Power load forecasting

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1 Problem Description

For the electric power factory, the power load forecasting problem, including load forecasting and consumption predicting, is crucial to work planning. According to the predicting time, it can be divided into long-term forecasting, mid-term forecasting, short-term forecasting and ultrashort-term forecasting. The long-term and mid-term forecasting are mainly used for macro control, and their forecasting time arrange are from one year to ten years and from one month to twelve months respectively. The short-term forecasting which prediction time is from one day to seven days is used in generators macroeconomic control, power exchange plan and some other areas. Predicting the situation in next 24 hours is named as the ultrashort-term forecasting which is used for failure prediction, emergency treatment and frequency control.

In general, the forecast accuracy is different for different prediction time. The longer is the time, the lower accurate is the prediction.

As the unique power supplier in Huizhou, a middle size city in Guangdong Province, China, Huizhou Electric Power wants to know the solution to the problems as bellowing:

1. Prediction of the total electrical consumption and the peak load of the city in 2006 based on the economy development and the feature of the city.
2. Monthly prediction of the consumption and peak load in 2006.
3. Daily prediction of the consumption and peak load from July 10^{th} to 16^{th} in 2006.
4. Prediction of the load every 15 minutes of July 10^{th}.
5. Real-time forecasting which means to amend the existing load prediction for next 15 minute.

2 Forecasting power consumption every year

Year	2001	2002	2003	2004	2005
Power (10000Kwh)	461142	579054	717037	875652	1034231

Table 1 Power consumption from 2001-2005

From the data in Table 1, we use **Improved Grey Method** to predict the power consumption in 2006.

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2.1 Method Description

Step1: Smooth the historical data in table 1 using Weighted Exponential Smoothing Method which is showed as $x_{t+1} = \sum_{i=0}^{t} \alpha(1-\alpha)^i x_{t-i}$.

Step2: Based on the smoothed data denoted as $\{x_1^{(0)}, x_2^{(0)} \dots x_t^{(0)}\}$, we can get $\{x_1^{(1)}, x_2^{(1)} \dots x_t^{(1)}\}$ by using $x_k^{(1)} = \sum_{i=1}^{k} x_i^{(0)}$ where k=1,2,…,t.

Step3: According to Table 1, t is 5. Define

$$Y = \begin{bmatrix} x_2^{(0)} \\ x_3^{(0)} \\ \dots \\ x_5^{(0)} \end{bmatrix}, \qquad B = \begin{bmatrix} -z_2^{(0)} & 1 \\ -z_3^{(0)} & 1 \\ \dots & \\ -z_5^{(0)} & 1 \end{bmatrix}$$

where $z_k^{(1)} = 0.5x_k^{(1)} + 0.5x_{k-1}^{(1)}$.

Step4: Let $\hat{a} = (B^T B)^{-1} B^T Y = \begin{bmatrix} a \\ b \end{bmatrix}$

We can get the estimated value of $x_{t+i}^{(1)}$ as $\hat{x}_{t+i}^{1} = (x_1^{(0)} - \frac{b}{a})e^{-a} + \frac{b}{a}$ and

$\hat{x}_{t+i}^{(0)1} = (x_{t+i+1}^{(1)} - \hat{x}_{t+i}^{(1)})$

2.2 Result

Let α=0.8, the predicted power consumption of 2006 is 1217238 kwh.

3 Forecasting power consumption every month

For March to December, we use **Ratio Method** to estimate their power consumptions. From the historical data from 2001-2005, we can get table 2 as bellowing where R is the ratio of the mean month consumption to the mean year consumption during 2001-2005.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
R	0.0632	0.0564	0.0761	0.0779	0.0861	0.0894	0.0986	0.1012	0.0941	0.0884	0.0830	0.0854

Table 2 Power consumption ratio from March to December

Based on the ratio and the predicted value of 2006, we can get the estimated values which are listed in Table 3.

2006	March	April	May	June
Predicted	91740	94154	103810	107432
Real	93435	95291	97137	102555

Table 3 The predicted and real value from March to June in 2006

From the historical data, we find the monthly consumptions in Jun and Feb is strongly effected by Spring Festival, so we model the daily consumption in Figure1 where E_M is the mean daily consumption in two months and Em is the minimum daily consumption normally found on the first day of Spring Festival denoted as T_0 which is between the 15^{th} day and 50^{th} day. The consumption declines from E_M to Em in t_1 days and increases from Em to E_M in t_2 days.

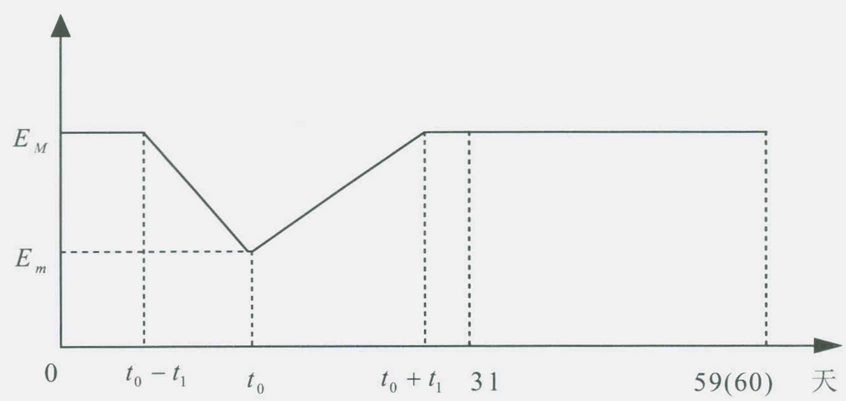

Figure 1 Feature curve of the power consumption from Jan to Feb

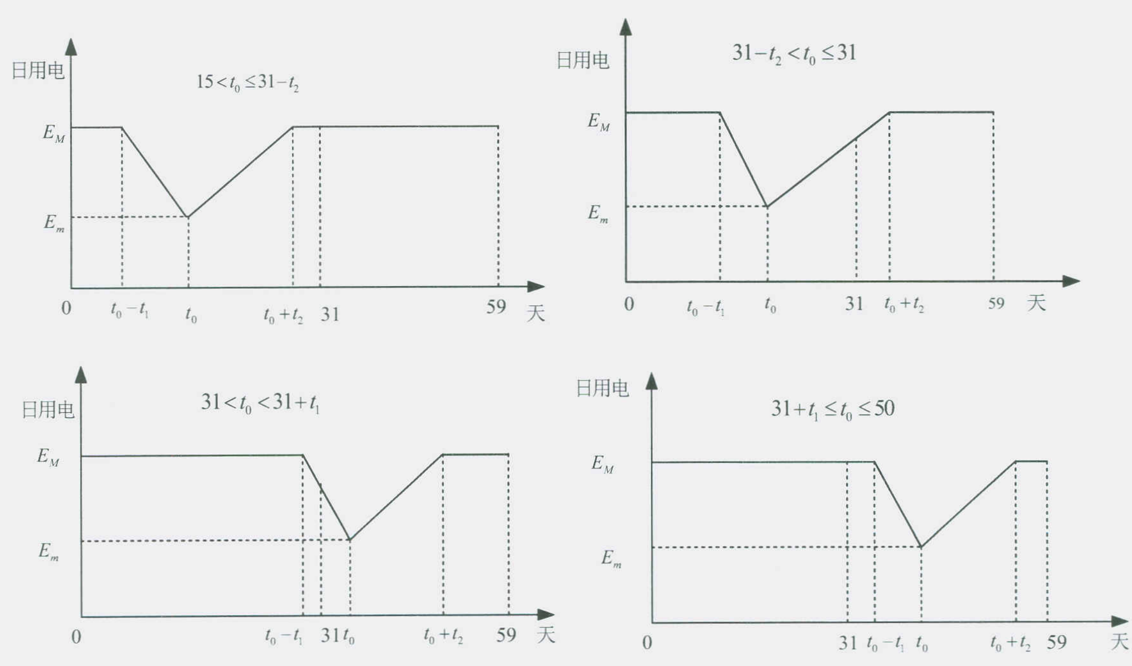

Figure 2 Patterns of the power consumption in Jan. and Feb.

Further Figure 2 shows the four consumption patterns the difference of which is the location of the first day of Spring Festival. Then we can get bellowing formulas to calculate the power consumption in January:

$$(I) 15 < t_0 \le 31 - t_2 : 31E_M - \frac{1}{2}(t_1 + t_2)(E_M - E_m)$$

$$(II) 31 - t_2 < t_0 \le 31 : 31E_M - \frac{1}{2}(t_1 + t_2)(E_M - E_m) + \frac{1}{2}(t_0 + t_2 - 31)\frac{(E_M - E_m)}{t_2}(t_0 + t_2 - 32)$$

$$(III) 31 < t_0 < 31 + t_1 : 31E_M - \frac{1}{2}(30 - t_0 + t_1)\frac{(E_M - E_m)}{t_1}(31 - t_0 + t_1)$$

$$(IV) 31 + t_1 \le t_0 \le 50 : 31E_M$$

Based on the historical data, we can get the mean of $t_1 = 8$, $t_2 = 11$ and $E_m \approx 0.4E_M$. So if the sum of power consumption in Jan and Feb is known, we divide it by 53.3 (or 54.3) which is the mean number of days in two month to get E_M.

For 2006, the predicted value of the sum of Jan and Feb is 1217238×0.1197=145703(10000kwh), the value for Jan is 74267 (real value is 74245) and for Feb is 71430 (real value is 70945).

4 Forecasting power consumption in seven days of a week

To forecast the daily consumption in a week, we use the following regressive formula

$$y(\text{day}) = a \times \text{Ratio}(\text{day}) + b \times Ht + c \times Lt + d$$
$$Ht = \text{MAX}(0, \text{HighTemp} - 28) + \text{MAX}(0, \text{LowTemp} - 25)$$
$$Lt = \text{MAX}(0, 15 - \text{LowTemp})$$

where Ratio of day as shown in Table 4 is the mean consumption of every day to the mean week consumption, HighTemp and LowTemp are the forecasted highest and lowest temperature in that day.

Day	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Ratio	0.14123	0.14438	0.14544	0.14596	0.14494	0.1439	0.13416

Table 4 Ratios of the mean day consumption to mean week one

With the above formula, the running data from 2001 to 2005 and also the forecasted highest and lowest temperature between June 26th and July 2nd 2006, we can predict the power consumption every. The results are listed in table 5 in which the real data and the relative error are also included.

Day	26-Jun	27-Jun	28-Jun	29-Jun	30-Jun	1-Jul	2-Jul
Predicted	3715	3811	3844	3583	3644	3705	3500
Real	3742	3960	3861	3601	3589	3557	3464
Error(%)	0.71%	3.76%	0.46%	0.49%	1.53%	4.14%	1.04%

Table 5 The predicted value and relative error in the week from June 26th to July 2nd, 2006

5 Forecasting power load

5.1 Max power load in one year, month and day

Theoretically, for a given time period such as [a, b], the power load function f(t) and the total power consumption A satisfy $\int_a^b f(t)dt = A$. If we know nothing about the shape of f(t) in [a,b], it would be more difficult to predict the maxim value of the power than to predict the power consumption. But in practice the power load function is regular in the time of one day, one month or even one year. So it is possible to predict the max load of day, month or year. Actually the following formula can be used to do this work $P_{max} = K_1 W + K_2 W^{\frac{1}{2}} + K_3$

where W is the total consumption, P_{max} the estimated max load.

	Max daily power load				Mean daily power consumption			
Year	2002	2003	2004	2005	2002	2003	2004	2005
March	805	979	1124	1349	1413	1723	2181	2494
April	918.5	1078	1298	1480	1577	1852	2257	2668
May	975.5	1123	1258	1525	1746	2030	2397	2974
June	1021	1161	1506	1656	1829	2035	2686	3022

Table 6. Max daily power load and mean daily consumption from 2002 to 2005(partial)

For example, we predict the max daily power in March, April, May and June, 2006. Based on the historical data in table 6, we have

For March: $P_{max} = 0.8348W - 30.674W^{\frac{1}{2}} + 812.008$

For April: $P_{max} = 1.0131W - 49.1078W^{\frac{1}{2}} + 1281.433$

For May: $P_{max} = 1.0833W - 56.1171W^{\frac{1}{2}} + 1455.311$

For June: $P_{max} = 1.3167W - 79.006W^{\frac{1}{2}} + 2013.9228$

By adopting the predicted mean consumption value in table 7 to above formula, we have the predicted max power load listed in the same table.

	Predicted value		Real value
	Mean consumption	Max load	Max load
March	1574	1644	1574
April	1745	1732	1745
May	1864	1775	1864
June	1978	1896	1978

Table 7 Max load prediction in 2006

5.2 Real-time load forecasting

Real-time load forecasting means to predict the max load in the next 15 minute. As it is impractical to forecasting the consumption in next 15 minutes, we should regress the load data on daily consumption based on historical data. That means we have $P_i = a_i W + b_i$ $(i=1,2,\cdots,96)$ where W is the daily consumption, P_i $(i=1,2,..,96)$ are the max load in every 15 minutes of a day.

The historical data we use are that in last month. For example, if we want to predict the real-time load in April 5^{th}, 2004, we first identify it as Monday. Then by using the real-time loads on Mondays in March, we can have 96 regressive formulas. Adopting the predicted value of day consumption on April 5^{th}, 2004 to these formulas, we have the 96 predicted values as shown in Figure 3.

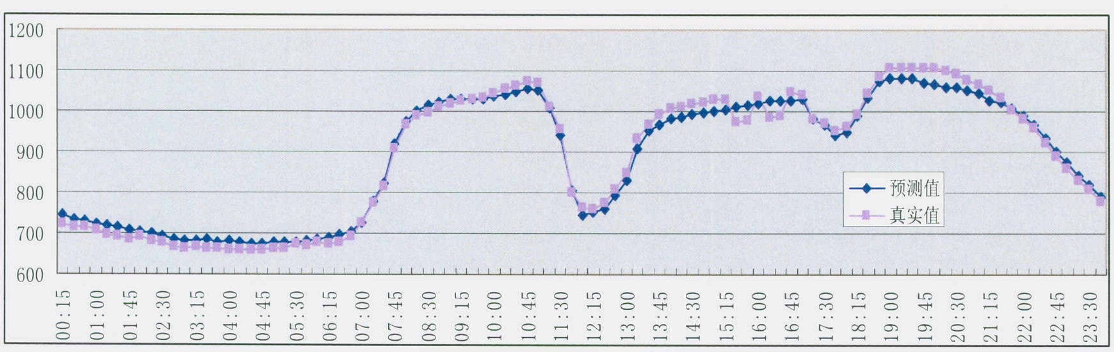

Figure 3