mustafa, “Different types of maximum power point tracking techniques for renewable energy systems: a survey”, 2016, AIP Conference Proceedings, 1715(1):020015.
[15]. R. Faranda, “A comparative study of MPPT techniques for PV systems”, 2008, Paper 2.4.
[16]. K. Aziz, “Parameter estimation of photovoltaic panels and a model-based maximum power point tracking algorithm”, 2016, Paper 8.4.
[17]. A. Mehaouchi, “Modélisation et simulation d'un système photovoltaïque adapté par une commande MPPT”, Master, 2011-2012.
[18]. K.Kanimozhi, B.Raja, “Development of Hybrid MPPT Algthm for Max Power Harvesting under Partial Shading Condition”,2016, Pap 7.8
[19]. A. Haque, “Maximum power point tracking (MPPT) scheme for solar photovoltaic system”, 2014, Paper 1,p.115-122.
[20]. B. Wafa, “Modelisation et Simulation d’un système photovoltaïque adapte par une commande MPPT”, 2012.
[21]. Y. Abu, N. Saad, “Enhancing the maximum power point tracking techniques for photovoltaic systems”, 2014, Paper 40, p. 505-514.
[22]. J. Prasanth, N. Rajasekar, “A new global maximum power point tracking technique for solar photovoltaic (PV) system under partial shading conditions (PSC)”, 2017, Paper 118, p. 512-525.
[23]. A.Kheldoum, “A new golden section method-based max power point tracking tech for solar photovoltaic systems”,2016, Pap111, p.125-136.
[24]. A. fathy, and H. rezk, “A novel methodology for simulating maximum power point trackers using mine blast optimization and teaching learning based optimization algorithms for partially shaded photovoltaic system”, 2016, Paper 8.2.
[25]. A. tobón , J. peláez-restrepo, Juan p. Villegas-ceballos, S. Ignacio, “Maximum power point tracking of photovoltaic panels by using improved pattern search methods”, 2017, Paper 10.9, p. 1316002E