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Load forecasting method considering temperature effect for distribution network

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Abstract. To improve the accuracy of load forecasting, the temperature factor was introduced into the load forecasting in this paper. This paper analyzed the characteristics of power load variation, and researched the rule of the load with the temperature change. Based on the linear regression analysis, the mathematical model of load forecasting was presented with considering the temperature effect, and the steps of load forecasting were given. Used MATLAB, the temperature regression coefficient was calculated. Using the load forecasting model, the full-day load forecasting and time-sharing load forecasting were carried out. By comparing and analyzing the forecast error, the results showed that the error of time-sharing load forecasting method was small in this paper. The forecasting method is an effective method to improve the accuracy of load forecasting.

Keywords: Load forecasting, Temperature, Multiple regression analysis, Time-sharing forecasting.

1 Introduction

The load level and structure of the power network has greatly changed [1], which has increased the difficulty of load forecasting. There are more factors that affect the load forecasting [2]. One of the more important factors is temperature. It's particularly vital to study the relationship between temperature and load [3]. Temperature has impacted on the prediction results largely [4].

When the weather is cold or hot, there will be a large number of heating or cooling loads put into operation, which will result in a substantial change in power consumption [5]. Therefore, the temperature has been become a common understanding factor in the short-term load forecasting. It is necessary to analyze the relationship between the load and the temperature [6]. There are many short-term forecasting methods, such as extrapolation method, regression analysis method, grey theory, neural network, etc. [2, 4]. Because of the advantages of the regression prediction, the method has been widely used in short-term load forecasting.

Using multi-variant regression method, this paper proposed the of distribution network load forecasting method considering the influence of temperature on load forecasting.

2 Analysis of temperature factors in load forecasting

Table 1 Peak load and temperature data in summer 2001

Date	Daily maximum load [MW]	Daily mean temperature [℃]
July 10th	2439	32.6
July 11th	2473	32.0
July 12th	2036	26.8
July 13th	2097	28.5
July 14th	1799	26.0
July 15th	1723	26.4
July 16th	1929	26.7

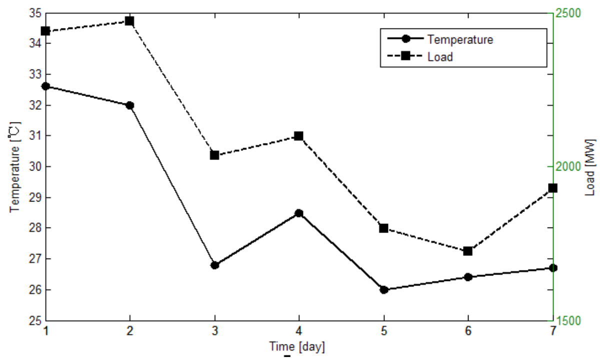

Fig. 1 Curve of load changes with temperature

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Using the daily maximum load as an example, this paper researched temperature factor. Based on the data of power consumption and temperature in summer of 2001 [7], this paper listed the typical summer daily peak load and the daily average temperature in Table 1. According to the table 1, the temperature-load change characteristic curve was shown in the figure 1. In the figure 1, the trend of daily power was very similar with the average temperature.

3 Mathematical model of load forecasting

It is assumed that the load is random variable y. The variable y is related to the control variable x. The variable x has n components x_i , which were $x_1, x_2, x_3,\dots$, x_n , (n>1). Supposed that there is only linear relationship between x and y. The two-variable linear regression model is as follows:

$$y = a_1x_1 + a_2x_2 + a_3 \tag{1}$$

Where y is load（MW）， and x_1 is time（h）， and x_2 is temperature（℃）, and **a** is regression coefficient, $\mathbf{a} = \begin{bmatrix} a_1 & a_2 & a_3 \end{bmatrix}^{\mathrm{T}}$.

For the sake of the regression coefficient **a**, assuming that the total data number is m, the i-th data is d_i . As follows:

$$d_i = \begin{bmatrix} y_i & x_{i1} & x_{i2} \end{bmatrix},\ i = 1, 2, \cdots, m \tag{2}$$

Further, the d_i is put into formula (1), and written as a matrix form：

$$\begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_m \end{bmatrix} = \begin{bmatrix} x_{11} & x_{12} & 1 \\ x_{21} & x_{23} & 1 \\ \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & 1 \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \\ a_3 \end{bmatrix} \tag{3}$$

Where $\mathbf{Y} = \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_m \end{bmatrix}$ ， $\mathbf{X} = \begin{bmatrix} x_{11} & x_{12} & 1 \\ x_{21} & x_{23} & 1 \\ \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & 1 \end{bmatrix}$, and the formula (3) can be written as：

$$\mathbf{Y} = \mathbf{Xa} \tag{4}$$

In order to get the regression coefficient a, according to the least square method [8], the type (4) is multiplied by $\mathbf{X}^{\mathrm{T}}$， and there is：

$$\mathbf{X}^{\mathrm{T}}\mathbf{Y} = \mathbf{X}^{\mathrm{T}}\mathbf{Xa} \tag{5}$$

Where $\mathbf{X}^{\mathrm{T}}\mathbf{X}$ is m×m symmetric positive definite matrices. So, the regression coefficient **a** can be obtained as follows:

$$\mathbf{a} = \left(\mathbf{X}^{\mathrm{T}}\mathbf{X}\right)^{-1}\mathbf{X}^{\mathrm{T}}\mathbf{Y} \tag{6}$$

4 The steps of load forecasting

For the load forecasting, the first step is to collect and analyze data. Then the content of the forecasting is determined, and the load forecasting model can be established. Next step is to calculate regression coefficient and the predictive value. The load forecasting steps are shown in figure 2.

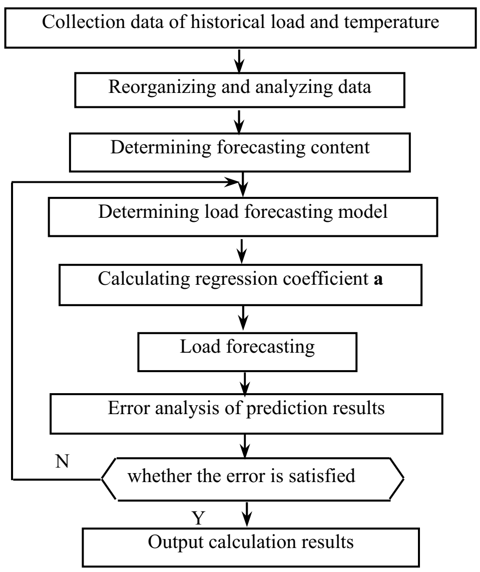

Fig. 2 The steps of load forecasting

5 Case analysis

Collect data and determine predictive content The January 28 of 2002 was selected as the forecast date [9]. Establishing mathematical model based on MATLAB, 24 point load value was forecasted on the forecast date.

All day load forecasting and error analysis According to the data and formula (6), the regression coefficient **a** was equal to

$\begin{bmatrix}0.7345 & 0.2502 & 65.6889\end{bmatrix}^T$ .Based on the formula (1), the load forecasting model of the all day was established on Monday. The forecasting model was:

$$y = 0.7345x_1 + 0.2502x_2 + 65.6889 \quad (7)$$

According to the formula (7), the predicted result was compared with the actual load as shown in Table 2, and the average relative error was 5.23%, and the maximum relative error was 16.28%.

Table 2 Analysis of forecast load and actual load

Time	Forecasting load [MW]	Actual load [MW]	Absolute error[MW]	relative error	Time	Forecasting load [MW]	Actual load [MW]	Absolute error[MW]	relative error
0:00	61.1853	64.10725	2.9219	4.56%	12:00	71.2503	70.68528	0.5650	0.80%
1:00	61.6696	62.39206	0.7225	1.16%	13:00	72.2350	69.86855	2.3665	3.39%
2:00	62.1539	62.32896	0.1751	0.28%	14:00	73.2197	74.26696	1.0473	1.41%
3:00	63.1386	60.7861	2.3525	3.87%	15:00	74.2044	74.25833	0.0539	0.07%
4:00	64.1233	64.23827	0.1150	0.18%	16:00	75.1891	75.68637	0.4973	0.66%
5:00	65.1080	67.55168	2.4437	3.62%	17:00	76.1738	84.10879	7.9350	9.43%
6:00	65.5923	70.55515	4.9628	7.03%	18:00	77.1585	86.70985	9.5513	11.02%
7:00	66.5770	78.02583	11.4488	14.67%	19:00	77.6428	81.05289	3.4101	4.21%
8:00	67.5617	73.76723	6.2055	8.41%	20:00	78.1271	83.56409	5.4370	6.51%
9:00	68.5464	73.32247	4.7761	6.51%	21:00	78.1110	79.84229	1.7313	2.17%
10:00	69.5311	75.80108	6.2700	8.27%	22:00	78.5953	75.42288	3.1724	4.21%
11:00	70.5158	75.69858	5.1828	6.85%	23:00	78.8294	67.79508	11.0343	16.28%

Time-sharing load forecasting and error analysis To reduce the error, using the time-sharing load forecasting, the 24 models were established respectively. The mathematical model is as follows:

$$y_i = a_{i1}x_1 + a_{i2}x_2 + a_{i3} \quad (8)$$

Where i is time (h), and y_i is the load of the time i (MW), $\mathbf{a} = \begin{bmatrix}a_{i1} & a_{i2} & a_{i3}\end{bmatrix}^T$ is the regression coefficient of the time i。

Table 3 Analysis of forecast load and actual load

Time	Forecasting load [MW]	Actual load [MW]	Absolute error[MW]	relative error	Time	Forecasting load [MW]	Actual load [MW]	Absolute error[MW]	relative error
0:00	59.2476	64.10725	4.8596	7.58%	12:00	70.9898	70.68528	0.3045	0.43%
1:00	58.1464	62.39206	4.2457	6.80%	13:00	67.6811	69.86855	2.1875	3.13%
2:00	58.3339	62.32896	3.9950	6.41%	14:00	70.1820	74.26696	4.0850	5.50%
3:00	58.3395	60.7861	2.4466	4.02%	15:00	71.0760	74.25833	3.1824	4.29%
4:00	59.9535	64.23827	4.2848	6.67%	16:00	72.3135	75.68637	3.3729	4.46%
5:00	64.1283	67.55168	3.4234	5.07%	17:00	87.0174	84.10879	2.9087	3.46%
6:00	70.2550	70.55515	0.3001	0.43%	18:00	83.7786	86.70985	2.9313	3.38%
7:00	75.9125	78.02583	2.1133	2.71%	19:00	79.4430	81.05289	1.6099	1.99%
8:00	70.3329	73.76723	3.4343	4.66%	20:00	77.6185	83.56409	5.9455	7.11%
9:00	69.0813	73.32247	4.2412	5.78%	21:00	76.2866	79.84229	3.5557	4.45%
10:00	71.4448	75.80108	4.3563	5.75%	22:00	69.8029	75.42288	5.6200	7.45%
11:00	74.1321	75.69858	1.5665	2.07%	23:00	63.7088	67.79508	4.0862	6.03%

The results predicted compared with the actual load as shown in table 3. To compare the accuracy of the whole day load forecasting and the time-sharing load forecasting, the two load forecasting waveforms were output into Figure 3. And the comparison of relative error was shown in Figure 4.

According to the table 3 and Figure 4, the average relative error of time-sharing forecast was 4.56%, the maximum relative error was 7.58%. The time-sharing forecast load values were similar with the actual values. So, the time-sharing method can meet the need for short-term load forecasting.

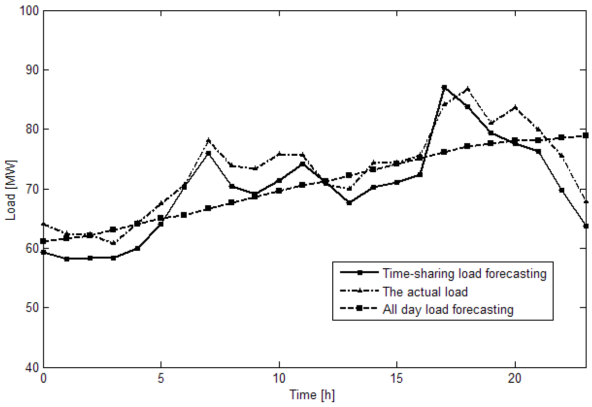

Fig. 3 Comparison curve of the forecast load and actual load

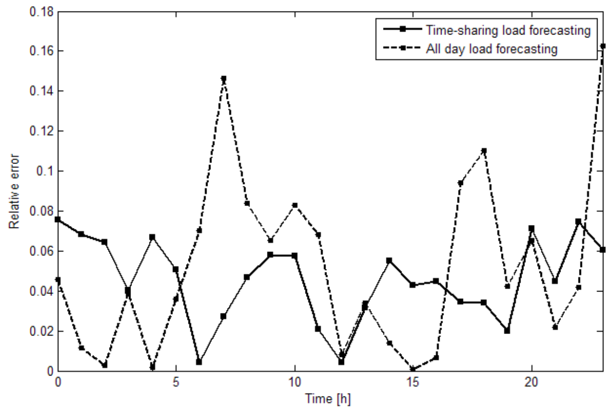

Fig. 4 Comparison curve of the forecasting relative error

6 Conclusion

(1) Temperature has become an important factor that affects the accuracy of load forecasting, and the effect of temperature on short-term load is most significant.

(2) Considering temperature effect, the linear regression forecasting method can meet the demand of short-term load forecasting of power system.

(3) Because the impact of temperature on the load is not exactly the same in different area, it is necessary to choose the forecast model to according to the specific circumstances of the region, which may avoid to increased load forecasting error.

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