International Journal of Engineering and Advanced Technology (IJEAT)
ISSN: 2249-8958 (Online), Volume-4 Issue-1, October 2014

Evaluation of Photovoltaic System with Different Research Methods of Maximum Power Point Tracking

Mehdi Ameur, Ahmed Essadki, Tamou Nasser

Abstract*—The objective of this paper is to evaluate the photovoltaic system with different techniques of MPPT system by modeling the whole system which is constituted of the photovoltaic generator connected to a DC-DC converter and commanded by three algorithms of MPPT :Perturb an Observe (P&O), Incremental Conductance (INC) and Fuzzy Logic Controller (FLC). The PV system will be simulated at different parameters such as the irradiation, the temperature to determine the influences of these conditions on the power, the voltage and the current generated by the PV system and also on the performance of each methods of the MPPT system. From the various tests and the results of the simulations the PV system can provide a maximum power with rapidity and precision using the MPPT algorithms discussed in this paper.

Index Terms*— Fuzzy logic controller (FLC), Hill Climbing (HC), Incremental Conductance (INC), Perturb and Observe (P&O)

I. INTRODUCTION

The consumption of the conventional energy gives rise to emissions of greenhouse gases and therefore an increase in the pollution, the rapid depletion and the instability of the prices of fossil fuels on a global scale have need an urgent search for new sources of energy to meet the current requirements [1]. The development and research in the PV systems has reduced the price and increased the performance, for that, the photovoltaic energy becomes an environmental solution for the production of clean energy.

Since the power provided by the photovoltaic system is variable and depends on irradiation, temperature and the load then the system cannot be considered as a current source, due to this fluctuation; one or more inverters static are inserted between the photovoltaic generator and the receiver and controlled by maximum power point tracking (MPPT) system allowing to pursue the maximum power point of PV array Fig.1.

Generally the MPPT system calculates the characteristics in output of PV panel (power-voltage) to reach the maximum converter. Several methods are used to track the MPP, the most recognized are Perturb and Observe (P&O), Incremental Conductance, Hill Climbing and intelligent MPPT as Fuzzy Logic and Neuron Network.

In this paper, different methods are studied and compared at the level of accuracy, response time and performance of these methods.

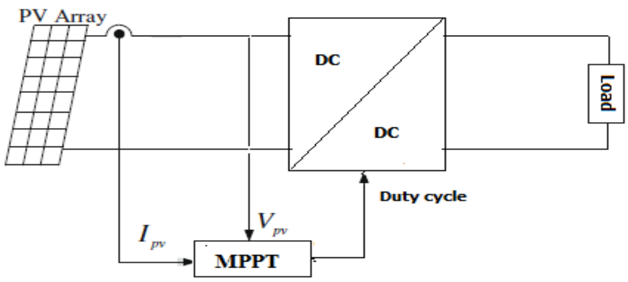


Fig. 1 Line of the photovoltaic conversion

II. MODELING OF A PHOTOVOLTAIC PANEL

A. Mathematical Model

The solar cell can be modeled by a current source in parallel with a diode and its own series resistance (Rs) which is due to the losses in the area P and N and also a resistance in parallel (Rsh) due to leakage current. Usually the resistance (Rsh) is very high can be neglected.

The diode Shockley current Id is represented by the equation [2]:

$$I_d = I_0 [\exp(\frac{V_d}{n.V_T})-1) \tag{1}$$

Where I_0 is the reverse saturation current, Vd is diode voltage, n is the diode quality factor and V_T is the thermal voltage which is expressed by the equation:

$$VT = \frac{KT}{q} \tag{2}$$

Where K is the Boltzmann constant (K= 1.380 x 10-23 J/K), T is junction temperature expressed in Kelvin and q is the electron charge (q= 1.6×10-19C).

The saturation current Io is depends on the nature of the materials and the temperature variation as indicated in the equation [2]:

$$I_0 = I_{0ref}\,(\frac{T}{T_{ref}})^3 \exp\left[q \times E_g (\frac{1}{T_{ref}} - \frac{1}{T})\right] \tag{3}$$

Manuscript published on 30 October 2014.
***** Correspondence Author (s)
Mehdi Ameur*, Department of Electrical Engineering, University Mohamed V Rabat ENSET, Rabat, Morocco.
Ahmed Essadki, Department of Electrical Engineering, University Mohamed V Rabat ENSET, Rabat, Morocco.
Tamou Nasser, Department of Embedded Systems Engineering, University Mohamed V Rabat ENSIAS, Rabat, Morocco.

Where Tref is the cell reference temperature, Ioref is the reverse saturation current at Tref and Eg is the bandgap energy of the semiconductor.

Considering the equivalent circuit in Fig.2 the mathematical model of the solar cell can be described by the following equation: [2]

$$I = I_{ph} - I_0 \, [\exp(\frac{V+R_s I}{n.V_T}) - 1) - \frac{V+R_s I}{R_p} \quad (4)$$

With Iph is Light-generated current at nominal condition given by the expression [2]:

$$I_{ph} = I_{sc} \, [1 + K_i \, (T - T_{ref}) \times \frac{G}{G_{ref}} \quad (5)$$

Where, Ki is current temperature co-efficient (%/°C), G is actual sun irradiation in (W/m²), Gref is nominal sun irradiation in (W/m²), (T-Tref) is the difference between actual temperature and nominal temperature in Kelvin (K)

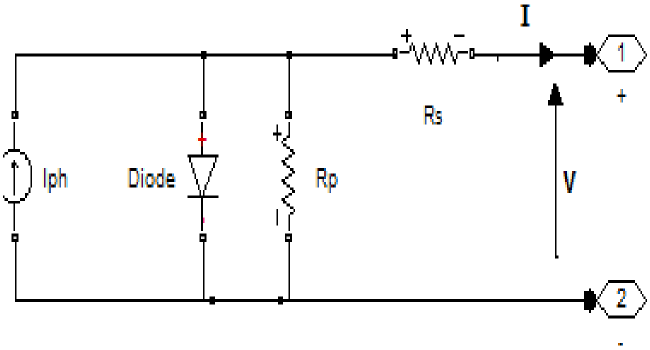


Fig. 2 Equivalent circuit for solar cell

A. *Curve Characteristic of Photovoltaic Panel*

The mathematical models allows to determine the characteristic current-voltage and power-voltage of photovoltaic cell, then it is necessary to model these equations to observe the influence of irradiation and the temperature on the characteristic curve.

PV-cell characteristics depend on insulation and temperature, this becomes apparent when evaluating (4) for selected values of temperature and irradiance and tracing the result shown in the Fig.3 using the datasheet of SUNPOWER A300 in Table I. Fig. 3(a) shows array output current I influenced by change in insulation G, whereas output voltage V is almost constant. Contrarily, for temperature that changes, voltage seems to vary widely, but current is unchanged in Fig.3 (b) [3].

TABLE I

PARAMETERS OF SUNPOWER A300 PANEL

Parameter	Symbol	Value
Maximum Power	*Pmax*	300W
Voltage at *Pmax*	*Vmax*	54.7V
Current at *Pmax*	*Imax*	5.49A
Open Circuit Voltage	*Voc*	64.0V
Short Circuit Current	*Isc*	5.87A
Temperature Coefficient of Voc	*Kv*	176.6mV/°C

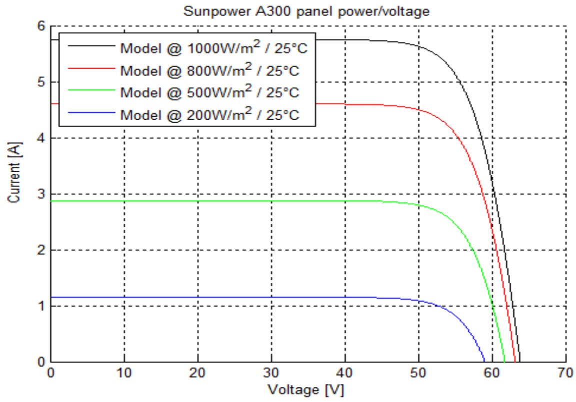


Fig. 3 (a) I-V characteristics of PV panel for various values of irradiation [4]

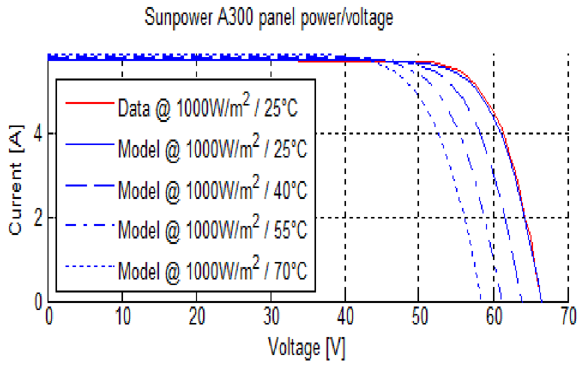


Fig. 3 (b) I-V characteristics of PV panel for various values of temperature [4]

III. DC-DC CONVERTER

The DC-DC converter is a power electronics device implementing one or more ordered switches and which allows modifying the value of the voltage of the DC voltage source. If the output voltage delivered is less than the voltage input, the converter is said step-down (Buck) shown in Fig. 4. In the contrary case, it says booster (Boost) shown in Fig. 5. A third converter is named buck–boost combines the properties of the buck and the boost converter configurations, he can be used for transform ideally any DC voltage input to any continuous tension wished output Fig. 6. [5].

During the functioning of the converter, we close the switch with closing time equal to (D.TS),and we open it in opening time ((1-D) .TS), where: Ts is the switching period and D the duty cycle.

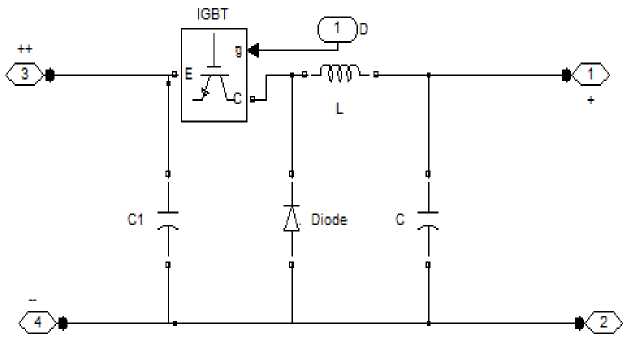


Fig. 4 DC-DC buck converter electric

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

circuit

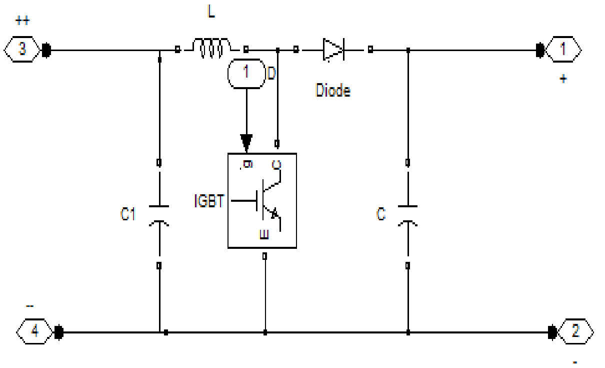


Fig. 5 DC-DC boost converter electric circuit

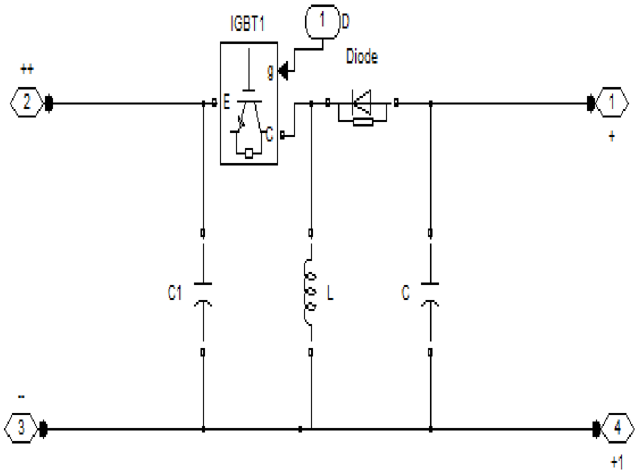


Fig. 6 DC-DC buck-Boost converter electric circuit

IV. MAXIMUM POWER POINT TRACKER (MPPT)

The photovoltaic power characteristics is nonlinear, as stated before, which vary with the level of solar irradiation and temperature, which make the extraction of maximum power a complex task, considering load variations.

A PV array under constant uniform irradiance has a current– voltage (I–V) characteristic like that shown in Fig. 3. The maximum power point (MPP) is a unique point on the curve, at which the array operates with maximum efficiency and produces maximum output power. Several systems are developed in order to extract the maximum power are called maximum power point tracker (MPPT) and the principal role of the MPPT is to maintain the PVarray's operating point at the MPP.[6].

V. TECHNIQUES OF MAXIMUM POWER POINT TRACKER

A. *Perturb and Observe (P&O)*

The Perturb and Observe command consists in disturbing the PV array voltage of low amplitude around the initial value and analyze the behavior of the power variation. The P&O algorithm measures the instant voltage Vpv and currant Ipv to calculate the power Ppv and then compare it with last calculated power Ppv (n-1).The algorithm perturbs the voltage in the positive direction when the power difference is always positive then, in this case, the perturbation will be maintained, in the contrary case, it is inverted to resume the convergence toward the new PPM. [7]. The flowchart of the P&O algorithm is shown in Fig. 7.

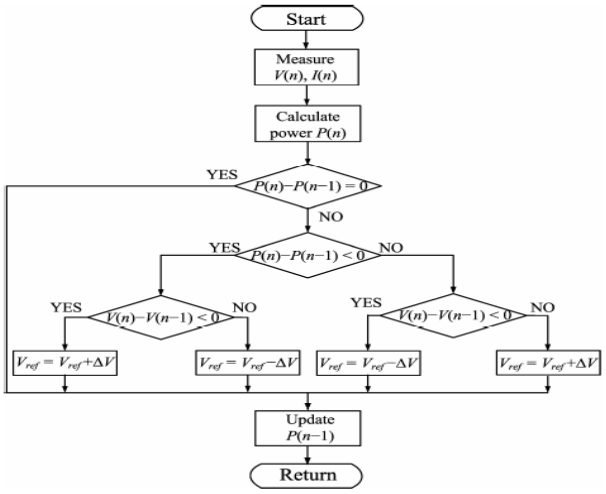


Fig. 7 Flowchart of the P&O algorithm [8]

B. *Incremental Conductance (INC)*

The Incremental Conductance based on the knowledge of the conductance variation of the pv array. Thus, the conductance is defined by the relationship between the current and the tension of the photovoltaic array as indicated below [9]:

$$G = \frac{I}{V} \tag{6}$$

On the other hand, the evolution of the power Ppv over voltage Vpv gives the position of the operating point compared with the MPP. When the derivative of power is zero, this means that one is on the MPP, if it is positive the operating point is located left of the maximum when it is negative; it is located on the right. The Fig. 8 explains the following expressions [9]:

$$If\ \frac{dP_{pv}}{dV_{pv}} > 0\text{, the operating point is on the left of the MPP} \tag{7}$$

$$If\ \frac{dP_{pv}}{dV_{pv}} = 0\text{, the operating point is on the MPP} \tag{8}$$

$$If\ \frac{dP_{pv}}{dV_{pv}} < 0\text{, the operating point is on the right of the MPP} \tag{9}$$

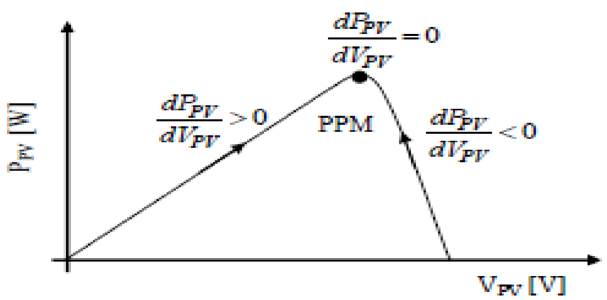


Fig. 8 positioning of the operating point on the current characteristic [10]

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

The relationship between the conductance given by (6) and the derivative of the dPpv/dVpv power can be described by the following equation:

$$\frac{dP_{pv}}{dV_{pv}} = \frac{d(I_{pv} \cdot V_{pv})}{dV_{pv}} = I_{pv} + V_{pv} \cdot \frac{dI_{pv}}{dV_{pv}} \cong I_{pv} + \frac{\Delta I_{pv}}{\Delta V_{pv}} \quad (10)$$

The Fig. 9 explains the new conditions on the variation of conductance as those given by (7), (8), and (9) on the derivative of power:

$$If\ \frac{\Delta I_{pv}}{\Delta V_{pv}} > -\frac{I_{pv}}{V_{pv}}, \text{ the op is on the left of the MPP} \quad (11)$$

$$If\ \frac{\Delta I_{pv}}{\Delta V_{pv}} = -\frac{I_{pv}}{V_{pv}}, \text{ the op is on the MPP} \quad (12)$$

$$If\ \frac{\Delta I_{pv}}{\Delta V_{pv}} < -\frac{I_{pv}}{V_{pv}}, \text{ the op is on the right of the MPP} \quad (13)$$

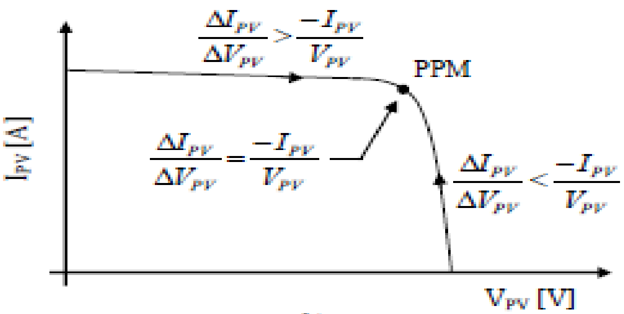


Fig. 9 positioning of the operating point on the voltage characteristic [10]

The maximum power can then be tracked by performing comparisons at every point in the value of the conductance Ipv/Vpv with conductance increment $\Delta I_{PV}/\Delta V_{PV}$ as the algorithm shown in the Fig. 10. Vr is the reference voltage and strength the PV array to operate at this value. If the operating point is on the MPP then the Vr voltage corresponds to the optimal voltage Vopt. Once the MPP reached, the operating point can be maintained on this position until the detection of variation of ΔI_{PV}. This indicates that the climatic conditions have changed, so a new PPM to search, for this, the algorithm increments or decrements the value of Vr until the MPP is reached. [10].

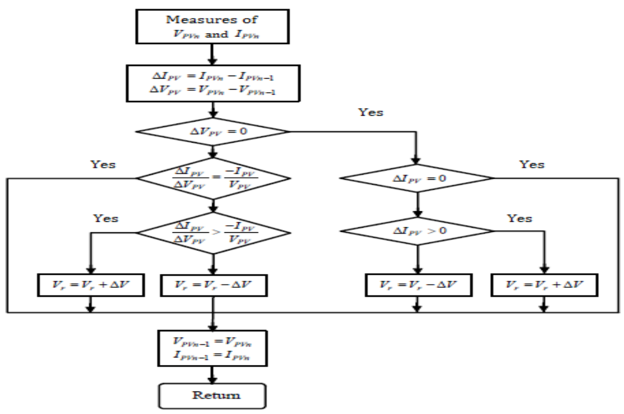


Fig. 10 MPPT algorithm based on the Incremental Conductance method [10]

C. Hill Climbing

The basic operating theory of the hill climbing method is similar to that of the P&O method. Both methods use the condition that P (n) is greater than P (n − 1). The P&O method uses the condition dP/dV to determine whether the maximum power point has been found or not. However, the hill climbing method uses the condition dP/dD to judge. In most applications, DC-DC converters and DC-AC inverters are usually used as the power interface devices between PV modules and loads. The hill climbing method uses the duty cycle (D) of these switching mode power interface devices as the judging parameter when the task of the maximum power point tracking is implemented [11].
When the condition dP/dD = 0 is accomplished, it represents that the maximum power point has been tracked. The flow diagram of the hill climbing algorithm is shown in Fig. 11.

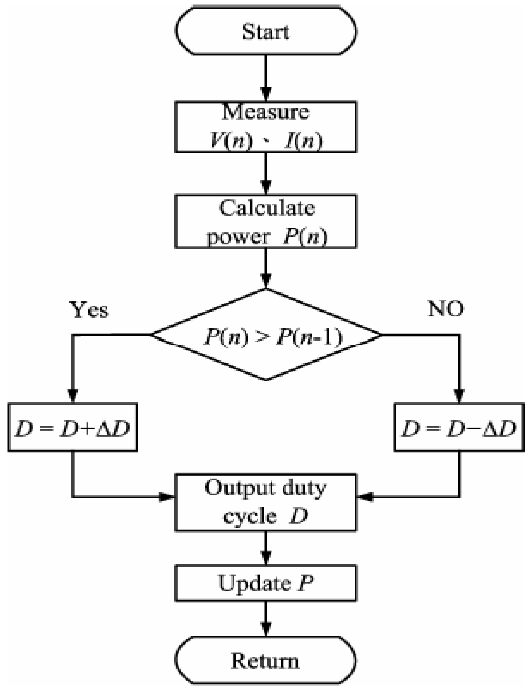


Fig. 11 Flowchart of the Hill Climbing algorithm [11]

D. Fuzzy Logic (FL)

The fuzzy logic method calculates the power variation compared to the voltage variation dP/dV. If the variation ratio is greater than zero, the FLC increases the voltage by adjusting the duty cycle, in the contrary case, if the variation ratio de is less than zero the controller reduces the voltage until the power is maximum or dP/dV=0. The FLC is composed of three main parts: fuzzification, inference, and defuzzification.

The fuzzification allows to convert the numeric input in Linguistics variable .The input are the error e (n) and the variation error Δe(n) defined as following:

$$e(n) = \frac{P(n) - P(n-1)}{V(n) - V(n-1)} \quad (14)$$

$$\Delta e(n) = e(n) - e(n-1) \quad (15)$$

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

These variables will be qualified as: NB: Negative Big, NS: Negative Small, ZE: Zero, PS: Positive Small, PB: Positive Big. As shown the Fig. 12.

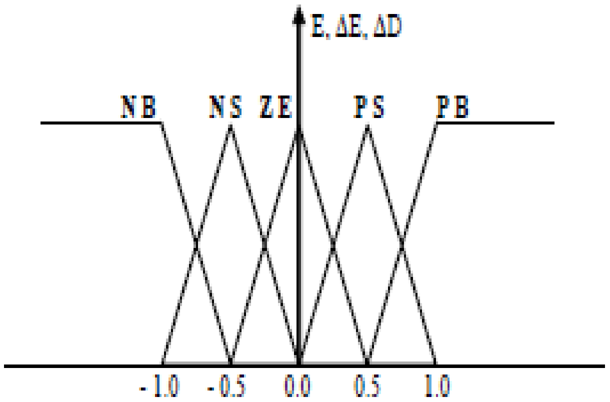


Fig. 12 Basic structure of the command fuzzy

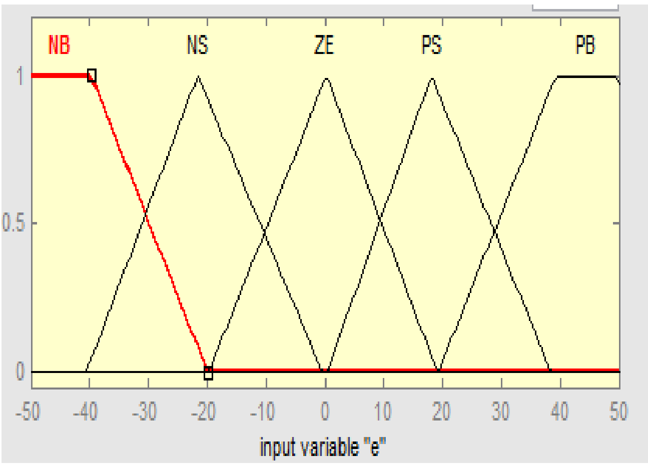


Fig. 12 (a) Membership functions of input E

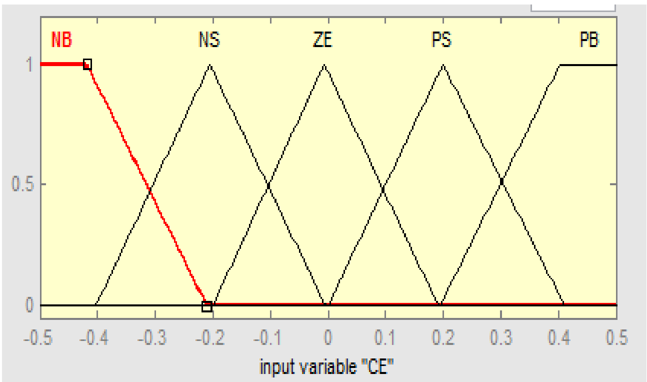


Fig. 12 (b) Membership functions of input CE

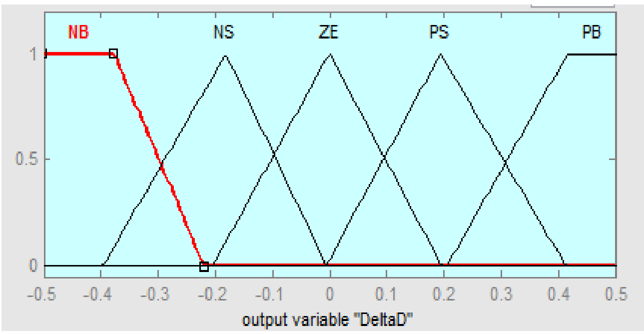


Fig. 12 (c): Membership functions of output Delta D

The interference is to define the logic report between the inputs and outputs by the base rule in the Table II.

TABLE II
FUZZY RULE TABLE

E \ ΔE	NB	NS	ZE	PS	PB
NB	ZE	ZE	NB	NB	NB
NS	ZE	ZE	NS	NS	NS
ZE	NS	ZE	ZE	ZE	PS
PS	PS	PS	PS	ZE	ZE
PB	PB	PB	PB	ZE	ZE

The defuzzification to convert the subset fuzzification in values using the centroid defuzzification to compute the output of the FLC which is the duty cycle (D):

$$D = \frac{\sum_{j=1}^{n} \mu(d_j) - d_j}{\sum_{j=1}^{n} \mu(d_j)} \qquad (16)$$

I. MODELING AND SIMULATION

A. Modeling the Photovoltaic System

In this part, we modeled the photovoltaic system, which consists of photovoltaic generator and DC-DC converter controlled by the MPPT commands. The equations from (1) to (5) for generating the current and the voltage by PV array are represented by MATLAB/SIMULINK as shown in Fig. 13.

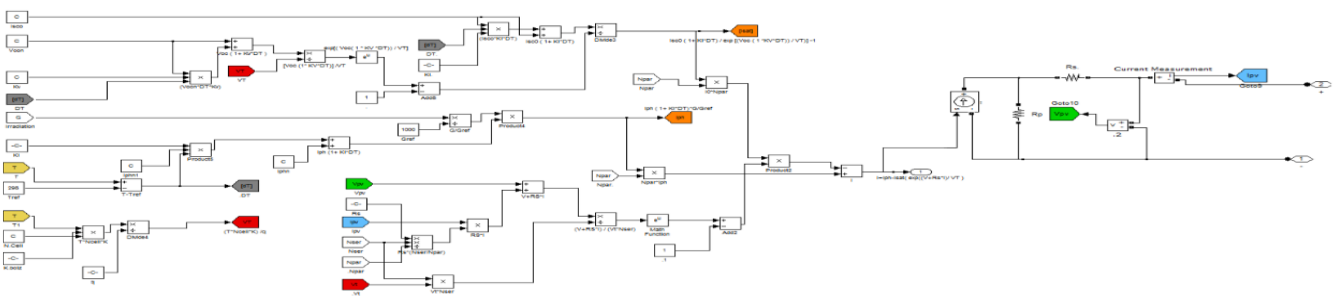


Fig. 13 Model of PV array in Matlab/Simulink

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

The photovoltaic model will be modeled as a single block, the input will be the temperature, irradiation, series and parallel number of the panels and the output will be the current and voltage as shown in the Fig. 14

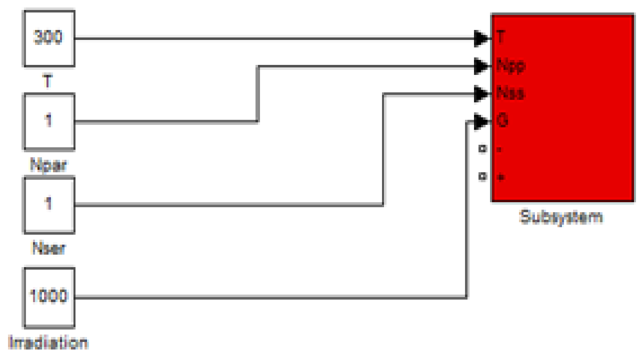


Fig. 14 PV model Subsystem.

The photovoltaic panel will be connected to the boost. Fig.15 shows DC-DC converter boost type which is connected to the photovoltaic panel to increase the input voltage.

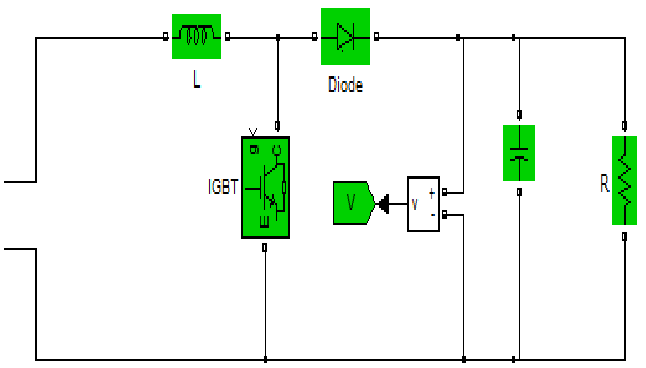


Fig.15 DC-DC converter (boost)

The converter will be controlled with the MPPT discussed previously. The Fig. 16 shows the model of the P&O which contains the calculate block of the power and voltage variation and the block of comparison which increases or decreases the duty cycle to control the boost converter.

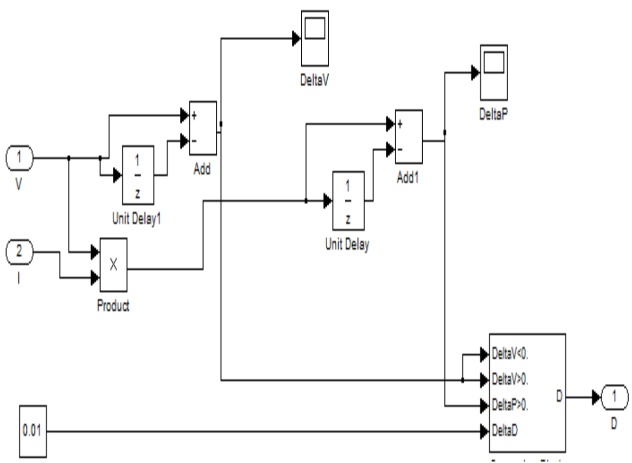


Fig. 16 Perturb and Observe (P&O) MPPT

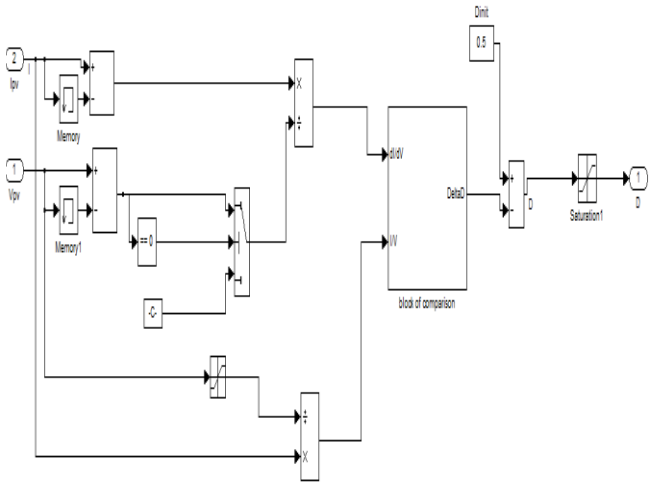


Fig. 17 Incremental Conductance (INC) MPPT

The maximum power can then be tracked by performing comparisons at every point in the value of the conductance Ipv/Vpv with conductance increment dIPV/dVPV as the Simulink model shown in the Fig. 17.For the Hill Climbing MPPT the Fig. 18 shows the model of the (HC).

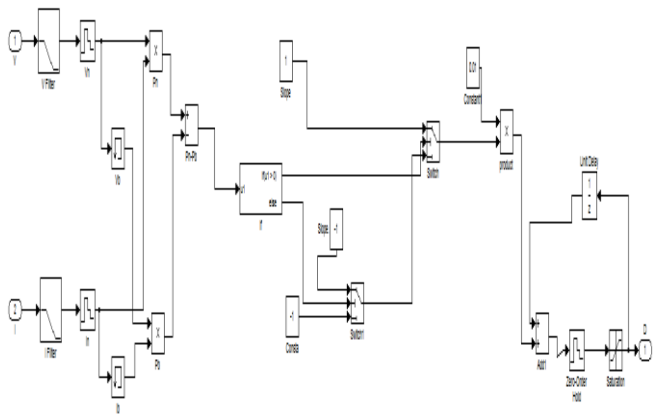


Fig.18 Hill Climbing (HC) MPPT

The Fig. 19 shows how (14) and (15) are represented, to generate the Error and Change in error signals as inputs for the fuzzy logic controller

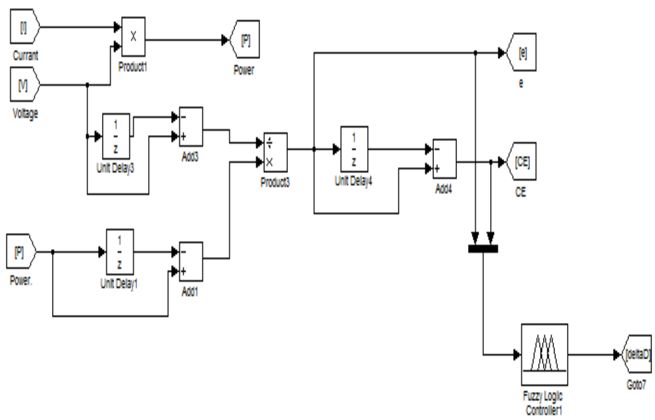


Fig. 19 Fuzzy Logic Controller (FLC) MPPT

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

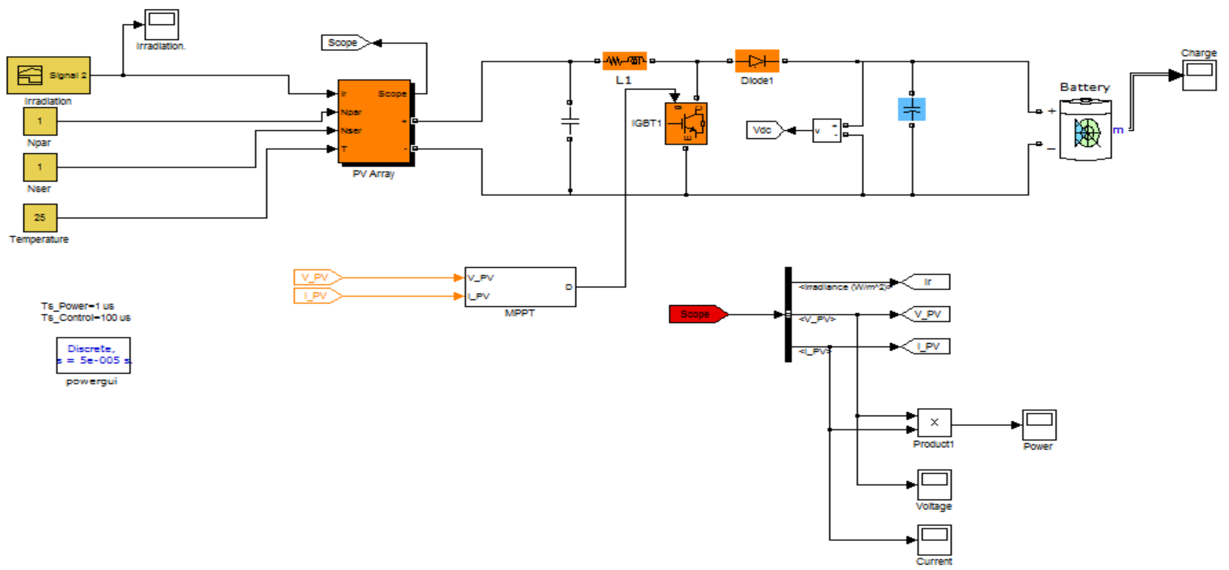


Fig. 20 The complete model of photovoltaic system

B. Simulation and Results

The simulation of the photovoltaic system is made under different conditions of temperature and the irradiation. The modeled MPPT has been implemented to maintain the maximal power. The complete system is shown in the Fig. 20 and the characteristics of the solar module are illustrated in Table III.

At t= 0s to t= 2s, the irradiation is at 1000W/m² and then drops to 800W/m², after a further increase which will last for 2 second before dropping to 400W/m² and the irradiation returns to 900W/m² at t= 8s as shown in Fig. 21, and another test concerns the influence of temperature when we change the temperature from 25°C to 50°C.The purpose of this test is to know the answer of every algorithm in terms of time response and the precision.

TABLE III
TECHNICAL SPECIFICATIONS OF THE SOLAR PANEL USED

Parameter	Symbol	Value
Maximum power	*Pmax*	265W
Voltage at *Pmax*	*Vmax*	35.49V
Current at *Pmax*	*Imax*	7.460A
Open circuit voltage	*Voc*	49.05V
Short circuit current	*Isc*	8.467A
Temperature coefficient of Voc	*Kv*	117.1mV/°C

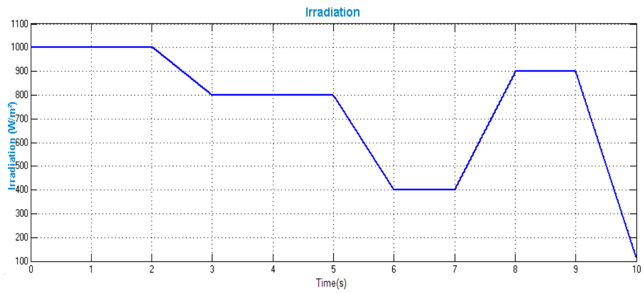
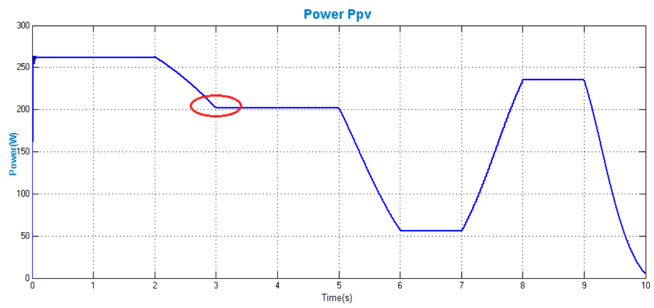
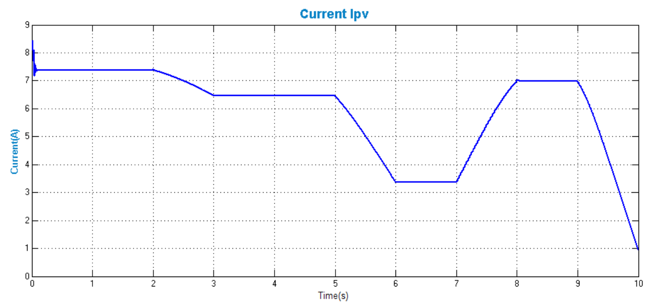


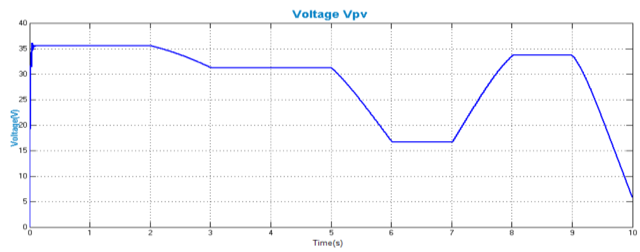
Fig. 21 Irradiation variation



(a)



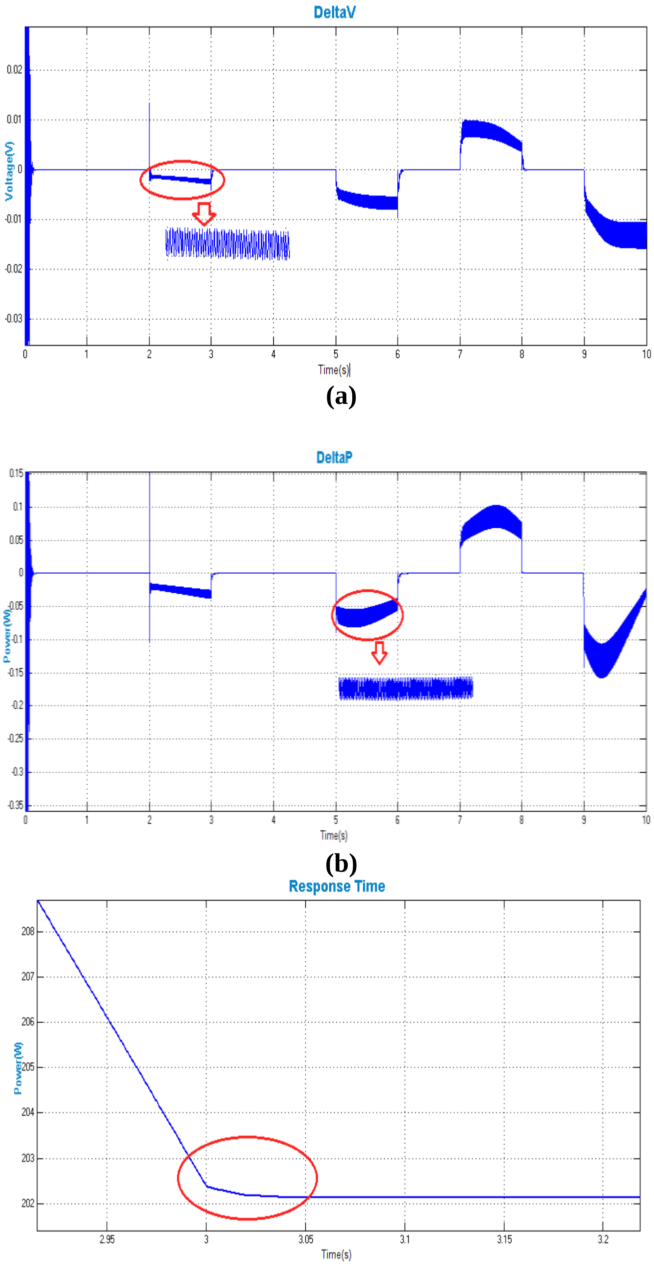
(b)



(c)

Fig. 22 P&O MPPT algorithm simulation when the irradiation is instantly fluctuated (a) Output Power. (b) Output Current variation. (c) Output Voltage

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)



(a)

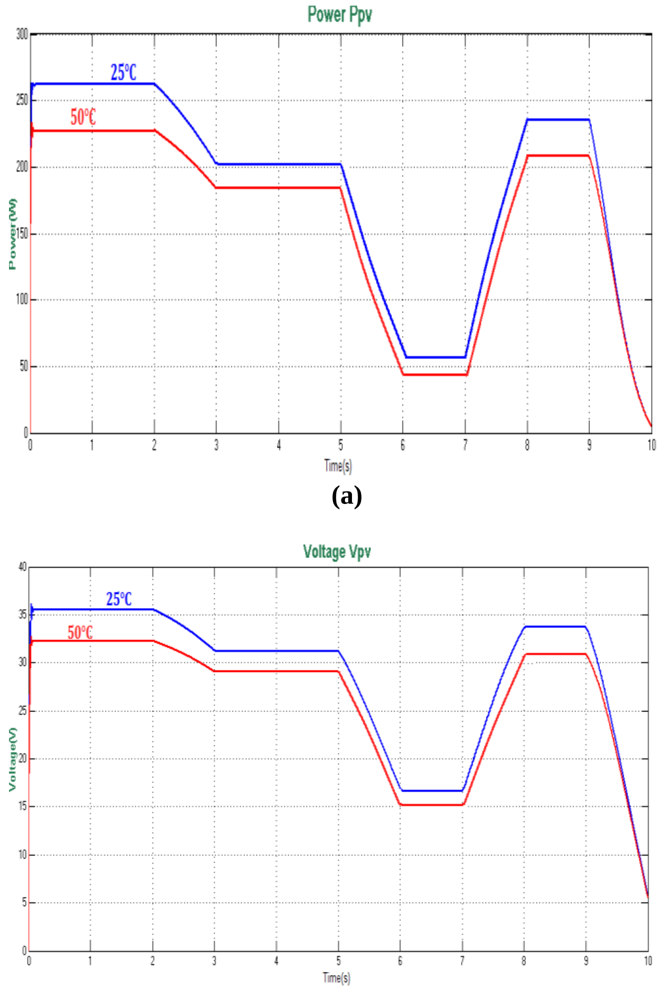
(b)

(c)

Fig. 23 Power and voltage compared with the last value to determine the variation DeltaP and DeltaV (a) The variation of ΔV. (b) The variation of ΔP.(c) Response time to achieve the MPP

The P&O oscillated the operating point around the PPM. after change of illumination the system converged on the new point PPM as the watch Fig. 22 (a).During the change of the Irradiation P&O MPPT calculates the ΔV and ΔP as shown in the Fig. 23(a) and (b) to increase or decrease the duty cycle to track down the new PPM in response time which does not exceed 30ms with ΔD=0.01 as shown in Fig. 23 (c).

From 0W/m² to 1000W/m² P&O MPPT takes approximately 30 ms to arrive at the power of 260W to oscillate around this point. At t = 0s to t = 2s and for 1000W/m² irradiation level, the voltage output is at 35.43V as shown in the Fig. 22 (c) and Because of the oscillations, the system loses power in the output. The Fig. 22 (b) shows the influence of irradiation on the output current Ipv which reached a value of 7.34 A at 1000W/m². When the temperature changes, it influences on the power and the voltage. In this test, the temperature is increased from 25°C to 50°C which causes a decrease of the power shown in the Fig. 24 (a) and the voltage shown in Fig. 24 (b). P&O MPPT track down the new operating point either when the irradiation, and the temperature changes at the same time.



(a)

(b)

Fig. 24 Influence of temperature on the power and the voltage of the photovoltaic system (a) Output Power at 25 ° C and 50 ° C. (b) Output voltage at 25 ° C and 50 ° C

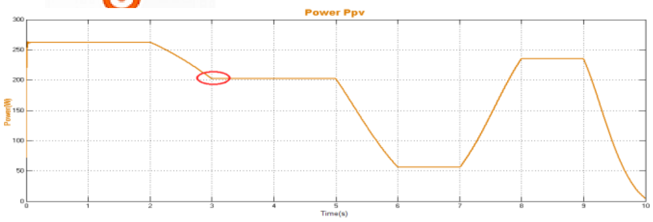
The Incremental Conductance highly extracted the maximum power with precision even if the irradiation varies rapidly as shown in the Fig.25 (a). Contrary to the P&O MPPT, Incremental conductance stop when the MPP is found which allows to extract the maximum power without losses owed to the oscillations. The difficulty is the check if:

$$\frac{\Delta I_{pv}}{\Delta V_{pv}} + \frac{I_{pv}}{V_{pv}} = 0 \qquad (17)$$

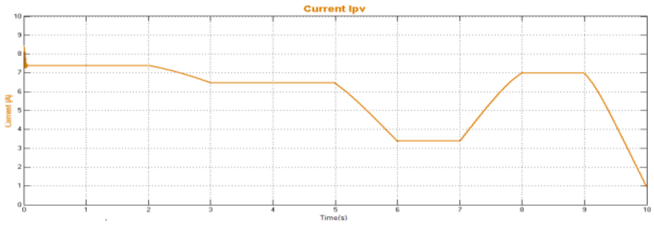
This makes the execution time of the algorithm longer compared to the P&O with 50ms as shown in the Fig. 26.For 1000W/m², the current output is at 7.38A as shown in the Fig.25 (b) and the voltage at 35.47V as shown in the Fig.25(c).

For the same test conditions, the temperature change from 25°C to 50°C which causes a decrease of the power shown in the Fig. 27 (a) and the voltage shown in Fig. 27 (b). The incremental conductance MPPT tracking the operating point with the same accuracy even the irradiation and temperature change at the same time.

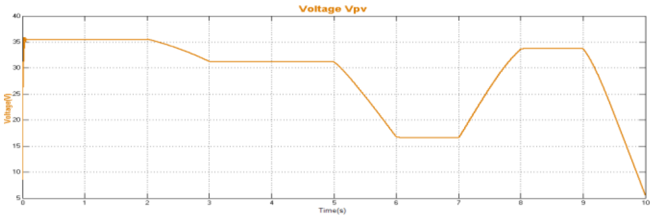
Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)



(a)



(b)



(c)

Fig. 25 Incremental Conductance MPPT algorithm simulation when the irradiation is instantly fluctuated (a) Output Power. (b) Output Current. (c) Output Voltage

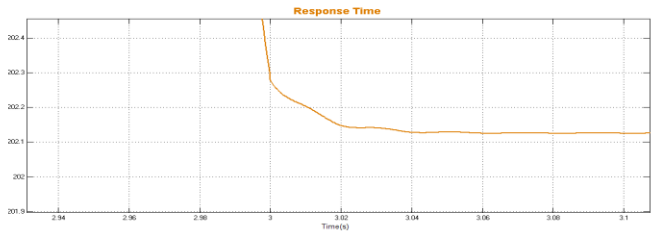
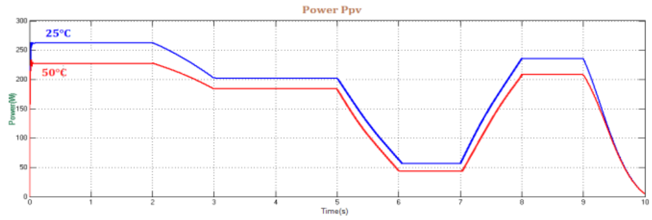
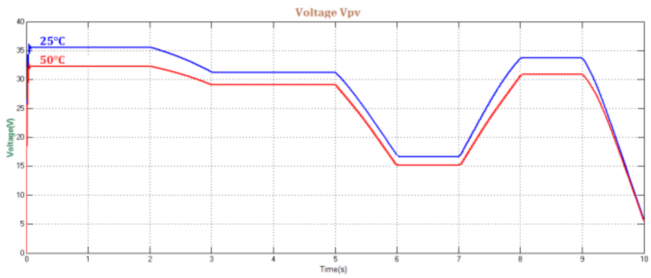


Fig. 26 Response time



(a)



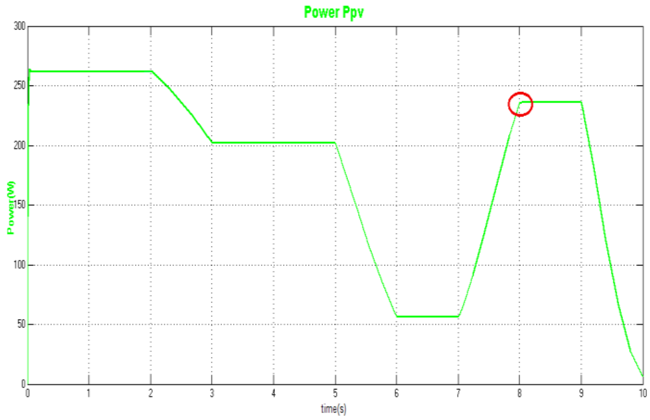
(b)

Fig. 27 Influence of temperature on the power and the voltage of the photovoltaic system. (a) Output Power at 25 ° C and 50 ° C.(b) Output Voltage at 25 ° C and 50 ° C

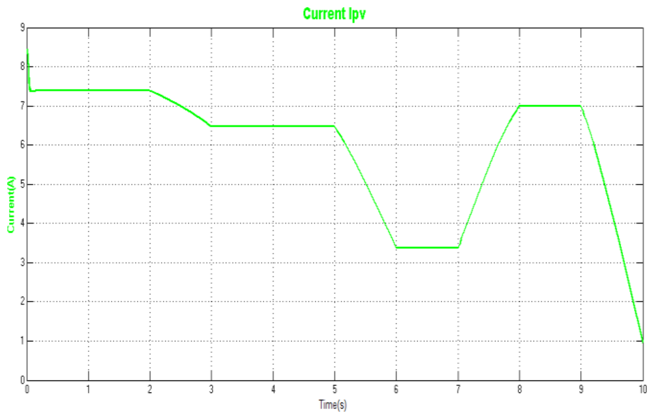
The Fuzzy Logic Controller is able to track the MPP very quickly as shown in the Fig. 29.So this performance is explained by the ability of fuzzy logic controller to reduce the oscillation around the MPP and allows to extract the maximum power. For 1000W/m² , the current output is at 7.41A as shown in the Fig. 28 (b) and the voltage at 35.48V as shown in the Fig. 28 (C).

The temperature change from 25°C to 50°C which causes a decrease of the power shown in the Fig. 30 (a) and the voltage shown in Fig. 30 (b)

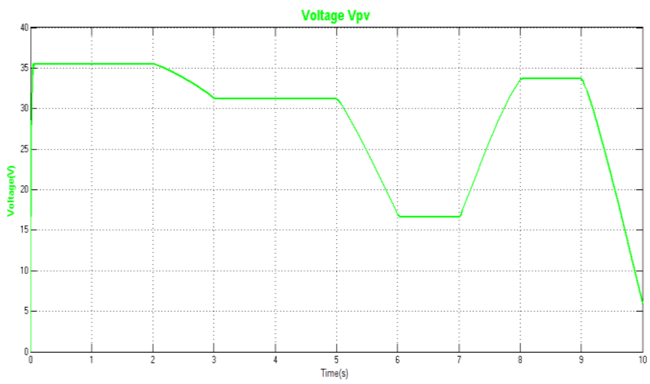
The fuzzy logic has better than the conventional MPPT and can track the MPP faster and controls the PV system to achieve better performance in term of power stability



(a)



(b)



(c)

Fig. 28. Fuzzy Logic controller algorithm simulation when the radiation is instantly fluctuated (a) Output Power. (b) Output current. (c) Output Voltage

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

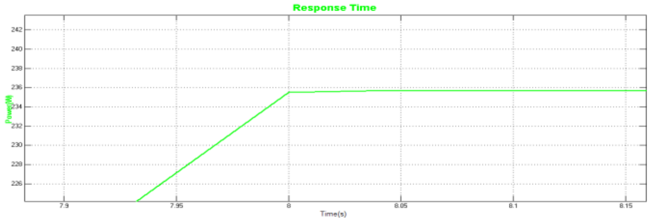
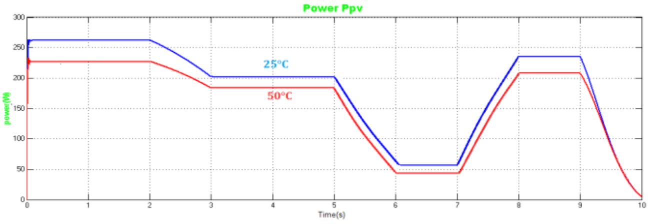
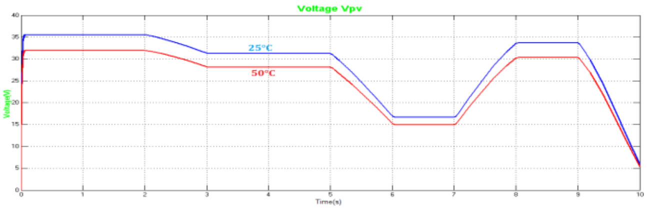


Fig. 29: Response time



(a)



(b)

Fig. 30: Influence of temperature on the power and the voltage of the photovoltaic system. (a) Output Power at 25 ° C and 50 ° C.(b) Output Voltage at 25 ° C and 50 ° C

The results of comparison is shown in TABLE IV

TABLE IV
COMPARISON OF THE THREE DIFFERENT MPPT

Controller	Power	Voltage	Current	Response Time
P&O InCond Fuzzy Logic	260W 261W 263W	35.43V 35.47V 35.46	7.34A 7.38A 7.41	30ms 50ms 20ms

VII. CONCLUSION

The power of the photovoltaic system still depends on the climate conditions, and even if the conditions are favorable, the system cannot provided the maximum power if it is not connected to system to track the maximum power point. In order to understand the influence of irradiation and temperature and the MPPT techniques on the power, this paper has presented a study of the photovoltaic system which includes the modeling of the PV array that is connected to the DC/DC converter controlled by the three MPPT, P&O, Incremental Conductance and The fuzzy logic. The results obtained by the three techniques are close to the level of the ability to track the PPM, but FLC controller has proven that it has a better performance and low response time compared to the P&O and Incremental Conductance which are performing well when they are optimized.

REFERENCES

[1] Pongsakor Takun, Somyot Kaitwanidvilai, Chaiyan Jettanasen "Maximum Power Point Tracking using Fuzzy Logic Control for Photovoltaic Systems" proceedings of the International MultiConference of Engineers and Computer Scientists 2011

[2] Vol II, IMECS 2011, March 16-18, 2011, Hong Kong.

[3] Guenounou Ouahhib, Boutaib Dahhou, Ferhat Chabour,"Adaptive fuzzy controller based MPPT for photovoltaic systems" February 2014. P.843–850.

[4] Krismadinata, Nasrudin Abd. Rahim, Hew Wooi Ping, Jeyraj Selvaraj "photovoltaic module modeling using simulink/matlab" Procedia Environmental Sciences 17 :537 – 546

[5] Francisco M. González-Longatt ,"Model of Photovoltaic Module in Matlab™," Francisco M, González-Longatt, "Model of Photovoltaic Module in Matlab™", 2do congresoı beroamerı cano de estudıantes de ıngenıeríaeléctrı ca, electrónıca y computacıón pp.1-5, 2005

[6] R.W. Erickson, ''Fundamentals of Power Electronics'', Chapman & Hall, 115 Fifth Avenue, New York, NY, 1997.

[7] de Brito MAG, Sampaio LP, Junior LG, Canesin CA. Evaluation of MPPT techniques for photovoltaic applications. In: Proceedings of the industrial electronics (ISIE) 2011 IEEE international symposium; 2011. p. 1039–44.

[8] Mummadi Veerachary, Tomonobu Senjyu and Katsumi Uezato, "Voltage-Based Maximum Power Point Tracking Control of PV System" IEEE Transactions on Aerospace And Electronic Systems, Vol. 38, No. 1, January 2002, pp.262-270.

[9] A. Oi, "Design and Simulation of Photovoltaic Water Pumping System," in Electrical Engineering, vol. Master of Science in Electrical Engineering. San Luis Obispo: California Polytechnic State University, 2005, pp. 113.

[10] C. Cedric, ".energy optimization of the electronic stage of adaptation dedicated to photovoltaic conversion». Thesis of the university Toulouse III - Paul Sabatier. (2008)

[11] Nacer K. M'Sirdi, A.Rabhi , M.Abarkan, "New VSAS approach for Maximum Power Tracking for Renewable Energy Sources (RES)" Mediterranean Green Energy Forum 2013: Proceedings of an International Conference MGEF-13, 708 – 717

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)