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THE VARIABILITY CHARACTERISTICS AND PREDICTION OF GUANGDONG POWER LOAD DURING 2002 – 2004

LUO Sen-bo (罗森波)[1], JI Zhong-ping (纪忠萍)[1], MA Yu-hua (马煜华)[2], LUO Xiao-ming (骆晓明)[2], ZENG Qin(曾沁)[1], Lin shao-bing(林少冰)[1]

(1. Guangzhou central meteorological observatory, Guangzhou 510080 China; 2. Guangdong Electric Power Dispatch Center, Guangzhou 510060 China)

Abstract: The variability characteristics of Guangdong daily power load from 2002 to 2004 and its connection to meteorological variables are analyzed with wavelet analysis and correlation analysis. Prediction equations are established using optimization subset regression. The results show that a linear increasing trend is very significant and seasonal change is obvious. The power load exhibits significant quasi-weekly (5 – 7 days) oscillation, quasi-by-weekly (10 – 20 days) oscillation and intraseasonal (30 – 60 days) oscillation. These oscillations are caused by atmospheric low frequency oscillation and public holidays. The variation of Guangdong daily power load is obviously in decrease on Sundays, shaping like a funnel during Chinese New Year in particular. The minimum is found at the first and second day and the power load gradually increases to normal level after the third day during the long vacation of Labor Day and National Day. Guangdong power load is the most sensitive to temperature, which is the main affecting factor, as in other areas in China. The power load also has relationship with other meteorological elements to some extent during different seasons. The maximum of power load in summer, minimum during Chinese New Year and variation during Labor Day and National Day are well fitted and predicted using the equation established by optimization subset regression and accounting for the effect of workdays and holidays.

Key words: Guangdong power load; low frequency oscillation; wavelet analysis; optimization subset regression

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1 INTRODUCTION

Power load is one of the most important indices for the planning, design, operation and management in the power system. The study on the characteristics and patterns of load variation is a prerequisite for safe, stable, quality and economic operation of the power grid[1]. As shown in many studies [1 – 6], power load is associated with the change of meteorological conditions; power load for individual power grids varies in its relationship with meteorological factors due to differences in geographic and climatic conditions and economic structure and development. Located in low latitudes and economically developed, Guangdong province is of the climate zone of tropical and subtropical monsoon with long summer and short winter. Persistently high temperature weather has been common in summer since 2003, resulting in sustained increase of power load and posing a serious challenge to the safe and stable operation and secured power supply of the power grid. In the middle of July 2005, for example, high temperature persisted in Guangdong and resulted in continued setting of maximum load of power. In 15 days of the month, the record of maximum power load was broken nine times in the power grid, with the maximum power load nearly 44,000,000 kw. Due to the sustained growth of the power load, supply was smaller than demand, severely offsetting the balance of power and energy and affecting the life and work of the inhabitants. It is then necessary to have more extensive analysis of the variation of power load and its relationship with meteorological factors and formulate a set of predictive equations. With them, specialized forecast products can be provided to the power departments for rational dispatching of power consumption, increasing the efficiency of power consumption and saving the energy

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Biography: LUO Sen-bo (1955-), male, native from Guangdong province, senior engineer, mainly undertaking the research on applied meteorology.
E-mail: luosenbo@tqyb.com.cn

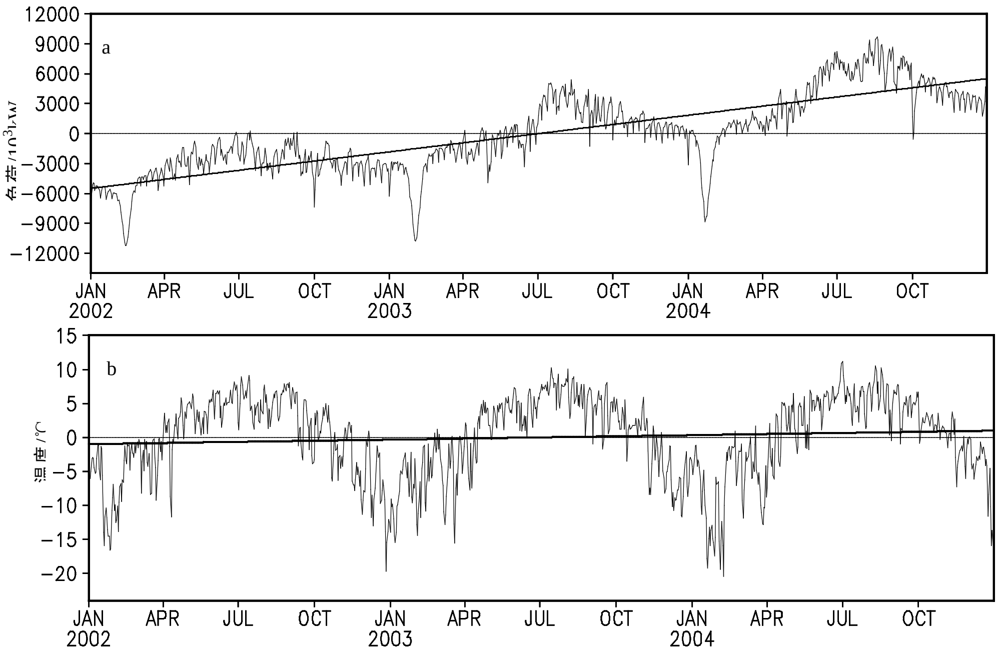

Fig.1 Variation of daily power load and temperature in 2002 – 2004 and their linear tendency. The fine straight lines are the linear tendency. (a) Daily power load in Guangdong (unit: 10^3kW); (b) Daily temperature in Guangzhou (unit: °C).

in Guangdong.

Stepwise regression is the main method used in previous studies to establish predictive equations for power load versus meteorological factors [3 – 6]. It is, however, confirmed in practice and theoretically that no optimum regression equation can be acquired under the condition of given independent variables. The regression of optimum subsets is a method by which an optimum regression equation is determined from all possible subsets regressed following a certain criterion. It has become a trend to replace the stepwise regression [7]. With daily data of power load available every 30 minutes for 2002 – 2004 and surface meteorological data for Guangzhou, the current work studies the variation of power load on a daily basis and its relationship with meteorological factors. Then optimum subset regression equations are set up to predict the power load for the operational scheduling in the power grid.

2 DATA AND METHODS

Daily values of power load were determined by averaging the 48 monitored values for each day in 2002 – 2004 from the Power Supply Bureau of Guangdong. The surface meteorological data for at 20:00 – 22:00 (L.T.) at the Wushan Observation Station, Guangzhou are eight elements of daily mean temperature, daily maximum temperature, daily minimum temperature, precipitation, relative humidity, wind speed, cloud cover, sunshine.

3 VARIATIONS OF POWER LOAD IN GD

3.1 *Annual variation and linear change*

The black and bold line in Fig.1 gives the anomalous variation of daily power load in Guangdong in 2002 – 2004. It is shown that the daily power load is of a clear annual variation and growing trend, mainly contributed by social and economic development and rising living standard. The dashed, straight line indicates the linear trend of variation daily power load in Guangdong as estimated with the least square method that has a linear tendency.

3.2 *Seasonal variation of the power load*

Fig.2a gives the variation of monthly mean of the power load in Guangdong in 2002 – 2004. It is known that the minimum load mostly appears in January and February, followed by substantial rise in March and slightly more in April and May, and then sharp increase in June, with peaks mostly in June – September. The power load begins to fall in October – December. The findings are generally consistent with the trend of variation of monthly mean temperature in Guangzhou (Fig.2b).

3.3 *Periodic change of the power load*

The harmonic analysis method is used to run a fitting of the seasonal variation and linear change of the original series. Then, deviations from the original time series is used to perform wavelet analysis using the

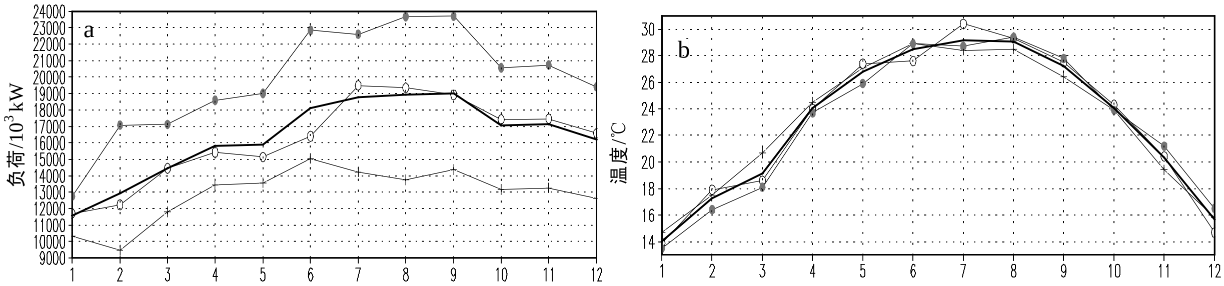

Fig.2 Monthly variation of power load in Guangdong (a, unit: 10^3 kW) and temperature in Guangzhou (b, unit: °C) in 2002 – 2004. *—— 2002, ○—— 2003, ●——2004, — mean for 2002 – 2004.

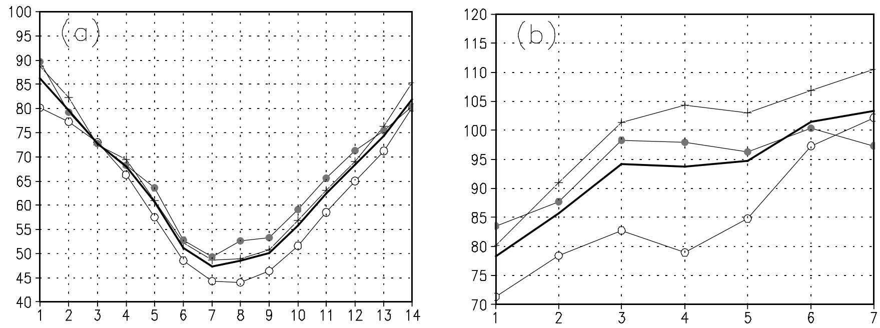

Fig.3 Distribution of percentage of power load and weekly mean in the weeks before and after it during the public holidays in 2002 – 2004. *—— 2002, ○—— 2003, ●—— 2004, — mean for 2002 – 2004. a. Spring Festivals; b. May Day.

Mexican hat wavelet[8] (figure omitted). It is found that there are mainly quasi-weekly oscillations of 5 – 7 days, quasi-by-weekly oscillations of 10 – 20 days and seasonal oscillations of 30 – 60 days.

4 DISTRIBUTION OF POWER LOAD DURING WEEKENDS AND PUBLIC HOLIDAYS

From our analysis of the effect of weekends and public holidays on the power load, it is shown that the percentage varies mildly from Monday to Saturday but significantly at lower levels on Sundays; the distribution is funnel-shaped during Spring Festivals in which power consumption drops gradually to the lowest point in the first and second day of the holiday before slowly increasing afterwards and returns to normal on the eighth day of the holidays. For May Day (Fig.3b) and National Day holidays (figure omitted), the power load is lower than normal in the first two days but returns to normal on the third day.

Tab.1 Optimum regression equations for power load in the four seasons and surface meteorological elements during the same periods

Season	Optimum regression equations	Complex correlation coefficients	Root mean square errors / 10^3 kW
Winter	Y_m = -230.4+575.5X_1-314.2X_2-205.2X_3-11.8X_4+220.0X_6-111.3X_7+65.5X_8	0.33	1 214.6
Spring	Y_m =-3 367.6+115.9X_1+92.624X_7+83.5X_8	0.51	978.3
Summer	Y_m =-16 712.8+191.3X_1+170.8X_2+290.7X_3	0.76	1 016.2
autumn	Y_m =-4 545.4+276.5X_1-8.8X_2-119.0X_3+4.1X_4+152.8X_5+16.0X_7-4.1X_8	0.72	706.6

5 PREDICTIVE MODEL FOR OPTIMUM SUBSET REGRESSION

The model of power load is described using the following equations:

$$Y = (Y_t+Y_m)\times \text{percentage of holidays} + \delta \qquad (3)$$

Specifically, $Y_t=a+bt$ (a is the term of constant and b the term of linear tendency), which shows the linear variation resulted from temporal growth, social and

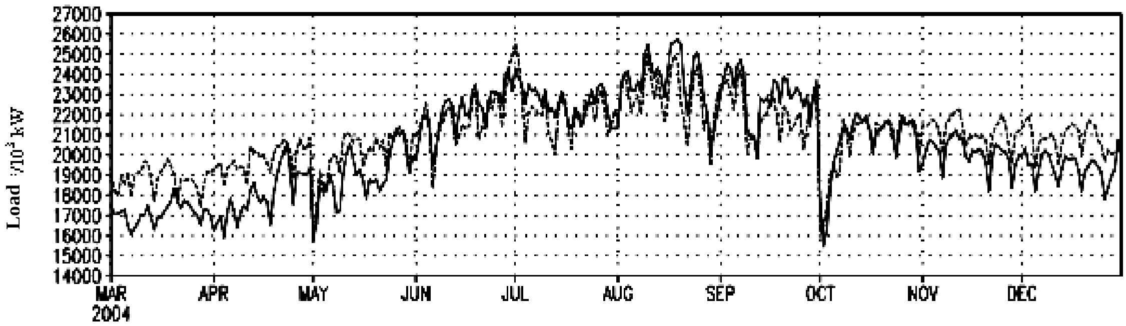

Fig.4 Daily power load predicted for 2004 in Guangdong.

economic development and rising of the living standard; Y_m is the part affected by weather and δ is the part affected by random factors. The last part is ignored here for it has only a small contribution to the power load.

Eight meteorological factors are selected. They are mean temperature (X_1), max. Temperature (X_2), min. temperature (X_3), relative humidity (X_4), wind speed (X_5), rainfall (X_6), cloud cover (X_7) and sunshine (X_8). With seasonal data from January 2002 to February 2004 that do not have linear tendency and public holidays (data for the winter of 2003 is removed for it was greatly affected by the outbreak of the SARS epidemic), optimum subsets, complex correlation coefficients and CSC values are determined. Then, following the principle of maximum CSC, optimum regression equations for individual seasons can be known (Tab.1). It shows that for the factors selected into the optimum regression equations, the number can be as few as three (spring and summer) and as many as seven (autumn and winter). Temperature factors (X_1, X_2, X_3) are found in all seasons, indicating that it is the primary factor affecting the power load in Guangdong.

The selected predictors are substituted into the regression equations presented above for individual seasons. Then the values of power load are substituted back in the equations to get the fitting value of Y_m. It is then added to the term of linear tendency of Y_t together with the effect of public holidays. The errors of the equations fitting are less than 6% relative to the prediction and both the fitting and prediction of power load are quite consistent with the peaks in summer, valleys during the Spring Festival, changes during the May Day and National Day holidays (Fig.4).

For analyses of other aspects, refer to the Chinese edition of the journal.

6 CONCLUSIONS

(1) Significant linear trend of daily power load is found in Guangdong province, with the minimum in the winter months of January and February, maximum in the summer months of June, July, August and September, and comparable spring and autumn.

(2) For the power load in Guangdong, there are quasi-weekly oscillations of 5 – 7 days, quasi-by-weekly oscillations of 10 – 20 days and seasonal oscillations of 30 – 60 days. They are mainly resulted from low-frequency oscillation of the atmosphere and the effect of weekends and public holidays.

(3) Temperature is the main meteorological factor affecting the power load in Guangdong, but varies slightly by season.

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