The Effect Analysis Based on Least Square Method on Meteorological Factors to Residential Electricity Consumption in Fujian Province

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Abstract. For the purpose of the effect analysis on meteorological factors to residential electricity consumption in Fujian Province, this article used the lowest, highest, and average temperatures and other meteorological factors from January 2019 to June 2019 to process the analysis, building the multiple nonlinear regression. And it also identified the abnormal data from the residual analysis on regression equation coefficients resulting from least square method. Data repair based on the identification was at last applied to testing regression results.

Keywords: the multiple nonlinear regression, residual analysis, least square method

Fujian ranked the 9th with 2313.8 hundred million kilowatt-hours total electricity consumption nationwide in 2018. Power load increase affects the economic development. It is of great significance to stabilize and increase economy by power load study and electricity demand forecasting precision increase. Electricity demand forecasting is the base of power system optimal dispatch, and forecasting precision affects economic development. [1]

1. The essentiality of residential electricity consumption
With the growth of economy and living standard, residential electricity is the important part of total electricity consumption. Take Fujian as an example, whose residential electricity accounts for 20% of the total electricity consumption, percentage hiking year-on-year. The results from the forecasting affects the work of power system dispatching, plan, marketing department and others. Influence factors to residential electricity are more than economic growth, climate and residential consumption index.

2. Influence of meteorology on Fujian residential electricity
Meteorological factors are one of the effects to residential electricity consumption. Mastering the effects especially those that caused by temperature gives references to power system dispatching and short-term consumption trend.[2]
Figure 1: Fujian residential electricity consumption per month

Figure 1 presented Fujian each month’s residential electricity consumption from January 2019 to June 2020. As the data showed, peak time of consumption matched the points when highest or lowest temperature occurred. The trend explained again, there is an important connection between electricity consumption and temperature which helps power dispatching a lot. (data from Process Data of Statistic Bureau of Fujian Province, and Meteorological Data from China Weather)

3. Temperature-residential electricity consumption-relation mathematical model

3.1 To build up the multiple nonlinear regression model

At first, draw the relation scatter diagrams between residential electricity consumption \( y \) and highest temperature \( x_1 \), between residential electricity consumption \( y \) and lowest temperature \( x_2 \), between residential electricity consumption \( y \) and average temperature \( x_3 \), respectively. As follows:

As the charts present, value of \( y \) increases obviously with the increase of \( x_1 \), \( x_2 \) and \( x_3 \). For the development was not linear, the secondary variable was introduced, \( x_1^2 \), \( x_2^2 \), \( x_3^2 \), \( x_1x_2 \), \( x_1x_3 \), \( x_2x_3 \)
Order respectively: \( x_1 = X_1, x_2 = X_2, x_3 = X_3, x_4 = X_4, x_5 = X_5, x_6 = X_6 \),
\( x_7 = X_7, x_8 = X_8, x_9 = X_9 \)
Therefore the relation that residential electricity consumption went with highest temperature, lowest temperature and average temperature was as
\[ y^* = b_0 + \sum_{j=1}^{9} b_j X_j \]

3.2 To obtain regression equation coefficients by use of the least square method
By use of the least square method, the regression coefficient was \( b_0, b_1, b_2, ..., b_9 \), then to make
\[ \left( \sum_{i=1}^{18} \left( y_i^* - y_i \right)^2 \right) \]
least, followed by solving the equation below
\[ Q(b_0, b_1, b_2, ..., b_9) = \sum_{i=1}^{18} \left( y_i^* - y_i \right)^2 = \sum_{i=1}^{18} \left( b_0 + \sum_{j=1}^{9} b_j X_{ij} - y_i \right)^2 \]
Find partial differential: \( [3] \)
\[ \frac{\partial Q}{\partial b_0} = 2 \sum_{i=1}^{18} \left( b_0 + \sum_{j=1}^{9} b_j X_{ij} - y_i \right) = 0 \]
\[ \frac{\partial Q}{\partial b_1} = 2 \sum_{i=1}^{18} \left( b_0 + \sum_{j=1}^{9} b_j X_{ij} - y_i \right) X_{ij} = 0 \]
\[ \vdots \]
\[ \frac{\partial Q}{\partial b_9} = 2 \sum_{i=1}^{18} \left( b_0 + \sum_{j=1}^{9} b_j X_{ij} - y_i \right) X_{ij} = 0 \]
Using MATLAB to regress, we had:

| Regression coefficients | \( b_0 = 139.8152 \), \( b_1 = 0.7079 \), \( b_2 = 0.0135 \), \( b_3 = 0.7530 \)  
|                         | \( b_4 = 0.3766 \), \( b_5 = -1.4769 \), \( b_6 = -0.2887 \), \( b_7 = -17.5826 \)  
|                         | \( b_8 = -5.6837 \), \( b_9 = 18.3212 \) |

The R-square statistic  \( r^2 = 0.9168 \)

the F statistic and p value for the full model,  \( p = 0.0019 < 0.05 \)

That was:  \( y^* = 139.8152 + 0.7079 X_1 + 0.0135 X_2 + 0.7530 X_3 + 0.3766 X_4 \)
\[ -1.4769 X_5 - 0.2887 X_6 - 17.5826 X_7 - 5.6837 X_8 + 18.3212 X_9 \]
After back substituting variables \( x_1, x_2, x_3 \), it was:
\[ y^* = 139.8152 + 0.7079 x_1^2 + 0.0135 x_2^2 + 0.7530 x_3^2 + 0.3766 x_1 x_2 - 1.4769 x_1 x_3 \]
\[ -0.2887 x_2 x_3 - 17.5826 x_1 - 5.6837 x_2 + 18.3212 x_3 \]

3.3 Residual analysis: regression model improvement
Draw residual plot: as followed
Average value of the before- and- after- two-time-point data was adopted to revise and eliminate abnormal data in Group 9. The new results were as followed:

Table 2 Regression adopted results

| Regression coefficients | $b_0 = 166.3896$, $b_1 = 0.7150$, $b_2 = 0.0551$, $b_3 = 0.7675$
|------------------------|----------------------------------|
| $b_4 = 0.3408$, $b_5 = -1.4226$, $b_6 = -0.3438$, $b_7 = -18.5214$, $b_8 = -4.2250$, $b_9 = 16.2364$ |

The R-square statistic $r^2 = 0.9502$

The F statistic and p value for the full model, $p = 0.0003 < 0.05$

Therefore, the function relation between residential electricity consumption $y$ and highest temperature $x_1$, lowest temperature $x_2$, average temperature $x_3$, was as followed:

$$y^* = 166.3896 + 0.7150x_1^2 + 0.0551x_2^2 + 0.7675x_3^2 + 0.3408x_1x_2 - 1.4226x_1x_3 - 0.3438x_2x_3 - 18.5214x_1 - 4.2250x_2 + 16.2364x_3$$

Residual plot
Fitting results are more reasonable after revision, with correlation coefficient $R^2$ closer to 1.

3.4 Data validation
As the example of Fujian, data of residential electricity consumption and meteorology from January 2019 to June 2020 were substituted into regression equation for validation, with the help of which graphic data of residential electricity consumption and fitting results came into being, as followed:

![Figure 5 Data of residential electricity consumption and fitting results](image)

Table 3 Error analysis

|                          | Absolute error | Relative error |
|--------------------------|----------------|----------------|
| Mean absolute error      | 0.85           | Mean relative error | 0.02   |
| Maximum absolute error   | 2.54           | Maximum relative error | 0.07   |
| Minimum absolute error   | 0.05           | Minimum relative error | 0.00   |
| absolute error variance  | 0.40           | relative error variance | 0.00   |
| Absolute error standard difference | 0.63 | relative error standard difference | 0.02 |

According to the table above, use of regression equation produced only 2% relative error, 7% maximum relative error, which are in the reasonable range, compared to actual data. Furtherly it tested the reasonability of the regression equation, which is valuable to practical application.

4. Conclusion
Forecasting of residential electricity consumption plays an important role in power dispatching and electricity security. There is a close connection between residential electricity consumption and meteorological factors especially temperature in winter or summer when the high frequency air conditioner or heating or warming appliance are involved.

References
[1] Lin Lin, Ju Sen, Yu Lijie, Research on ultra-short-term prediction of residential electricity consumption[J], Electronic Measurement Technology, 2019(5), 98-101
[2] Liu Yu, Interaction between urban Micro Weather and power air conditioning load in high temperature season[D], Hu Nan, Hunan University, 2012, 10-13
[3] He Yongxiu, Wang Yue-in, Yang Lifang, He Haiying, Luo Tao, Research on residential electricity prediction based on the least squares support vector machine[J], POWER DSM, 2010(5)19-23