Distributed Photovoltaic Short-Term Power Prediction Based On Genetic Algorithm Optimized BP Neural Network

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Abstract. With the rapid development of the world economy, energy demand is increasing. Photovoltaic power generation has the advantages of green, environmental protection and renewable, and the proportion of photovoltaic power generation, a new reusable clean energy in the power generation system, has shown a steady increase; However, the power output of photovoltaic power generation systems is affected by many factors, presenting a high degree of uncertainty and volatility, which brings high difficulties to the large-scale grid-connected operation of photovoltaic power generation. Aiming at the shortcomings of existing photovoltaic power generation forecasting, this paper builds a photovoltaic power station power prediction model based on genetic algorithm and BP neural network algorithm, and uses photovoltaic power station operation examples to verify the validity of the model. By using the global search capability of genetic algorithm to optimize the initial weights and thresholds of BP neural network, the prediction accuracy of photovoltaic power generation is improved, which can provide a reference for photovoltaic power generation prediction engineering practice.

Keywords: Photovoltaic power generation; power prediction; genetic algorithm; BP neural network.

1. Introduction

The influencing factors of photovoltaic power generation are unstable, which leads to the fact that the output power of photovoltaic power plants is not smooth, but has a high degree of randomness, volatility and intermittency. The integration of a large number of photovoltaic power plants into the existing grid will affect the balance of the entire power generation and consumption, and will have a great impact on the safe and stable operation of the power system and the quality of power. In-depth study of the output power prediction of photovoltaic power plants has high academic research value and practical application value [1].

Literature [2] studied the output power prediction of photovoltaic power plants, considering the influence of photovoltaic module temperature and radiation intensity on the output power of photovoltaic power plants, the neural network is used to solve the I/V curve, so as to establish the
functional relationship between the temperature of the photovoltaic backplane, the radiation intensity and the output power of the photovoltaic power station. Through strength analysis, it is found that the correlation coefficient between his predicted result and the actual output power of photovoltaic power station is as high as 0.998. Literature [3] uses the least squares method to fit the irradiance at each time of the day and the surface illumination amplitude to predict the power generation at each time of the next day. The advantage of this method is that the modeling requires fewer input parameters, but when the weather fluctuates greatly, the prediction error will increase significantly. Literature [4] conducted a comprehensive study on tree-based integrated machine learning models, decision trees and support vector regression. In order to predict the power generation of the photovoltaic system, the generalization ability (stability), accuracy and calculation cost of the model were compared. Literature [5] proposed a hybrid prediction model combining wavelet transform, particle swarm optimization and support vector machine for short-term power generation prediction of actual microgrid photovoltaic power generation system. The hybrid model first uses wavelet transform to transform the meteorological data, and then uses the particle swarm algorithm to optimize the parameters of the support vector machine to obtain higher prediction accuracy.

Based on this, this paper establishes a power prediction model for photovoltaic power plants based on genetic algorithm optimized BP neural network. Photovoltaic prediction technology is of great significance to grid planning and stable operation, it has a great impact on the safety, reliability, economic operation and power quality of the power system.

2. BP neural network model optimized by genetic algorithm.

2.1. BP neural network

The BP neural network uses the gradient descent method to adjust the weights and thresholds, so that the mean square error between the expected output value of the network and the actual output value is minimized. BP neural network is a multi-layer feedforward neural network. The topology of a 3-layer BP neural network is shown in Figure 1, including input layer, hidden layer and output layer. The neurons in the input layer or hidden layer are connected to all neurons in the next layer, and there is no connection between neurons in the same layer. The setting of the hidden layer is based on Kolmogorov's theorem. If the output layer has n nodes, the number of nodes in the hidden layer is 2n+1.

![Fig. 1 BP neural network structure](image-url)
2.2. Genetic algorithm optimizes BP neural network

2.2.1. Basic ideas. Genetic algorithm is good at global search, while BP neural network is more effective in local search. Therefore, the combination of genetic algorithm and BP algorithm can improve the accuracy of prediction and the convergence speed of the algorithm. The genetic algorithm is used to optimize the initial weight of the neural network to locate a better search space, and then the BP algorithm is used to search for the local optimal value in a small space, which can improve the prediction accuracy and the convergence speed of the network.

Based on this, this paper uses genetic algorithms to optimize the weights and thresholds of the BP neural network. Through genetic algorithm selection, crossover and mutation operations of genetic operators, population individuals are selected from generation to generation, find the optimal initial weights and thresholds of the network and assign them, and then learn and train the BP neural network model to obtain the optimal prediction value. The specific process of genetic algorithm optimization of BP neural network is shown in Figure 2.
### 2.2.2. Optimization steps

1) Topological structure of BP neural network. In this paper, the input is salt density and gray density, and the output is pollution flashover voltage, the hidden node of the network is set to 1, and the number of hidden nodes can be determined by the following empirical formula:
\[ l = \sqrt{m + n + a} \]  

Where: \( m \) and \( n \) are the number of input nodes and output nodes respectively; \( a \) is a constant between 1 and 10.

2) Preprocessing of sample data. The size of data input and output will affect the convergence of the network, so it is necessary to normalize the parameters. Perform normalization processing according to formula (2) to make the change interval in \([-1, 1]\):

\[ x_k = \frac{x_k - x_{\text{min}}}{x_{\text{max}} - x_{\text{min}}} \]  

3) Determine the weights and thresholds of the network and perform population initialization coding.

4) Select operation. This article uses the roulette method to operate, the probability of a single individual \( i \) being selected is

\[ p_i = \frac{f_i}{\sum_{j=1}^{p} f_j} \]  

Where: \( f_i \) is the reciprocal of individual fitness, and \( p \) is the population size.

5) Cross operation. This paper adopts the real number crossover method, the cross operation method of \( k \) chromosome \( a_k \) and \( l \) chromosome \( a_l \) at \( j \) position is as follows

\[
\begin{align*}
\begin{cases}
    a_{ij} = a_{ij}(1-b) + a_{lj}b \\
    a_{lj} = a_{lj}(1-b) + a_{ij}b
\end{cases}
\end{align*}
\]  

Where: \( b \) is a random number in the interval \([0,1]\).

6) Mutation operation. Select the \( j \)-th gene \( a_{ij} \) of the \( i \)-th individual for mutation, and the mutation operation method is

\[
\begin{align*}
\begin{cases}
    a_{ij} = a_{ij} + (a_{ij} - a_{\text{min}}) \times f(g) & r > 0.5 \\
    a_{ij} = a_{ij} + (a_{\text{max}} - a_{ij}) \times f(g) & r \leq 0.5
\end{cases}
\end{align*}
\]  

Where: \( a_{\text{max}} \) is the upper bound of gene \( a_{ij} \); \( a_{\text{min}} \) is the lower bound of gene \( a_{\text{max}} \); \( f(g) = r_2(1 - g / G_{\text{max}})^2 \), \( r_2 \) is a random number, \( g \) is the current iteration number, \( G_{\text{max}} \) is the maximum number of evolution; \( r \) is a random number in the interval \([0,1]\).

7) By solving the optimal chromosome of the genetic algorithm, the optimal weight and threshold of the BP network are obtained, and the optimal value is assigned to the prediction model for training to obtain the optimal prediction value.

2.3. The short-term power prediction process of photovoltaic power plants based on genetic algorithm optimized neural network

When establishing a short-term power prediction model for photovoltaic power plants based on genetic algorithm optimized BP neural network, firstly establish a BP neural network model for photovoltaic output power, then use the back propagation error calculation of the neural network model as the objective function of the genetic algorithm to optimize the network weight parameters, and perform secondary training on them to form an improved neural network; Finally, the forecast of
the daily power generation to be predicted is realized. The specific forecasting process is shown in Figure 3.

![Power prediction process](image)

**Fig. 3** Power prediction process

3. Simulation and analysis

3.1. Selection of calculation examples

This paper uses a certain substation as the research object, and the designed model selects 15 input variables, which are the power generation at 13 times from 7 to 19 on the day before the forecast, plus the average temperature of the previous day and the forecast day. The output variable is the output power of 13 power generation time series from 7:00 to 19:00 on the forecast day.

3.2. Case analysis

In these historical data, the actual historical photovoltaic power generation curve of a certain day is used as the basic basis to verify the validity of the prediction model established in this article. When forecasting, we have to consider the corresponding sunlight type, and get the basic parameters of the optimized BP neural network algorithm. Considering the influence of different factors such as light intensity and average temperature on the prediction of photovoltaic power generation, the improved BP neural network prediction model is used to predict the photovoltaic power. The obtained prediction results are shown in Figure 4.

![Prediction results](image)

**Figure 4** The obtained prediction results

It can be seen from Figure 4 that the prediction results obtained by the prediction model are basically consistent with the actual situation, indicating that the prediction model proposed in this article has good sample training capabilities and can obtain more accurate prediction results.

The specific forecast data is shown in Table 1.
Tab. 1 Forecast result

| Forecast time point | Actual value (w) | Predicted value (w) |
|---------------------|-----------------|---------------------|
| 7 o'clock           | 3889            | 3978                |
| 8 o'clock           | 4569            | 4099                |
| 9 o'clock           | 7550            | 7590                |
| 10 o'clock          | 11361           | 11667               |
| 11 o'clock          | 14001           | 14506               |
| 12 o'clock          | 14523           | 15004               |
| 13 o'clock          | 14211           | 13128               |
| 14 o'clock          | 13840           | 13236               |
| 15 o'clock          | 10471           | 10398               |
| 16 o'clock          | 4500            | 4699                |
| 17 o'clock          | 2849            | 3120                |
| 18 o'clock          | 2360            | 2579                |
| 19 o'clock          | 1908            | 2107                |

4. Conclusion
1) The results show that the optimized BP neural network short-term power prediction method has better stability and more accurate prediction results, and is more suitable for the prediction of photovoltaic system power generation.
2) The use of genetic algorithm to optimize the neural network significantly improves the convergence of the network and greatly improves the prediction accuracy of the model, and the probability distribution of the average relative prediction error in each period of the model obeys the normal distribution, and its prediction result has a high confidence.

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