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MPPT Based Artificial Neural Network Versus Pertub & Observe For Photovoltaic Energy Conversion System

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Abstract. In this paper, we present a study of maximisation power tracking for photovoltaic energy conversion chain. We give a comparison between two techniques of tracking maximum power; Perturb &Observe (P&O) as first method versus a second method using artificial neural network (ANN). The two methods are designed, modelled and simulated in MATLAB/Simulink environment. The simulation results are discussed involving performance and constraints of these two algorithms.

1 Introduction

In general, photovoltaic energy conversion System (PECS) are used to produce electric power for utilities along sunny day. To maintain supplying load under variables irradiation the current and voltage are adjusted to maximum power available for climatic conditions, MPPT techniques are used for extracting the maximum power from the PV arrays at different environmental conditions such as temperature and solar irradiance. Many MPPT algorithms have been used in the literature [1-5]. MPPT techniques are clustered into two major groups: the conventional and intelligent techniques. The conventional MPPT algorithms include Hill-Climbing (HC) [1], Perturb and observe (P&O) [1,2], and incremental conductance (INC) [2]. These techniques show obvious shortcomings, such as low tracking efficiency during quickly changing solar irradiation and fluctuations about the point of maximum power. The intelligent techniques, including fuzzy logic controller (FLC) [3,4], artificial neural network (ANN) [5], particle swarm optimization (PSO) [1], genetic algorithm (GA) [6]. These algorithms present many advantages, such as low oscillations around the point of maximum power and a speedy tracking response to changing conditions. The DC-DC boost converter is designed to be placed between a PV array and a load, it is used to transfer the maximum power to load by changing the duty cycle of the DC-DC boost converter.

In this study, P&O and artificial neural network (ANN) techniques are simulated using with Simulink /Matlab. Thus, ANN is designed and compared with P&O technique

2 Modelling of the PV array and boost converter

The proposed system is shown in Fig.1 which consists of a PV array, DC-DC boost converter, load and MPPT controller [7].

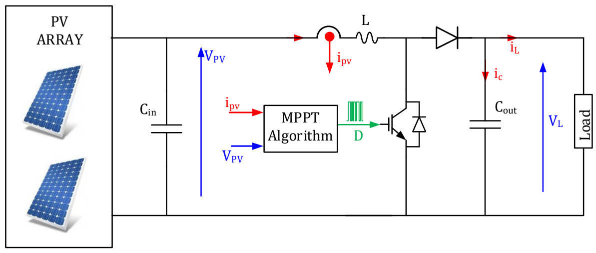

Fig. 1. Block diagram of the studied system

2.1 PV ARRAY

The equivalent model used to represent parasitic the pv cell consists of a current source, one diode, and resistors which is illustrated in Fig.2 [7,8].The relation between the terminal current (I_{pv}) and voltage (V_{pv}) of a PV array is expressed by following equation [8]:

$$I_{pv} = N_p I_{ph} - N_p I_s \left[exp\left(\frac{V_{pv}+I_{pv}R_s\left(\frac{N_s}{N_p}\right)}{V_t} \right) - 1 \right] - \frac{V_{pv}+I_{pv}R_s\left(\frac{N_s}{N_p}\right)}{R_p\left(\frac{N_s}{N_p}\right)} \quad (1)$$

With: $V_t = \frac{nN_{sc}KT}{q}$

Where, I_{ph} is the photovoltaic current, I_s is the reverse saturation current of the diode, V_t is the thermal voltage,

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n is the diode ideality factor, k is the boltzman constant (1.38e-23J/K), q is the electron charge (1.602e-19C), T is cell temperature in Kelvin, Nsc number of series cells per module, Ns and Np are the number of series and parallel modules, Rp and Rs are the shunt and series resistors of the cell, respectively.

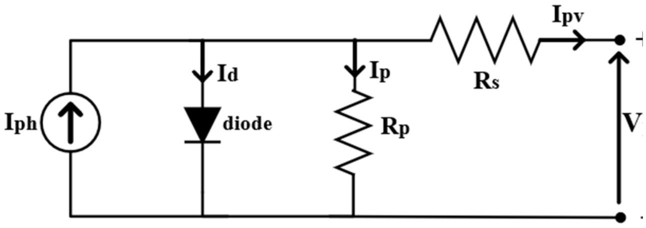

Fig. 2. Equivalent circuit of the one diode model

The Canadian Solar CS6P-240P PV array is chosen for our modeling and simulation. We used MATLAB/Simulink, for the simulation. The I-V and P-V characteristics of modeled PV array with variation of temperature and irradiance shown in Fig.3 and Fig.4.

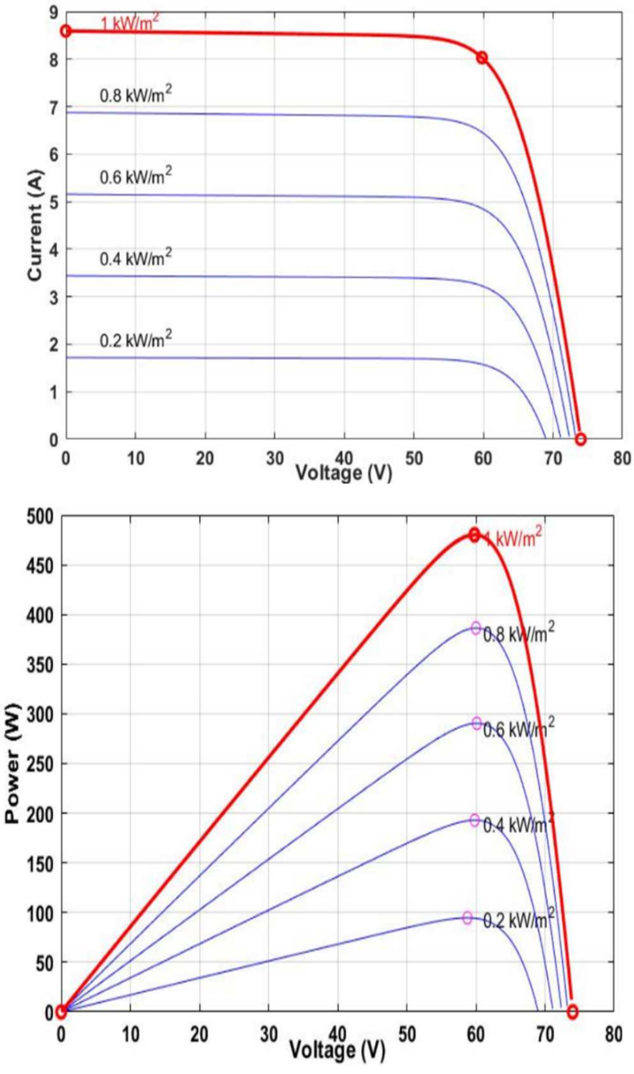

Fig. 3. The I–V and P-V characteristics for PV array with varying irradiation at 25°C

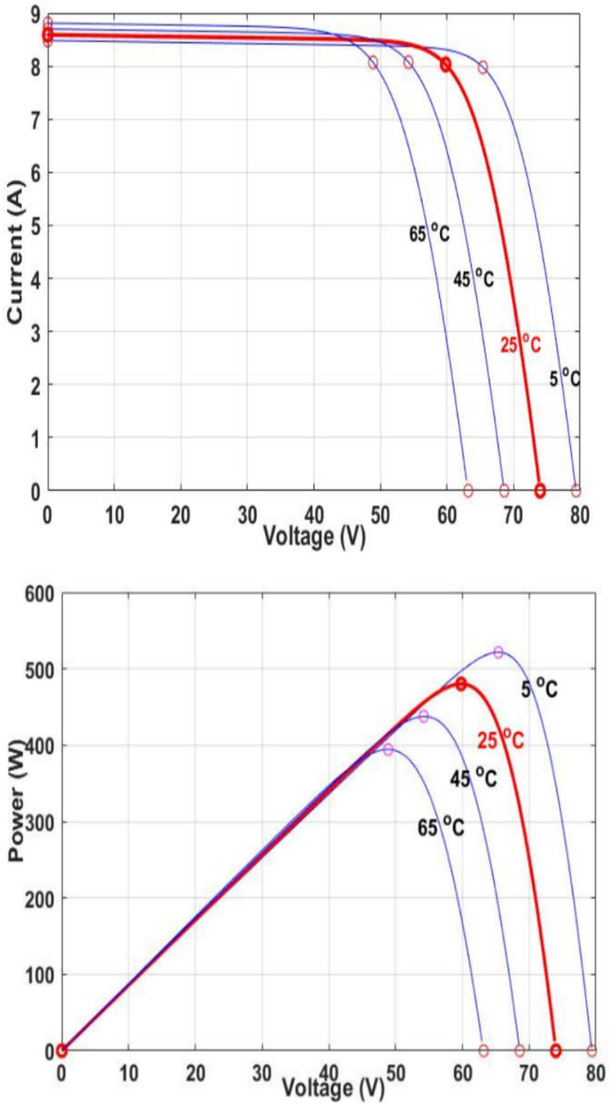

Fig. 4. The I–V and P-V characteristics for PV array with various temperature at 1000w/m²

2.2 Boost converter

The DC-DC converter acts as an interface between the PV array and the load to boost voltage at PV terminal. The bloc Boost is depicted in fig1 and it consists mainly of inductor, transistor switch, diode and filter capacitor [4].

The voltage conversion ratio of the boost converter can be expressed as in (2) [9]:

$$\frac{V_L}{V_{pv}} = \frac{1}{1-D} \quad (2)$$

Where, V_{pv} is input voltage (PV voltage), V_L is output voltage, and D is the duty cycle of the switch PWM signal.

The inductor L and capacitor C_{out}, are designed to limit respectively current and voltage ripple. These main elements are designed according to boost performances. Table 1, summarizes the calculated values of inductor L and capacitor C_{out}, as in (3), (4) [10]:

$$C_{out} = \frac{D}{R.f_s.\frac{\Delta V_L}{V_L}} \quad (3)$$

$$L = \frac{V_{pv} \cdot D}{I_{pv} \cdot f_S \cdot \delta} \quad (4)$$

Where, δ is the percentage of the inductor current ripple, $(\Delta V_L/V_L)$ is the percentage of output voltage ripple.

Table 1. Parameters of the boost converter

Parameters	Symbols	Values
Input filter capacitor (μF)	C_{in}	390
Output filter capacitor (μF)	C_{out}	470
Boost inductor (mH)	L	10
Switchng frequency (KHz)	f_s	24
Resistive load (Ω)	R	40

3 MPPT algorithms

To track the set point at optimal available power, MPPT algorithms adjust voltage and current to deliver its maximum power regarding climatic circumstances. The following describes two algorihtms Pertub and Observe .

3.1 Perturb and Observe

The Perturb and observe (P&O) is the most popular used MPPT, because of it simple structure and easy implementation The flowchart of P&O MPPT algorithm is shown in Fig. 5 [11].

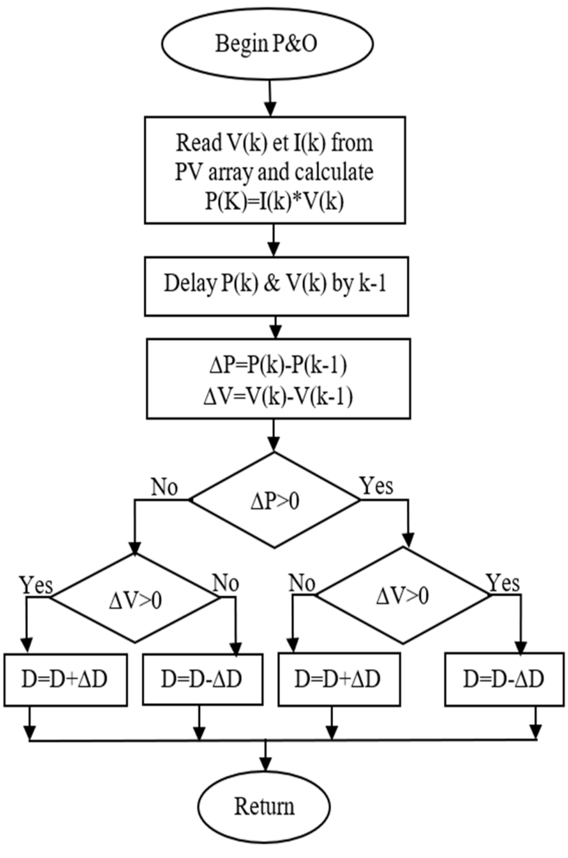

Fig. 5. Flowchart of P&O MPPT algorithm

The P&O technique continuously increments or decrements the PV array terminal voltage with a small amount until reaching to the maximum power point and compares the trend of the output power with that of the perturbation. Consequently, The perturbation must continue in the same direction if the output power increases and reverses if it decreases. the algorithm continues in the same way.

3.2 MPPT based Artificial Neural Network

In this work, the proposed (ANN) aims to predict the maximum power point (MPP) of PV array.The four steps for designing ANN can be summarized by:

- Selection of ANN architecture
- Data collection
- Training the ANN
- Testing the ANN

We have used a Multi-Layer Perceptron (MLP) network, contains three layers as shown in Fig.6.[12,13]:

- The first layer: where the inputs to the network are the PV current (I_{pv}) and voltage (V_{pv}) of PV system recorded under different temperature and irradiance
- The second layer: is the hidden layer, contains 10 hidden neurons which receive data from the input layer and send them to the output layer. Its activation functions are the sigmoid functions (Tansig)
- The third layer : is the output layer, contains one neuron duty cycle (D) whose activation function is linear function (Purelin).

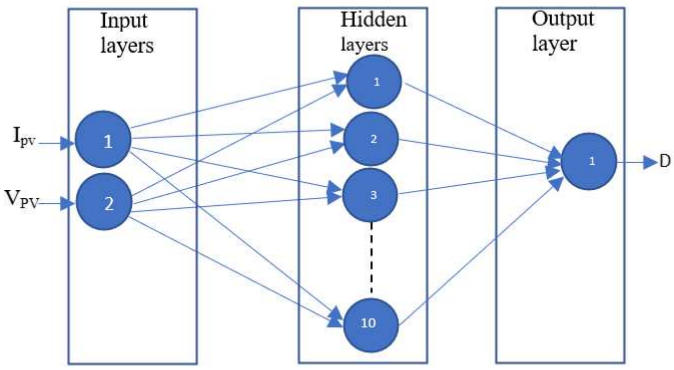

Fig. 6. The proposed neural network architecture

The training phase uses the data set obtained from the simulation of the PV array in Matlab / Simulink using the P&O method, the ANN inputs variables are the voltage V_{pv} and current I_{pv} of PV array corresponding to a given solar radiation and ambient temperature temperature conditions, while the duty cycle D is chosen as output. The nntool Toolbox can be used to design, train, validate and test a neural network in Matlab, the data set are divided into three parts 70% for training, 15% for validation, and 15% for testing. The neural network is trained with Levenberg-Marquardt backpropagation algorithm, which is a very fast and accurate technique for minimizing the mean square error (MSE) as shown in Fig.7. This algorithm provides better results than others. As shown in Fig. 8, the regression

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analysis is performed to measure the correlation between target and output.

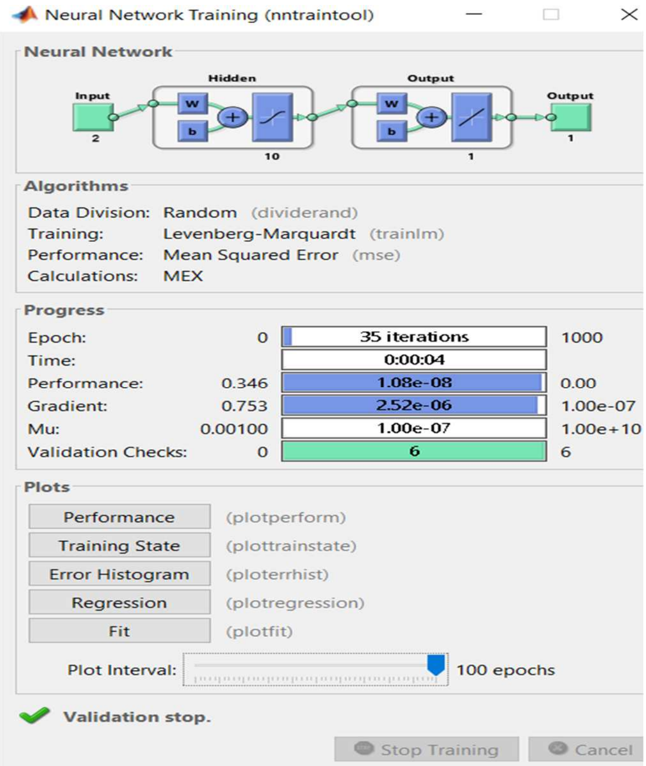

Fig. 7. Training neural network

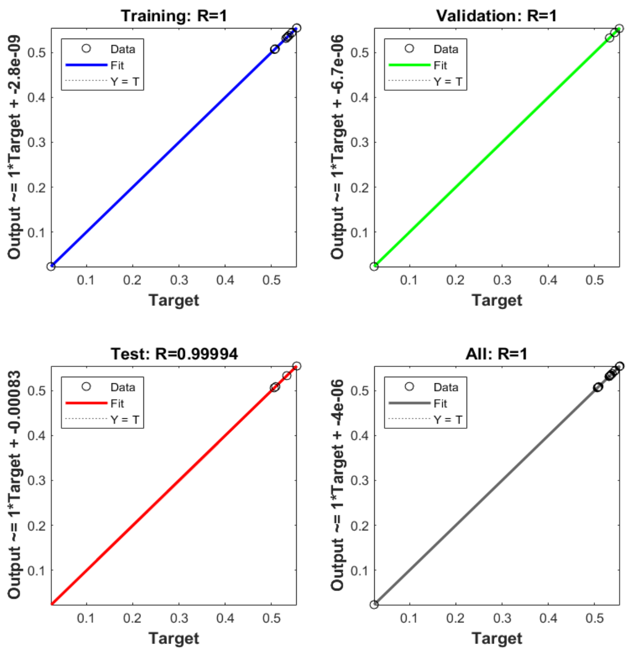

Fig. 8. Regression

4 RESULTS AND DISCUSSION

In this section, we present simulation results on the MATLAB/ Simulink environment of the system proposed (PV arrays, DC–DC converter, MPPT controller and load). The electrical parameters of the PV array are given in Table 2.

Table 2. Electrical parameters of the Canadian Solar CS6P-240P

Parameters	Symbols	Values
Maximum power (w)	P_{mpp}	240.097
Maximum power point current (A)	I_{mpp}	8.03
Maximum power point voltage (V)	V_{mpp}	29.9
Short circuit current (A)	I_{sc}	8.59
Open circuit voltage (V)	V_{oc}	37
Temperature coefficient of Isc (A/K)	K_{sc}	0.0637
Temperature coefficient of Voc (V/K)	K_{oc}	-0.3654
Series cells	N_{sc}	60
Number of parallel modules	N_p	1
Number of series modules	N_s	2

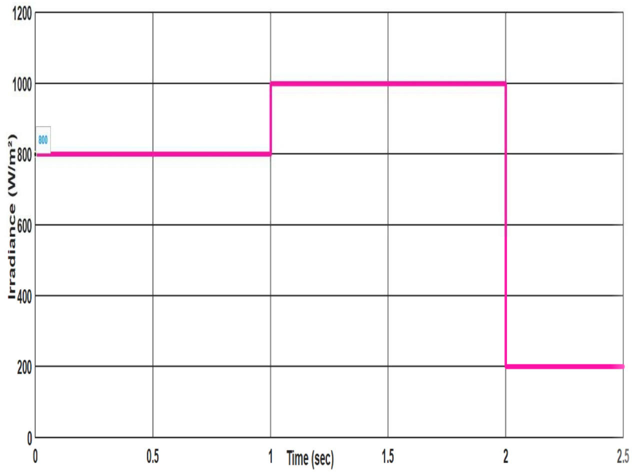

Fig. 9. Slope variation of irradiance

As shown in Fig. 9, the irradiation level was suddenly increased from 800 W/m2 to 1000 W/m^2 then decreased from 1000W/m² to 200W/m². The temperature is constant at 25°C.

The simulation results are presented in Fig. 10 which shows the generated power of the PV arrays with ANN and P&O MPPT techniques. when decreasing or increasing the irradiance level, the ANN rapidly tracks the MPP with an efficiency of 97.64% compared to the P&O.

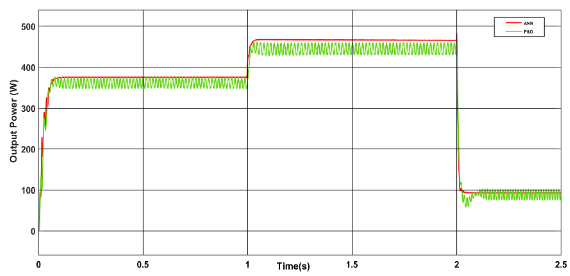

Fig. 10. output power from both method under fast-changing solar irradiation

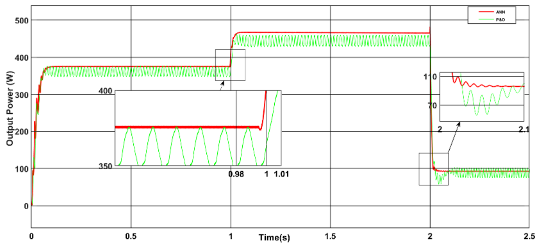

Fig. 11. Output power Overshoot with both methods in the case of sudden increase and decrease of irradiation

The overshoot in case of sudden increase or decrease in irradiation is more important with P&O MPPT controller compared to overshoot using the proposed artificial neural network MPPT controller, as shown in Fig.11.

In this test, ANN technique can quickly track the MPP under fast-changing solar irradiation, while P&O fails to track MPP when irradiation changes fast.in addition, ANN has small oscillation about the maximum power point, while P&O technique has high oscillation around a maximum power point MPP.

5 Conclusion

This paper presents MPPT based ANN to obtain maximum power for PECS at any atmospheric conditions and comparing the results with conventional P&O method. to find which algorithm gives better performance. Inputs ANN are electrical parameters obtained from PV array under changing atmospheric conditions and output is duty ratio for boost converter. DC-DC converter is used to track MPP of PV array. These techniques are simulated using with Simulink /Matlab. The simulation results it is concluded that ANN based MPPT gives better performance in terms of dynamic and fast response, less steady state oscillations under fast-changing solar irradiation. On the contrary, P&O technique fails to track MPP when irradiation changes fast.

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