Short-term Photovoltaic Power Forecast Based on Greenhouse Energy Supply Requirements

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Abstract. In order to solve the problem of “disposal of light” in distributed photovoltaic power plants, this paper proposed that the energy supply of photovoltaic power plants could achieve local consumption in agricultural greenhouses, and predict the photovoltaic power generation in advance according to the load demand of greenhouses. The historical power data and meteorological data of the input variables were normalized, and the PV power prediction was performed at a time interval of 1 h for a time comparison. The prediction method based on the iterative improved BP neural network model was proposed. The prediction results showed that the prediction error was not more than 2%, could meet the energy supply stability requirements of greenhouse loads.

Keywords: Photovoltaic Power Station, Power prediction, Agricultural Greenhouse, Short Term

1. Introduction

In the northern winter, it was necessary to keep the temperature in the agricultural greenhouse constant to meet the growth requirements of crops. Therefore, in addition to strengthening the insulation, the energy supply in the greenhouse was the key to ensure the heat load and other loads in the greenhouse.

Xinjiang's solar radiation and illuminance were abundant. The annual average sunshine hours in southern Xinjiang was 3000~3600h. Photovoltaic energy-powered agricultural greenhouses were an important idea to use renewable energy. Predicting the power before supply ensures the stability of energy supply. Sex. Existing power forecasting studied at home and abroad have achieved certain results. Physical analysis and statistical analysis were two common types of research methods[1]. The use of meteorological data to build physical models based on BP neural networks to predict power in haze weather[2], but physical modeling was more complicated. Statistical analysis was widely used to predict the power of photovoltaic power plants through historical power statistics[3]. Common statistical methods included regression analysis[4], time series and other methods. Statistical methods have the advantage of simple modeling in prediction[5], but the disadvantage was that a large amount of historical data needs to be collected and processed. In addition, photovoltaic power prediction also...
includes meta-heuristic methods including neural network[6], Kalman filter algorithm[7], particle swarm algorithm[8] and other algorithms, and scholars use BP neural network to predict photovoltaic power output[9], this kind of method requires a large amount of historical data, and the operation was simple, but there were defects that are easy to fall into the local optimal solution[10].

In this paper, the PV power prediction was performed at a time interval of 1 h and the accuracy was compared. A prediction method based on iterative improved BP neural network model was proposed to provide a prediction method for stable energy supply in greenhouses.

2. Photovoltaic Greenhouse Load

2.1. Photovoltaic Greenhouse Structure

The excess power of photovoltaic power stations in southern Xinjiang is used for energy supply in greenhouses, replacing the previous traditional coal-fired power supply, providing a way for photovoltaics to be consumed locally.

The steel structure design of the photovoltaic greenhouse mainly includes the load-bearing structure and the overall frame of the greenhouse. The basic structure is as follows: the span of the greenhouse is 10.6 meters, the height of the shed is 5 meters, the angle of the dip of the front roof is 43 degrees; the back wall is 3 The high-cement cement wall is equipped with expanded polystyrene insulation board; the vent is installed 1.5 meters from the ground on the north wall; the front window also has a vent for the indoor temperature adjustment in hot summer weather.

2.2. Photovoltaic Greenhouse Load

The main loads of photovoltaic greenhouses include heating energy, roller blinds, water pumps, air conditioners, plant fill light and lighting, etc. The load varies according to the needs of the greenhouse.

The main energy-using equipment for greenhouse roller blinds and pumps and air-conditioning machines is an electric motor with a power of 2 kW and a working power supply of 220 V or 380 V AC power.

Plant fill light is to promote the growth of crops by emitting electromagnetic spectrum suitable for photosynthesis of crops in the greenhouse. The use of plant fill light extends the photosynthesis time of crops. The design uses a full-spectrum 36W LED plant growth lamp. The whole greenhouse is evenly distributed to 10 units. The hanging lamp height is between 0.5 and 1m from the plant leaves. Five daily LED lights, each with a power of 30W.

2.3. Photovoltaic Greenhouse Power Consumption

According to the energy demand of photovoltaic greenhouses, the greenhouse equipment load is shown in Table 1.

| Electrical equipment | Average daily | Power | Annual energy | Remarks       |
|----------------------|---------------|-------|---------------|---------------|
| Rolling machine      | 0.25h/d       | 2kW   | 182kW·h       | regular use   |
| Sprinkler pump       | 0.5h/d        | 2kW   | 365kW·h       | regular use   |
| Fill light, lighting | 3h/d          | 360W  | 395kW·h       | Evening use   |
| Air conditioner      | 1h/d          | 2kW   | 730kW·h       | regular use   |

Considering the actual use load of the greenhouse and the stability of the power supply, the maximum daily load power is designed, and the battery is used as the backup power source.
2.4. Load Control

The choice of circuit breaker is calculated according to the classification of the load.

Current value of pure resistive load

\[
I = \frac{P}{V}
\]  

(1)

Calculation of the current value of the inductive load

\[
I = \frac{P}{U \cdot \cos \Phi}
\]  

(2)

The load of equipment capacity in the greenhouse can be roughly classified as inductive load, but the calculation of the motor should be added to the efficiency of the motor. In this design, the motor \( \cos \Phi \) is taken as 0.8, and the efficiency value \( \eta \) is taken as 0.9. Then the current values of the two motors in the greenhouse are:

\[
I = \frac{P}{U \cdot \cos \Phi \cdot \eta}
\]  

(3)

According to the calculation, the current value of the equipment in the greenhouse is taken into consideration, and the rated current of the circuit breaker is designed according to the starting current of the motor.

The selection of the cross-section of current-carrying conductors such as wires and cables generally takes into account the heating conditions, allowable voltage loss, mechanical strength, dynamic stability, and thermal stability during short-circuit, and the coordination of the conductors with the protective appliances. According to the calculation of the load current, the copper conductors, the current value select according to Table 2.

Table 2 Copper core wire safe current carrying capacity and greenhouse load

| No. | Copper core wire specification(mm²) | Safe current capacity (A) | Load(kW) |
|-----|-----------------------------------|---------------------------|----------|
| 1   | 1                                 | 17                        | 3.8      |
| 2   | 1.5                               | 21                        | 4.6      |
| 3   | 2.5                               | 28                        | 6.2      |
| 4   | 4                                 | 35                        | 7.7      |
| 5   | 6                                 | 48                        | 10.5     |
| 6   | 10                                | 65                        | 14.3     |
| 7   | 16                                | 91                        | 20       |
| 8   | 25                                | 120                       | 26.4     |

3. Photovoltaic System

3.1. Photovoltaic System Package

Photovoltaic systems include photovoltaic cells, inverters, controllers, and batteries. The schematic is as follows.
The single crystal silicon solar cell consumes a large amount of energy, and the conversion efficiency of the amorphous silicon thin film battery is low. The design uses a polycrystalline silicon solar panel, and the production cost and manufacturing cost of the polycrystalline silicon solar cell are low, and the conversion efficiency is high.

In order to display various states of the photovoltaic power generation system, prevent internal short circuit of load and other equipment, and prevent overcharging and overdischarging of the battery pack, a pulse width modulation type photovoltaic controller, that is, an intelligent photovoltaic controller with maximum power tracking technology is used.

The system stores electric energy through the battery pack. Since the daylight is sufficient, the photovoltaic cell generates electricity to the electrical equipment while storing the excess electricity to the battery pack. The power supply of the load is provided by the stored energy of the battery in the absence of light such as cloudy weather. In order to improve the stability of the battery pack and reasonably select the type and capacity of the battery pack, this design selects a maintenance-free lead-acid battery, that is, a lithium battery or a nickel-chromium battery, which has advantages of high resistance to high temperature, fast charging speed, and repeated charging. More times.

3.2. Photovoltaic Power supply Complementary Power Supply System

Xinjiang agricultural greenhouses are located in remote areas. In order to ensure the reliability of photovoltaic power supply, greenhouse photovoltaic power supply system design uses solar power supply complementary power supply to avoid the economic loss caused by power failure caused by insufficient battery power supply in the shed. Solar energy and city The electric complementary power supply mode not only saves energy but also ensures the reliability and stability of the power supply system.

When the sunshine is sufficient, the solar energy is converted into electric energy by the solar photovoltaic cell, and the direct current is converted into 220V alternating current by the inverter to supply the power of the load in the greenhouse, and the excess part of the electric energy is charged to the battery pack through the intelligent controller.

At night or in the windy and rainy weather, the equipment in the greenhouse is powered by a battery, and the current of the lead battery is converted into 220V AC for the load.

In extreme weather, under the wind and sand for a long time, the city power supply is connected to supply power to the greenhouse. When the sun is sufficient or the photovoltaic power generation system equipment is faulty, the photovoltaic power supply is connected, and the mains power supply is disconnected.

4. Photovoltaic Power System Short-term Power Forecasting

4.1. Factors affecting photovoltaic power

The main factors affecting photovoltaic power generation are radiation intensity, weather type and temperature.

The influence of radiation intensity on output power, solar radiation intensity is the main factor
affecting photovoltaic power generation, and the prediction of photovoltaic power generation mainly predicts the intensity of light radiation. Photovoltaic power generation gradually rises from sunrise at sunrise, reaches a maximum at noon, and falls to zero at sunset. The photovoltaic output power is similar to solar radiation.

The influence of weather type on photovoltaic output power, weather conditions such as sunny, cloudy, shower, etc., has a significant impact on the output power of photovoltaic power generation systems. For example, cloud photovoltaic output power decreases rapidly, and the movement of clouds affects the intensity of solar radiation, so cloudy and sunny weather have a great impact on photovoltaic power output.

The influence of temperature on output power, the output power of photovoltaic power generation system is also affected by atmospheric temperature. The change of atmospheric temperature will map the change of height of power curve. The output power of photovoltaic power generation system will fluctuate greatly due to temperature.

4.2. Photovoltaic power prediction model
Because the neural network has powerful learning functions, it can easily implement the nonlinear mapping process and has the ability of large-scale calculation. At the same time, the traditional BP neural network learning algorithm network has a slow convergence rate. Due to the complicated photovoltaic power factor, the learning samples increase. After the network, there is often a great deal of redundancy, which also increases the burden of network learning to a certain extent. Let the error indicator function be expressed by the following formula:

\[ E(w) = \frac{1}{2} \sum_{i=1}^{P} \| Y_i - Y'_i \|^2 = \frac{1}{2} \sum_{i=1}^{P} e_i^2(w) \]  

(4)

In the middle, \( Y_i \)-the expected network output vector; \( Y'_i \)-the actual network output vector; \( P \)-the number of samples; \( w \)-the vector of network weights and thresholds; \( e_i(w) \)-error.

The weights and thresholds are set, and the Gauss-Newton method is used to iteratively obtain the predicted values. Therefore, this paper uses the improved BP neural network model to predict the photovoltaic power generation.

4.3. Photovoltaic Power Prediction Simulation Experiment
On the day of 2018, the time interval is selected to be 1 h for PV power prediction and the accuracy is compared. Due to the time difference of Xinjiang time, the time period is selected from 8:00 to 20:00 during the day. Since the historical power data and meteorological data as input variables are large, the normalization formula is adopted

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

(5)

In the middle, \( x \)-Historical power value; \( x_{\text{min}} \)-the minimum value of historical power in the sample; \( x_{\text{max}} \)-the maximum value of historical power in the sample; \( \hat{x} \)-normalized data (as input to the algorithm model).

The improved neural network model is used for simulation training and analysis under Matlab simulation software. The neural network training state window and training results are shown in Figure 2 and Figure 3.

The BP neural network uses a function that determines the performance of the neural network based on the mean absolute error. It can be seen from Figure 3 that after five training sessions, the network error meets the requirements. The error between the network predicted value and the true value is small, and a large error occurs at 5 pm, which is only 2%, which satisfies the requirement shown in Figure 4.
Figure 2. Neural network training status window

Figure 3. Training results (time interval is 1h)

Figure 4. Predictive absolute error (time interval is 1h)

5. Conclusion

1) Although the traditional BP neural network had better self-learning ability, it also had problems such as slow network convergence and long training time. Therefore, based on the traditional BP neural network, an improved BP neural network prediction model based on iterative method was proposed.

2) Considering the influence of the environmental factors of the output power of the photovoltaic power station, using the improved BP neural network prediction model, the training and prediction were performed every hour during the day, and the prediction result of the power generation of the photovoltaic power station was not more than 2%, and the output was The characteristics of power can meet the thermal and electrical load requirements of agricultural greenhouses.

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