

Research on MPPT Control Algorithm of Flexible Amorphous Silicon Photovoltaic Power Generation System Based on BP Neural Network

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Key words: Flexible amorphous silicon photovoltaic cells; Maximum Power Point Tracking (MPPT); BP neural network; PID control; MATLAB

Abstract. Output efficiency decreasing phenomena also occur when environmental factors of flexible amorphous silicon photovoltaic power generation system (PV system) change. On the basis of building the system simulation model via MATLAB tool, researches are conducted on the issues of tracking time (0.04s), overshoot volume (11.7%) and steady-state error (0.5V) when performing maximum power point tracking with classic perturbation and observation method; the paper proposes BP neural network MPPT control algorithm combining PID control. The results of stimulation indicate that this method could complete the maximum power point tracking of flexible amorphous silicon photovoltaic cells in 0.01s, reduce the overshoot volume to 0.003%, decrease the steady-state error to 0.15V, eliminate the voltage oscillation, reduce the lag time, and improve the robustness of the system.

Summary

The researching purport of the flexible amorphous silicon PV system MPPT. The thickness of flexible amorphous silicon photovoltaic cells is 1/300 of crystalline silicon cells, easy to carry, lower raw material costs and the maximum conversion efficiency of it up to 18%, it is the direction of future development of photovoltaic cells. However, to make flexible amorphous silicon photovoltaic cell power generation reached the practical level, must improve the photoelectric conversion efficiency, and therefore it becomes very important to study the MPPT. Since the output characteristics of P-U of flexible amorphous silicon photovoltaic cells influenced by the external environment, shown in Fig 1, so in order to improve the conversion efficiency of the photovoltaic array, let it always work at the maximum power point, it must be the maximum power point tracking control, in order to array in any lighting can ensure maximum power output.

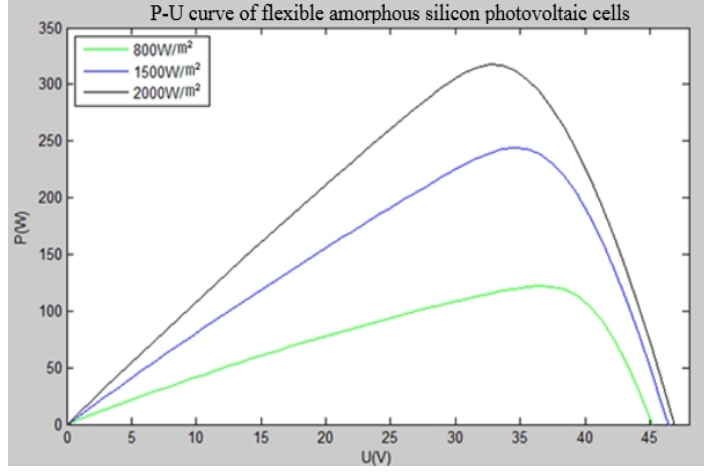


Fig1 P-U curve of flexible amorphous silicon photovoltaic cells

Flexible amorphous silicon photovoltaic cells. Flexible amorphous silicon photovoltaic cells model is established by physical model, that is, the physical model is determined after basic circuit model expression is built and then quasi-newton method is used to calculate the parameter values[5].

The equivalent circuit model is shown in Fig 2.

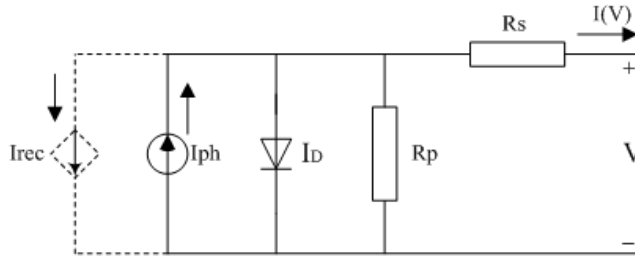


Fig2 The equivalent circuit model

Output expression of monomer battery I is as (1).

$$I = 0.3181 - \frac{0.4755 \times 10^{-3}}{0.9963 - (V + 0.4706I)} - 3.078 \times 10^{-14} \left(e^{\frac{q(V+0.4706I)}{1.9931kT}} \right) - \frac{V + 0.4706I}{13.9288} \quad (1)$$

q is the electron charge ($1.6 \times 10^{-19} \text{C}$), k is the Boltzmann constant ($1.38 \times 10^{-23} \frac{\text{J}}{\text{K}}$), T is the standard Kelvin temperature.

Flexible amorphous silicon photovoltaic power generation system. The simulation model of flexible amorphous silicon photovoltaic power generation system in this paper consists of four modules, it is: flexible amorphous silicon photovoltaic cells, boost DC-DC circuit, control module and load module, shown in Fig 3. Its working principle is: simulation model of flexible amorphous silicon photovoltaic cells receive the solar energy and converted it into electrical energy, then supplied to the load through the DC-DC circuit, wherein the control module make sure the flexible amorphous silicon photovoltaic cells always working at maximum power point.

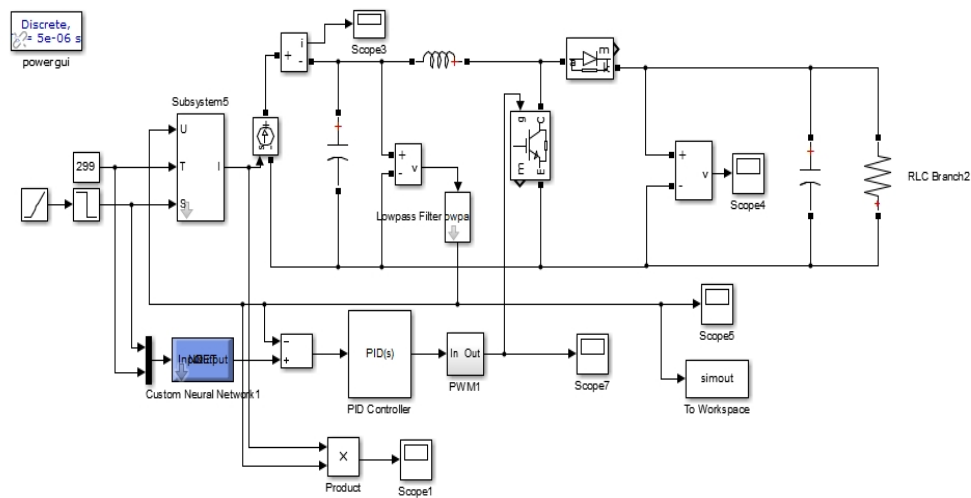


Fig 3 Simulation Model of flexible amorphous silicon photovoltaic power generation system

Variable step-size perturbation and observation method

Variable step-size perturbation and observation method is one of the most common algorithms applying to MPPT, which is to find the direction of the maximum power point via continuously perturbing working point of PV system. The principle is to perturb the output voltage value at first; the next step is to measure the power change, then to compare with the former power value. If the power value increases, it means the direction of perturbation is correct and the perturbation can be continued in the same direction. If the power value decreases, then the perturbation of opposite direction is needed. Variable step-size perturbation and observation method is to use $|K|$ of the curve as adjusting reference of step-size ΔD , so that it can take into account the tracking speed and tracking accuracy.

The stimulation research on variable step-size perturbation and observation method is carried out via established flexible amorphous silicon PV system in this paper. Its stimulation result is shown in Fig 4.

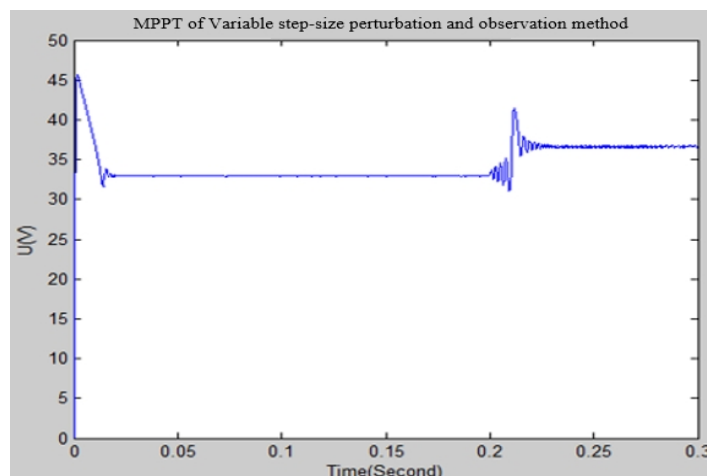


Fig 4 The MPPT simulation results of variable step-size perturbation and observation method

According to the tracking effect, it can be concluded that:

1. A balance is achieved within 0.04 seconds with perturbation and observation method;
2. The overshoot of perturbation and observation method is 11.7% with voltage oscillation;
3. The steady-state error of perturbation and observation method is 0.5V.

Voltage oscillation will directly lead to the decreasing of output power quality and large overshoot volume will impact on the load. The paper proposes BP neural network MPPT control algorithm combing PID control.

BP network structure

Profile of BP neural network. BP (Back Propagation) neural network was put forward in 1986 by the scientist group led by Rumelhart and McClland, it is a multilayer feedforward network and it is one of the most extensive models, which applies to the direction of classification, clustering, and prediction. BP neural network is able to learn and store large amounts of input-output mode mapping relationship. Its learning rule is to use the steepest descent method, namely, the weights and threshold of the network are continuously adjusted by back propagation in order to minimize the error square sums of the network. The topology of BP neural network includes input layer, hidden layer and output layer. Shown in Fig 5[2].

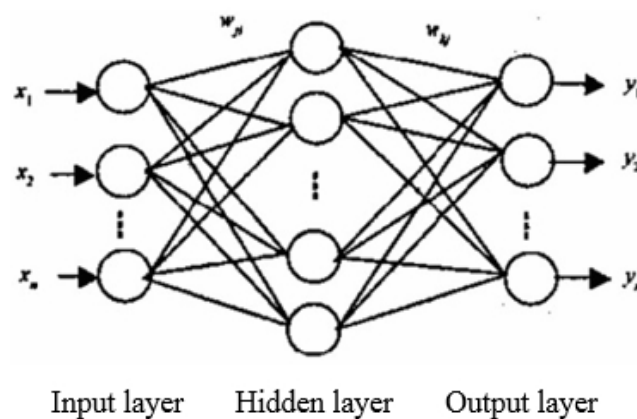


Fig 5 The topology of BP neural network

MPPT design of BP neural network

Design of input layer. Neuron number of BP neural network input layer is determined by the parameters which cause changes. For maximum power point tracking of flexible amorphous silicon PV system, the factors that cause changes are light intensity, temperature, shadow area and so on. The paper designs the network input layer as two-dimensions: light intensity, temperature.

Design of hidden layer. The design of hidden layer includes two side. They are:

- (1) Design of hidden layer amount

In 1989, Robert Hecht - Nielsen proved that a continuous function could be approached with BP neural network that had only one hidden layer. Therefore, a three-layer BP network can accomplish mapping any n-dimension to m-dimension. The paper uses three-layer BP neural network.

- (2) Design of hidden layer's node number

The nodes number of BP network's hidden layer will directly influence the effect of the network. If the number of node is few, it would lead to divergent trained network; on the contrary, if the number of nodes is too many, it will make the network too complex and even increase the errors.

Hence, the number of nodes is determined according to the actual condition, namely, multiple experiments, finding the most suitable values. At the same time, the following empirical formula can be referred to determine the nodes number.

$$m = \sqrt{n + 1} + a \quad (2)$$

$$m = \log_2^n \quad (3)$$

$$m = \sqrt{n} \quad (4)$$

About the above formula, m is the nodes number of hidden layer, n is the nodes number of input layer, and a is a positive integer between 1 and 10.

The nodes number of hidden layer is determined as $m=6$ with the reference to empirical formula and through multiple experiments.

The establishment of MPPT stimulation model

The MPPT structure of BP neural network in this paper is: 2 input neurons, 6 hidden neurons, 1 output neuron. The inputs are light intensity and temperature and the output is the maximum power point voltage of the flexible amorphous silicon photovoltaic cells. The model is shown in Fig 6

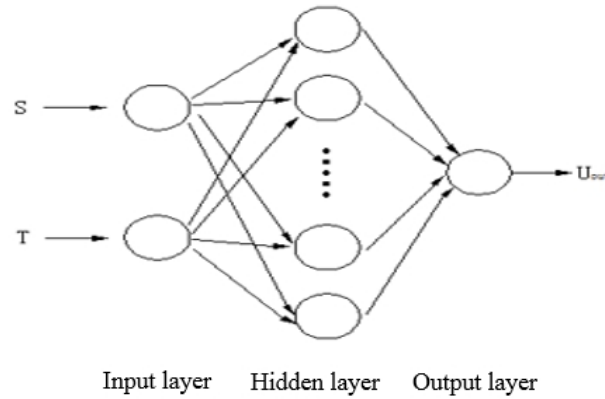


Fig 6 The model of BP neural network

The structure applies to BP neural network algorithm of Flexible amorphous silicon photovoltaic cells. Shown in Fig 7.

BP neural network:

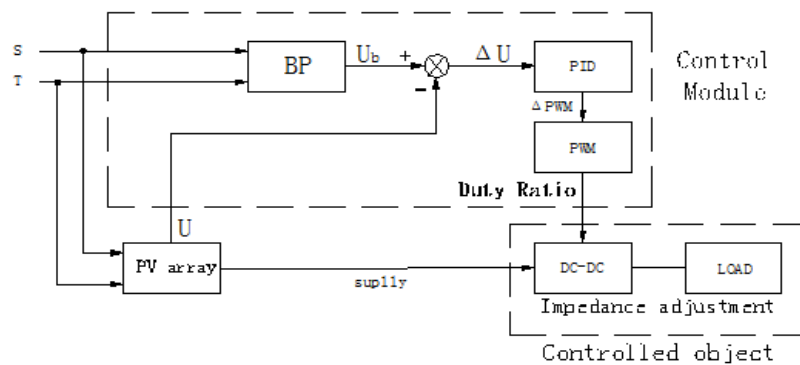


Fig 7 The MPPT structure of flexible amorphous silicon photovoltaic power generation system

The results analysis of BP neural network

Design validation of BP neural network. The corresponding data of maximum power point voltages of the PV cells are collected from 25 groups of different light intensity and temperature as training samples to train BP neural network. Stimulation experiment is carried out by setting the maximum training times as 1000; the mean square error is 0.01; the training function is “trainlm”. The validation is verified for the output voltages of designed BP neural network, in other words, 10 groups of data are randomly selected except the above 25 groups of data; the values of actual maximum power point voltages are measured; and then it is predicted by BP neural network. The result of comparison is shown in fig 8.

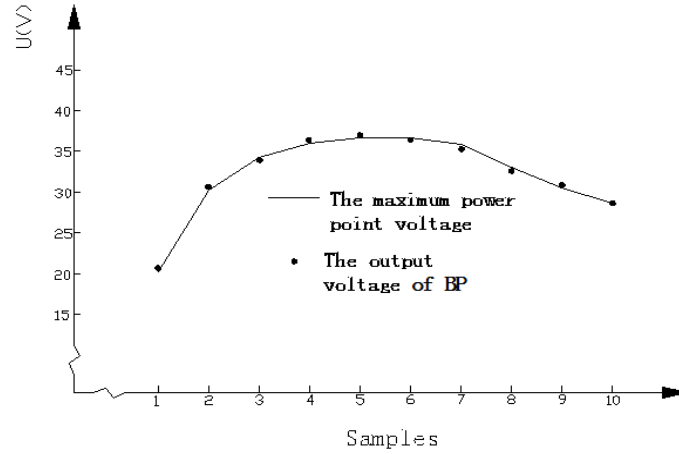


Fig 8 The experimental result of effectiveness of BP neural network

Conclusion can be got from Figure 7 that error range between output voltage of BP neural network and actual voltage of maximum power point is within $\pm 0.2V$.

MPPT stimulation results of BP neural network. The stimulation validation is performed on BP neural network with Simulink platform. In the tracking process, the constant temperature is 25 degrees centigrade; the constant light intensity is 2000W/m² in 0 to 0.2s, it linearly reduces to 800W/m² in 0.2 to 0.21s, and it is constant 800W/m² in 0.21 to 0.3s. The result is shown in Fig 9.

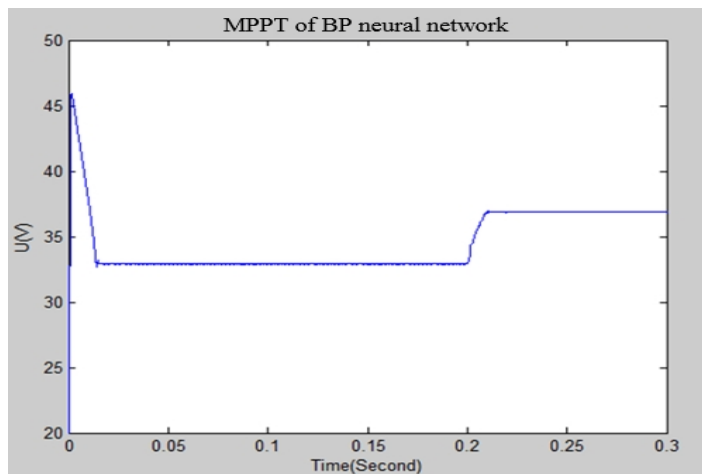


Fig 9 The MPPT simulation results of BP neural network

Compared with figure4, according to the tracking effect of BP neural network, it can be concluded that:

1. A balance of voltage is achieved within 0.04 seconds with BP neural network;
2. Use BP neural network, the overshoot of system is 0.003%, and the voltage oscillation is eliminated;
3. Use BP neural network, the steady-state error of system is 0.15V.

Comparing with variable step-size perturbation and observation method, the BP neural network control algorithm combining PID control reduces the overshoot volume, eliminates the voltage oscillation and decreases the steady-state error.

Conclusion

The paper combines the previous researches on the flexible amorphous silicon photovoltaic cells to propose BP neural network control algorithm combining PID control. BP neural network combining PID control is designed, and also experiments and stimulation are performed on it, in terms of the issues of long tracking time (0.04s), large overshoot volume (11.7%) and big steady-state error (0.5V) when applying perturbation and observation method to MPPT of flexible amorphous silicon photovoltaic power generation system. The results shows that this method can achieve maximum power point tracking of flexible amorphous silicon photovoltaic cells within 0.01s; the overshoot volume is reduced to 0.003%; the steady-state error is decreased to 0.15V; and the temporary voltage oscillation is eliminated, which improves ability of flexible amorphous silicon PV system to adapt to the environment mutation.

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