Research on prediction model of construction period of overhead line project based on BP neural network

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Abstract. With the stable development of economy and society, the power load increases year by year, so the power transmission company needs to build enough transmission lines to ensure the power supply. Overhead line project is the most commonly used form of transmission line, but the overhead line project often encounters the situation that cannot be completed on time, which affects the satisfaction of users’ electricity demand. Therefore, it is necessary to reasonably predict the construction period of the overhead line project, so as to provide a reasonable reference for the formulation of the production plan of the grid company. Firstly, this paper analyses the key factors that affect the construction period of overhead line project. Based on the BP neural network method, the construction period prediction model of overhead line project is established. The accuracy of the prediction is high.

1. Introduction
The overhead line project is the most economical and reliable type of power transmission at present, but it is often built in the areas with bad construction conditions and great construction difficulties, and the factors affecting the construction period of the overhead line project are complex. When predicting the construction period, the key to improve the efficiency of the enterprise is to choose the accurate and efficient prediction method. In the long-term construction practice, the enterprise has accumulated a large number of valuable construction period data, but due to the lack of attention to these data, data resources have been wasted.

Reasonable prediction is the premise for enterprises to make various production plans. For the power industry, the contents to be predicted include power load, project cost, construction period, etc. Dordonnat, V[1] based on the semi parametric regression model of point load forecasting, the multivariable time series simulation model for temperature forecasting and the resampling strategy for constructing probability forecasting from the residual of point load forecasting, a method for load forecasting is established. Lu, Y[2] through the analysis of transmission and transformation engineering cost, the total cost is divided into construction cost, equipment purchase cost, installation cost and other costs. On the basis of fully considering the cost characteristics, taking a substation project as an example, a decomposition integration cost prediction model is proposed. Thomas, K.E[3] thinks that the deviation in task duration prediction is due to memorizing the previous task duration incorrectly, and using the previous task duration as the basis of prediction, proposes a duration prediction method.

In the aspect of prediction method research, Ming-Yi You[4] compared the influence of weight function on prediction accuracy by adjusting the parameters of weight function in a wide range of numerical research, and evaluated the prediction robustness of the remaining life prediction method based on similarity by comparing with the remaining life prediction method based on time series.
prediction. Ma, J.H\cite{5} considered the multi variable nonlinear prediction method and the single variable nonlinear prediction method, both of which adopted the concept of phase space reconstruction. The results show that the multivariate nonlinear prediction model is better than the element nonlinear prediction model, and the local linear prediction method of multivariate time series is better than the local polynomial prediction method.

2. Analysis of the factors influencing the construction period of overhead line project

2.1. Identification of factors affecting the construction period of overhead line project

The construction stage of line project refers to the process from the commencement of the project to the completion and production, which requires the placement of tower foundation, tower erection, stringing, commissioning, material procurement, power outage planning and coordination, etc. The influencing factors of the construction period of the line project are mainly attributed to the influencing factors of the civil construction period, the installation period and the commissioning period.

(1) Influencing factors of civil construction period

The influencing factors of the construction period in the civil engineering stage of the line project mainly include natural factors, management factors and technical conditions, such as geological conditions, topographic conditions, vegetation conditions, visibility conditions, traffic conditions, hydrometeorological conditions, route altitude, number of severe weather, construction season, rainfall of the route passing through, etc., and management factors such as construction team operation Capacity, land certificate (real estate certificate) handling, technical factors such as "cableway transportation" quantity, line discount length, etc.

(2) Influencing factors of installation period

The influencing factors of the construction period in the installation stage of the line project mainly include natural factors, management factors and technical conditions, such as terrain conditions, geological conditions, severe weather conditions, management factors such as the working capacity of the construction team, the implementation of the power outage plan, traffic conditions, etc., and technical conditions factors such as the length of the line fold, the number of "cableway transportation" and the number of "large span" Quantity, "three span" quantity, etc.

(3) Factors affecting commissioning period

The influence of the construction period in the commissioning stage of the line project is mainly the management factors, such as the traffic conditions, the implementation of the outage plan, the operation capacity of the commissioning unit, etc.

2.2. Analytic hierarchy process

Analytic hierarchy process (AHP) is a kind of practical multi-objective decision-making method. Its basic idea is: firstly, according to the nature and general goal of the multi-objective decision-making problem, the essence of the problem is decomposed by levels to form a hierarchical structure from bottom to top.

The process of determining factor weight by AHP includes four basic steps:

(1) According to the three-tier structure of AHP, the hierarchical system of influencing factors is established;

(2) Experts construct judgment matrix for each influencing factor, and calculate and determine the comprehensive judgment matrix of each influencing factor according to the evaluation and expert weight of each influencing factor, as shown in the following matrix:

\[
\begin{bmatrix}
A_1 & B_1 & B_2 & L & B_n \\
& b_{11} & b_{12} & L & b_{1n} \\
B_1 & b_{21} & b_{22} & L & b_{2n} \\
& M & M & M & M \\
B_n & b_{n1} & b_{n2} & L & b_{nn}
\end{bmatrix}
\]
(3) The influencing factors are ranked in different levels, the consistency is checked and the index weight is calculated.

The eigenvalues and eigenvectors of each synthetic judgment matrix are calculated by MATLAB software, and the consistency of each expert judgment matrix is checked by using the random consistency ratio CR. Among them:

\[ CR = CI / RI \]  
\[ CI = \frac{\lambda_{\text{max}} - n}{n - 1} \]  

When \( n < 3 \), the matrix is considered to have satisfactory consistency; when \( n > 2 \) and \( CR < 0.1 \), the judgment matrix is considered to have satisfactory consistency; when \( n > 2 \) and \( CR > 0.1 \), each expert needs to adjust their judgment matrix until they pass the consistency test. For the comprehensive judgment matrix passing the consistency test, the weight value \( \omega_i \) of each index can be obtained by using the following formula.

\[ \omega_i = \frac{\prod_{j=1}^{n} b_{ij}}{\sum_{i=1}^{n} \prod_{j=1}^{n} b_{ij}}, \quad i = 1, 2, \ldots, n \]  

(4) According to the literature, the factors with weight greater than 0.08 are selected as decision factors to form the final evaluation results of influencing factors.

2.3. Analysis of decision factors based on AHP

The influencing factors of the progress in the construction stage of the line project are shown in Table 1 below. The comprehensive judgment matrix of each factor \( D_{ij} \) is obtained after the expert scoring, as shown in Table 2.

| Table 1. Influencing factors in construction stage of line engineering |
|---------------------------------------------------------------|
| Stage | Factor attribute | Progress influencing factors |
|-------|-----------------|-------------------------------|
| Natural factors D1 | Geological conditions | D11 |
| | Topographic condition | D12 |
| | Vegetation condition | D13 |
| | Visibility condition | D14 |
| | Traffic condition | D15 |
| | Hydrometeorological conditions | D16 |
| | Path altitude | D17 |
| | Construction season | D18 |
| | Rainfall of route passing area | D19 |
| Progress of construction stage of line project D | Line length | D21 |
| | Three span number | D22 |
| | Number of large span | D23 |
| | Type of shipping | D24 |
| | Capacity of construction team | D25 |
| Technical factors D2 | Commencement time | D31 |
| | Delivery of tower foundation before commencement | D32 |
| Management factors D3 | Cultural environment | D41 |
| Social factors D4 | External force obstruct | D42 |
Table 2. Comprehensive judgment matrix

|   | D   | D1  | D1  | D1  | D1  | D1  | D1  | D3  | D4  | D4  | ω   |
|---|------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| D11| 1    | 1   | 3   | 3   | 5   | 7   | …   | 1   | 2   | 7   | 5   | 0.0854 |
| D12| 1    | 1   | 3   | 3   | 5   | 7   | …   | 1   | 2   | 7   | 5   | 0.0887 |
| D13| 1/3  | 1/3 | 1   | 1   | 3   | 5   | …   | 1/4 | 1/2 | 5   | 3   | 0.0291 |
| D14| 1/3  | 1/3 | 1   | 1   | 3   | 5   | …   | 1/4 | 1/2 | 5   | 3   | 0.0291 |
| D15| 1/5  | 1/5 | 1/3 | 1/3 | 1   | 3   | …   | 1/5 | 1/4 | 3   | 1   | 0.0157 |
| D16| 1/7  | 1/7 | 1/5 | 1/5 | 1/3 | 1   | …   | 1/7 | 1/6 | 1   | 1/3 | 0.0092 |
| …  | …    | …   | …   | …   | …   | …   | …   | …   | …   | …   | …   | …     |
| D31| 1    | 1   | 4   | 4   | 5   | 7   | …   | 1   | 2   | 7   | 5   | 0.0843 |
| D32| 1/2  | 1/2 | 2   | 2   | 4   | 6   | …   | 1/2 | 1   | 6   | 4   | 0.0476 |
| D41| 1/7  | 1/7 | 1/5 | 1/5 | 1/3 | 1   | …   | 1/7 | 1/6 | 1   | 1/3 | 0.0088 |
| D42| 1/5  | 1/5 | 1/3 | 1/3 | 1   | 3   | …   | 1/5 | 1/4 | 3   | 1   | 0.0150 |

λ_{max}=18.6363, n=18, RI=1.6133, CI=0.0374, CR=0.0232

Through calculation, the weight of each influencing factor $\omega$ is obtained, and the factors with the weight greater than 0.08 are selected as the decision-making factors. It can be concluded that the decision-making factors of the progress of the construction stage of the line engineering are the length of the line, the terrain conditions, the geological conditions, the rainfall of the route passing through the ground, the starting time, the altitude, etc.

2.4. Determination of key factors

For the overhead line project, the influencing factors preliminarily determined include the area, the length of line fold, the number of three spans, the number of large spans, the number of tower foundation sites before the commencement, the special transportation mode, the commencement time, the operation capacity of the construction team, terrain, geological conditions, altitude, rainfall and other influencing factors. Combined with the analytic hierarchy process in Chapter 5, the weight of factors is determined. Among them, the area, voltage level, start-up time, rainfall, line fold length, altitude section, terrain, geology and construction team's operation ability are greatly affected. These factors are taken as input variables of the intelligent prediction simulation model. The key influencing factors of construction period are selected as area, voltage level, start-up time, rainfall, line fold length, altitude section, terrain and geology.

3. Prediction of construction period of overhead line project based on BP neural network

3.1. BP neural network

The basic BP algorithm includes two processes: the forward propagation of signal and the back propagation of error. That is to say, the error output is calculated according to the direction from input to output, while the adjustment of weight and threshold is carried out from the direction from output to input. In the forward propagation, the input signal acts on the output node through the hidden layer, and generates the output signal through nonlinear transformation. If the actual output does not match the expected output, the error is transferred into the back propagation process. Error retransmission is that the output error is retransmitted to the input layer layer by layer through the hidden layer, and the error is allocated to all cells of each layer, and the error signal obtained from each layer is used as the basis for adjusting the weight of each cell. By adjusting the connection strength between the input node and the hidden layer node, the connection strength between the hidden layer node and the output node and the threshold value, the error is reduced along the gradient direction. After repeated learning and training, the network parameters (weight and threshold) corresponding to the minimum error are determined, and the training stops. At this time, the trained neural network can process the information of non-linear transformation with the minimum output error for the input information of similar samples.
3.2. BP neural network prediction of construction period of overhead line project

Based on the BP neural network method, the input variables of the construction period prediction model of the overhead line project are determined as 12 variables: city number, voltage level number, starting section number, rainfall, line fold length, elevation section number, plain proportion, non-plain proportion, common soil proportion, non-common soil proportion, rock proportion, construction team operation ability.

81 samples are randomly selected from 91 samples of overhead line project as training samples, and the remaining 10 samples are used as verification samples. The number of neurons in the input layer is 12, the number of neurons in the output layer is 1, and the number of neurons in the middle layer is 15. A three-layer neural network structure is established. The prediction results of BP neural network are shown in Table 3 and figure 1.

Table 3. Prediction results of BP neural network

| Sample number | actual value | predicted value | deviation | Deviation percentage |
|---------------|--------------|-----------------|-----------|---------------------|
| Sample 1      | 428          | 427.99          | -0.01     | 0.00%               |
| Sample 2      | 426          | 501.47          | 75.47     | 17.72%              |
| Sample 3      | 388          | 342.03          | -45.97    | -11.85%             |
| Sample 4      | 370          | 455.97          | 85.97     | 23.24%              |
| Sample 5      | 432          | 329.07          | -102.93   | -23.83%             |
| Sample 6      | 392          | 348.89          | -43.11    | -11.00%             |
| Sample 7      | 373          | 454.92          | 81.92     | 21.96%              |
| Sample 8      | 421          | 357.86          | -63.14    | -15.00%             |
| Sample 9      | 372          | 387.56          | 15.56     | 4.18%               |
| Sample 10     | 428          | 394.60          | -33.40    | -7.80%              |

The training error effect of BP neural network is shown in Figure 2.

Figure 1. Comparison of actual duration and training duration

The training error effect of BP neural network is shown in Figure 2.
Figure 2. Training error effect diagram of BP neural network

From the above chart analysis, it can be seen that BP neural network can get more accurate scatter diagram and fitting curve according to the characteristics of data, and the prediction error is mostly within 10%.

4. Conclusion
This paper takes the prediction of construction period of overhead line project as an example to study the prediction of construction period of power transmission and transformation project. Based on the analytic hierarchy process, 12 factors affecting construction period of overhead line project are determined, which are used as the input variables of the prediction model of construction period of overhead line project. Based on the BP neural network method, the prediction model of construction period of overhead line project is established. The input variables used in this paper consider all aspects that affect the construction period of power transmission and transformation projects, almost covering the whole process of construction. The prediction model of construction period based on BP neural network has a good prediction effect, which can be regarded as a reference for the establishment of production plan of power grid company.

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