Artificial intelligence based P&O MPPT method for photovoltaic systems

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Artificial intelligence based P&O MPPT method for photovoltaic systems

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Abstract - *The output characteristics of photovoltaic arrays are nonlinear and change with the cell's temperature and solar radiation. Maximum power point tracking (MPPT) methods are used to maximize the PV array output power by tracking continuously the maximum power point (MPP). Among all MPPT methods existing in the literature, perturb and observe (P&O) is the most commonly used for its simplicity and ease of implementation; however, it presents drawbacks such as slow response speed, oscillation around the MPP in steady state, and even tracking in wrong way under rapidly changing atmospheric conditions. In this paper, it is shown that the negative effects associated to such a drawback can be greatly reduced if the Artificial Intelligence (AI) concepts are used to improve P&O algorithm. The perturbation step is continuously approximated by using artificial neural network (ANN). By the simulation, the validity of the proposed control algorithm is proved.*

1. INTRODUCTION

The output characteristics of photovoltaic arrays are nonlinear and change with the cell's temperature and solar irradiance. For a given conditions there is a unique point in witch the array produces maximum output power. This point is called maximum power point (MPP) witch varies depending of cell temperature and present irradiation level. To obtain the maximum power from a photovoltaic array, a maximum power point tracker (MPPT) is used. The Perturbation and observation is one of the most commonly used MPPT methods for its simplicity and ease of implementation [2-4]. The P&O works well when the irradiance change slowly but it presents drawbacks such as slow response speed, oscillation around the MPP in steady state, and even tracking in wrong way under rapidly changing atmospheric conditions [2-5].

In this paper, a new modified perturbation and observation method (MP&O) is proposed. The MP&O method is based on an adaptive algorithm which automatically adjusts the reference voltage step size to achieve dynamic response and search MPP under rapidly changing conditions by exploiting artificial neural networks capabilities.

2. PERTURBATION AND OBSERVATION METHOD

The perturbation and observation method has been widely used because its simple feedback structure and fewer measured parameters witch are required [2-4].It operate by periodically perturbing (incrementing or decrementing) the array terminal voltage and comparing the PV output power with that of the previous perturbation cycle. If the power is increasing the perturbation will continue in the same direction in the next cycle, otherwise the perturbation direction will be reversed. The flowchart of this method is represented by figure 1.

The P&O method presents, in some cases, two drawbacks:

- By forcing the operating point to operate near the MPP, oscillations around the MPP appear in steady state as shown in figure 2. Such a drawback gives rise to the waste of some amount of available energy.

- It can confuse; it moves the operating point far from the MPP instead of close to it under rapidly changing atmospheric conditions [3, 4].

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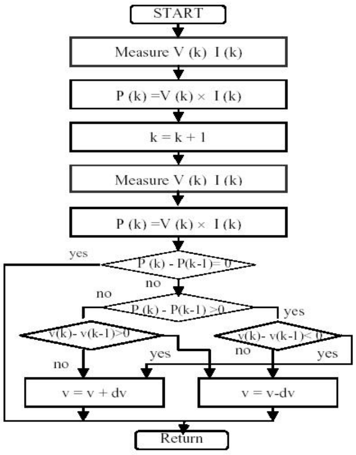

Fig. 1: Flowchart of the P&O method

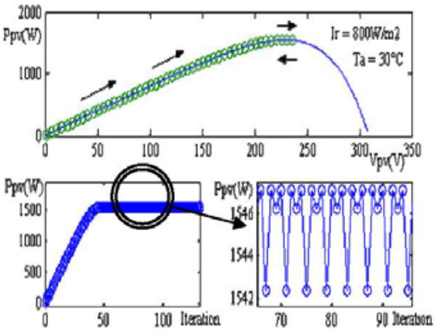

Fig. 2: System response with P&O under steady state for dv=5V

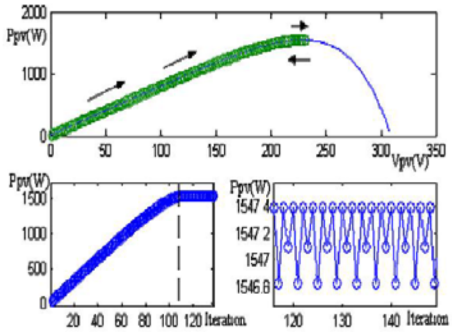

Fig. 3: System response with P&O under steady state for dv=2V

3. THE PROPOSED AI BASED MODIFIED P&O METHOD

In order to solve the P&O drawbacks, many improvements have been proposed [2-5]. Most of them suggest the adjustment of the perturbation step (dv). A small value decrease the amplitude of the oscillations around the MPP and then the power losses, but slow down the response of the control algorithm to changing atmospheric condition and then lower it efficiency [3, 4].

In [6] we proposed a new technique to solve the P&O drawbacks by auto tuning the perturbation step in order to make the control algorithm adaptive to the working state. To do this, we exploited the slop of the P-V curve during the previous perturbation period to predict the suitable step of perturbation for the next cycle. So the step of perturbation is continuously determined according to the variation of the output voltage and power of the PV array as shown by figure 4.

The characteristic slop during a perturbation cycle provide the best information concerning how much the operating point is far from the MPP in steady state, but when a variation occur suddenly , this information will alter the behaviour of the algorithm and cause it divergence by moving the operating point far from the MPPT. This problem can be solved if the algorithm acquires a skill which allows the detection of the working conditions variations and its extents also.

It is well known that any atmospheric condition variation induce a proportional PV array output power variation. From this idea, we decided to use an artificial neural network ANN to detect any atmospheric conditions variation. The ANN role consists in predicting the power value during the next cycle of perturbation, the difference between ANN output value and the measured one (the reel furnished power) gives us a precious information about the atmospheric conditions evolution. This information will be used to adjust the perturbation step value for the next cycle perturbation according to the following equation.

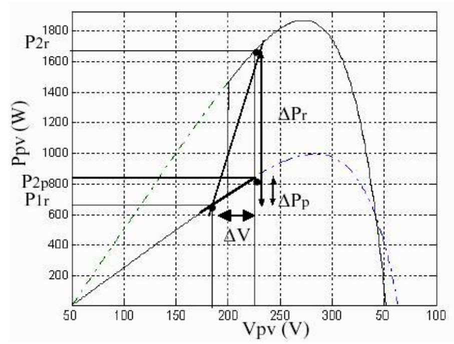

Fig. 4: P-V characteristic slop- Irradiance variations dependency

$$\Delta v_{i+1} = k \cdot \frac{\Delta P_r}{\Delta v_i} \cdot f\left(\frac{P_r}{P_p}\right) \tag{1}$$

with v_i is the perturbation step during the cycle i, k : a constant, P_r : the reel furnished power, P_p is the predicted power and f is a function with the input/output characteristic illustrated by figure 5.

The equation (1) can be expressed, after simplification by:

$$\Delta v_{i+1} = k \cdot \frac{\Delta P_r}{\Delta v_i} \cdot f\left(\frac{I_r}{I_p}\right) \tag{2}$$

with I_r is the reel currant and I_p its predicted value.

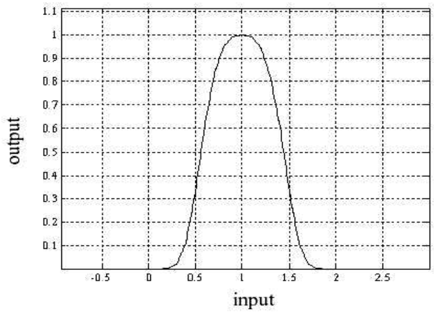

Fig. 5: Input-output characteristic of the function f

4. SIMULATION RESULTS

In order to show the feasibility and performance of the proposed modified P&O tracking algorithm, a simulation study was carried out using the PV array model given in [7]. We used one ANN with 3 inputs (dimension of x vector), two hidden layers of 50 and 20 neurons, and one output layer of one neuron corresponding to the dimension of the output vector Ip. Note that the ANN is trained in offline manner using the back propagation algorithm with a momentum to accelerate the learning phase and to avoid falling into a local minimum [8]. Figures 7 and 8 represent the training samples while figure 9 represents the evolution of the training error. After the ANN has been trained, a validity test was executed. For this task, we took a set of samples different of those used for the training procedure.

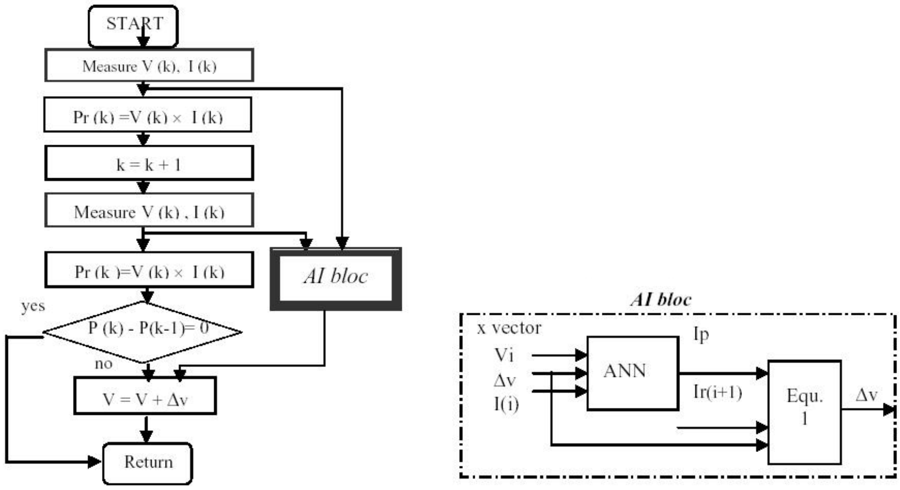

Fig. 6: Modified P&O flowchart

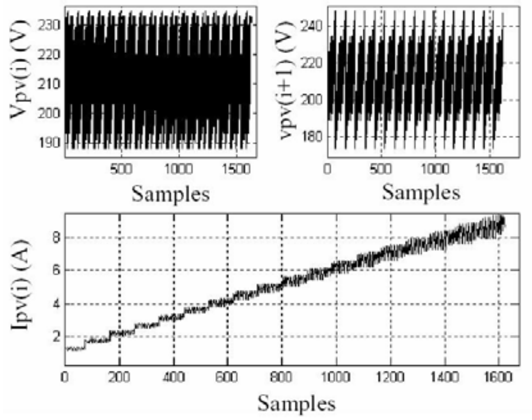

Fig. 7: System

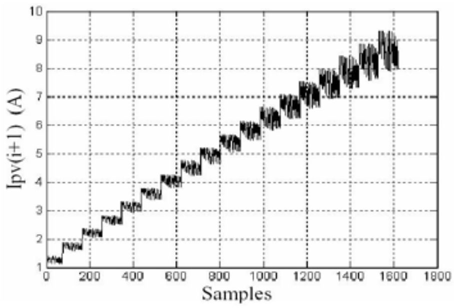

Fig. 8: ANN training samples' output data

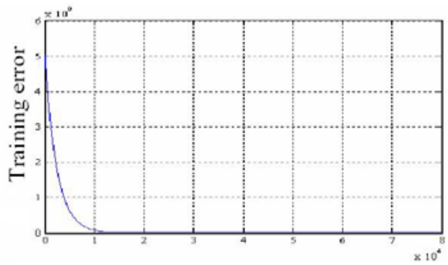

Fig. 9: ANN learning error evolution Iterations

According to figures 10 the modified perturbation and observation method is faster than the classical P&O algorithm. We can see that the perturbation step is continuously adjusted according to the P-V characteristic slop variation. So the algorithm reaches the PPM, for this simulation case, after only 6 perturbation cycles and remains there without oscillations.

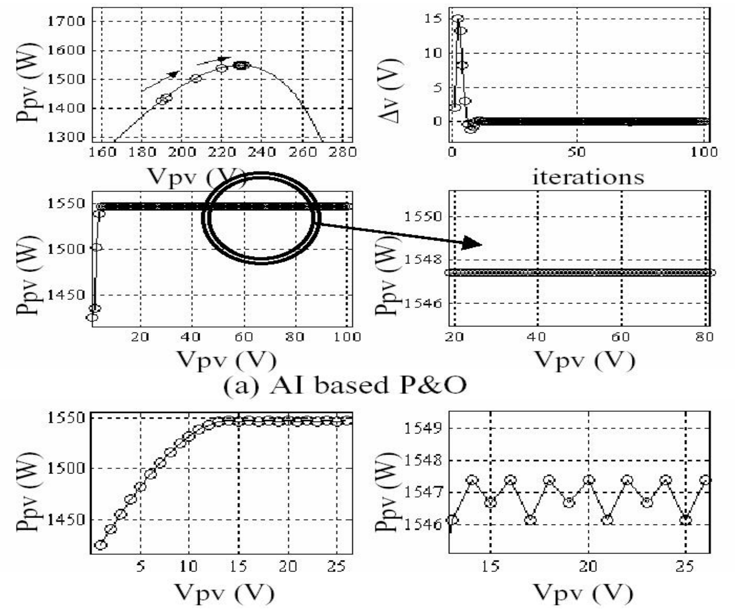

Fig. 10: Results of the MPPT efficiency in steady

Figures 11 and 12 show the system response to a sudden large variation in irradiance. As we can see, the perturbation step is adapted allowing satisfactory behaviour to be maintained in spite of the sudden changes in irradiation.

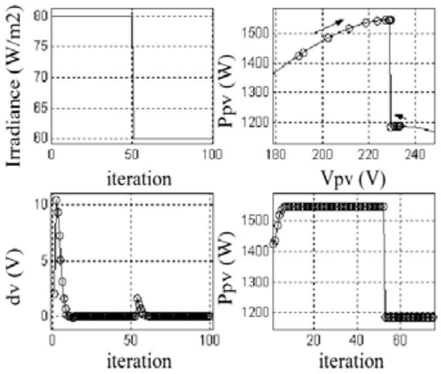

Fig. 11: System response to a sudden large decrease in irradiance

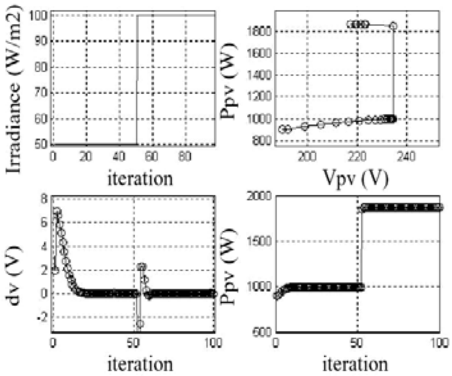

Fig. 12: System response to a sudden large increase in irradiance

5. CONCLUSION

The PV array output power delivered to the load can be maximized using MPPT control method. In this paper, an Artificial Intelligence based perturbation and observation method was presented. The proposed modified tracking algorithm uses an Artificial Neural Networks to detect the atmospheric conditions variations in order to adjust the perturbation step for the next perturbation cycle. The improved tracking performance of this presented method was verified trough simulation. The presented tracking algorithm shows better steady state and dynamical performance than traditional P&O.

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