Research of PV Power Generation MPPT based on GA-BP Neural Network

Yu Su¹, Xianfu Lin²

¹Beijing Institute of Technology, Zhuhai, School of Information Technology, Guangdong Zhuhai, 519088, P.R.China
²Central South University, School of Information Science and Engineering, Hunan Changsha, 410083, P.R.China

E-mail: 2007youter@163.com

Abstract. Photovoltaic power generation has become the main research direction of new energy power generation. But high investment and low efficiency of photovoltaic industry arouse concern in some extent. So maximum power point tracking of photovoltaic power generation has been a popular study point. Due to slow response, oscillation at maximum power point and low precision, the algorithm based on genetic algorithm combined with BP neural network are designed detailedly in this paper. And the modeling and simulation are completed by use of MATLAB/SIMULINK. The results show that the algorithm is effective and the maximum power point can be tracked accurately and quickly.

1. Introduction
Nowadays energy shortage and environmental pollution problems are attracting attention. Solar energy is one kind of widely used renewable energy in the current availability renewable energies because it is abundant, clean and safe. So many countries have increased the investment of photovoltaic research. The photovoltaic array is easily influenced by the light and temperature of the environment, and output characteristics have obvious nonlinear. Therefore solar energy photovoltaic power cost is high and its conversion efficiency is low. In order to solve the problem, it is important to carry out the maximum power point tracking.[1,2] A variety of commonly used maximum power point tracking methods are introduced at home and abroad. [3,4,5] Analyzing the conventional MPPT control methods, the advantages and disadvantages are listed. BP neural network also has strong nonlinear approximation ability, but its gradient decent algorithm determines it is easy falling into local optimum and sensitive to the initial values. So the algorithm based on genetic algorithm combined with BP neural network are proposed in this paper for carrying out the maximum power point tracking. Improving the efficiency of photovoltaic array is a great sense to the development of photovoltaic industry.

2. Analysis of the output characteristics of photovoltaic array
The output characteristics of photovoltaic array refer to relationships under certain temperature and light intensity. One is the relationship between the output voltage and current of the battery, the other is the output voltage and the corresponding power relation. According to the theory of Electronics[6], the equivalent circuit of photovoltaic array is shown in figure 1:
Figure 1. equivalent circuit of photovoltaic array

The parameters of one existing photovoltaic array are as follows:

\[ U_{oc} = 350V, I_{sc} = 13A, U_m = 260V, I_m = 10A \]

In the condition of illumination intensity \( G_{ref} = 1000W/m^2 \), the \( I-U \) characteristic curve and \( P-U \) characteristic curve are obtained by using MATLAB/SIMULINK and shown in Figure 2, when temperature is set to \( 0°C, 25°C, 50°C, 75°C, 100°C \). At the same time in the condition of temperature \( T = 25°C \), the \( I-U \) characteristic curve and the \( P-U \) characteristic curve are shown in Figure 3, when the illumination intensity is set to \( 200W/m^2, 400W/m^2, 600W/m^2, 800W/m^2, 1000W/m^2 \).

Figure 2. I-U (left) characteristic curve and P-U characteristic curve (right)

By analyzing the above curves, it is obvious that the output characteristics of photovoltaic array are nonlinear. And with the change of environmental factors the maximum power point will inevitably change. In order to improve photovoltaic conversion efficiency, it is very nec-
necessary to make the photovoltaic array work near the maximum power point.

3. MPPT analysis of GA-BP neural network

3.1. Analysis of advantages and disadvantages of BP neural network

BP neural network is a multilayer feedforward neural network with error back propagation algorithm[7], which is one of the most widely used neural network models in the present application. BP neural network with the ability of nonlinear mapping implements mapping function from input to output. Its three layer neural network can approximate any nonlinear continuous function with any precision and has a high degree of self-learning and self-adaptation. However, its disadvantages are also quite obvious. (1) The local minimization problem that is different initial weights will lead to the network into local extremum point or nonconvergence. (2) Slow convergence. (3) Because the initial weights and thresholds of the training network are randomly generated, which are lack of basis for choice. But the final imitative effect of data is determined by weights and thresholds. The choice of initial weight determines the direction of convergence. So its prediction ability is not ideal.

3.2. Genetic algorithm and BP neural network

The genetic algorithm combined with BP neural network makes up the deficiency of the existing problems is designed. In this paper, we use this algorithm to establish the maximum power point tracking of photovoltaic array. The processes are as follows: (1) Initialization parameters of BP neural network. Because the maximum power point of the photovoltaic array is affected by light and temperature, so the number of neurons in the input layer is 2, and by trial and error the number of neurons in the hidden layer is set to 5, the output neuron is 1 that is the maximum power point. (2) Initial population and population coding. Taking into account the tracking accuracy of the maximum power point and reducing non-essential process of encoding and decoding, it adopts floating point real number as gene coding. (3) The error between the forecast data and the expected data is selected as fitness function. (4) Loop selection, crossover, mutation, and computational adaptation need to be done until evolution times is reached. In this selection roulette method is used for individual choices. (5) Getting the best initial weights and thresholds. (6) Using genetic algorithm to work out the optimal initial weights and thresholds for training BP neural network. The GA-BP neural network architecture is shown in Figure 4 and diagram flow chart is shown in Figure 5.

![Figure 4. GA-BP neural network architecture](image-url)
Whether or not to meet the accuracy
Neural network initialization parameters
Set population size and optimization objectives
Real number coding value of neuron
Population fitness calculation
Selection, crossover and mutation

Whether to achieve the goal of optimization
Yes
No

Optimal weights and thresholds are obtained
Error calculation
Weight and threshold updating

Whether or not to meet the accuracy
No
Yes

End of training

Figure 5. Algorithm flow chart

3.3. Training of GA-BP neural network
Firstly, the 500 sets of data are obtained through the P-U output characteristics of PV array, which is the maximum power point data at different temperature and illumination intensity. Among them 350 sets of data are training samples and 150 sets of data are test samples. Each set of data includes three values (temperature, illumination intensity, maximum power point). As to initial parameters of BP training network, Input layer transfer function adopts tansig type, output layer function adopts purelin type, the training function adopts trainlm, and expected error is set to 0.00015, learning rate is set to 0.02, maximum of training steps is set to 2000. For the weight and threshold of genetic algorithm initial parameter values are selected as follows, population size is 200, genetic algebra is 150, crossover rate is 0.3, and mutation rate is 0.2. By use of MATLAB/SIMULINK the PV array MPPT model is shown in figure 6.

Figure 6. Simulation model of photovoltaic array MPPT
The main work is as follows. During runtime, the temperature and illumination intensity is modified. Then the GA-BP neural network which has been trained starts to track the maximum power point. Through the BOOST voltage module, the duty cycle is adjusted. Thus changing the output voltage of the photovoltaic array and working on the maximum power point tracked by the GA-BP neural network is implemented. The iteration process respectively used GA-BP neural network (left) and BP neural network (right) is shown in figure 7. From this figure, under the same conditions we can find that the number of iterations is only 8 by use of genetic algorithm combined with BP neural network. Compared with 58 times only using BP neural network algorithm, the convergence rate is greatly improved. The two different kinds of algorithms for tracking maximum power of photovoltaic array is shown in figure 8. From this figure, we can find that the tracking by use of BP neural network has a better accuracy in the condition of $T = 25^\circ C$, $G$ from $800W/m^2$ to $G = 1000W/m^2$. But in other cases the algorithm will bring on higher error. By use of GA-BP neural network, in most cases it can achieve high accuracy of the PV array maximum power point tracking. In addition it can be seen from Figure 9, if using GA-BP neural network algorithm to track maximum power point, the error is about 2%. Compared with only using BP neural network algorithm, the error is reduced about 3%.

Figure 7. Iteration process

Figure 8. MPPT comparison of BP and GA-BP

Figure 9: MPPT error of BP and GA-BP

4. Summary
The convergence rate of the BP neural network for tracking the maximum power has its own characteristics, such as slow, low accuracy and local optimal value. The efficiency of photo-
The voltaic array can not be ignored. In order to optimize, the proposal of genetic algorithm combined with BP neural network is designed. In this paper, we analyze the $P-U$, $I-U$ output characteristics of photovoltaic arrays firstly. Due to the maximum power point of PV arrays is dynamic and changes with different external conditions. The genetic algorithm combined with BP neural network is used for optimizing and tracking the maximum power point in different cases. The algorithm is introduced in this paper, at the same time its modeling and simulation by MATLAB/SIMULINK are completed in detail. The simulation results show that the algorithm not only improves the convergence rate, but also reduces the relative error. The optimization is effective and feasible, and the maximum power point can be tracked accurately and quickly.

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Acknowledgement

This research was financially supported by the Guangdong Province Education Office Foundation for excellent young teachers 2015.