Electricity Demand Prediction of Beijing during the 13th Five-year

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Abstract: With the emergence of a “new economic norm” and the development of “economic integration in Beijing, Tianjin and Hebei”, electricity demand situation in Beijing will change significantly in the future. To guide the planning and construction of power grid in Beijing, it is indispensable to predict electricity demand during the 13th Five-year. Since the factors and affecting mechanisms for electricity demand are different in different sectors, the total electricity consumption in this paper is divided into five parts: the first industry, industry, construction industry, the tertiary industry and resident sectors. The exponential smoothing method and co-integration theory are introduced to establish the forecasting model of electricity demand in different sectors. Therefore, based on the forecasting model and scenario analysis, the analysis results show that the total electricity consumption will grow at an annual rate of 4.9%-6.0% during 13th Five-Year-Plan period, and the consumption would reach more than 0.1397×1012 kWh in 2020.

Keywords: Electricity demand, forecasting, subsectors, Exponential smoothing method, co-integration theory

1. Introduction

Electricity production and supply, as the foundation of national economy, provides an essential condition for economic and social development, and the improvement of living standard. The incompatibility between electric industry and economic development may put negative impact on the national economy and people’s life[1-2]. Therefore, in the electric power market, the balance of demand and supply is one of the most important problem attracting stakeholders from many aspects. Meanwhile, with the emergence of a “new economic norm” and the development of “economic integration in Beijing, Tianjin and Hebei”, the electricity demand situation in Beijing will change significantly in the future. [3]. On this basis, combing the economic development planning and the goal of economic structure adjustment, the electricity demand in Beijing during 13th Five-Year-Plan period is important to ensure the harmonious development between electricity industry and economy development [4].

In order to fully reflect the characteristics of each industry and the effect of the economic structure adjustment, the whole society electricity demand in this paper is divided into five parts: the first industry, industry, construction industry, the tertiary industry and resident sectors. According to the influencing factors of each sector for electricity demand, the demand forecasting model of each sector is establish. In addition, the whole society electricity demand equates to the sum of the demand of five sectors. The whole society electricity demand based on subsectors can fully consider the influencing factors in different sector respectively, which can better control the prediction error and make the prediction more accurate.

2. Research Methods

2.1. Exponential Smoothing Method

Exponential smoothing is one of time series prediction method which has been used widely. It combines the advantages of period average and moving average. This method does not discard the past data, which gradually weakened the influence of the past date, through the adjustment coefficients[5-6]. Exponential smoothing method can be divided into three categories: Single Exponential Smoothing, Double Exponential Smoothing and Holt-Winters. Different models can realize the prediction of
different types of time series. In this paper, the Holt-Winters
method is used to forecast the electricity demand of the first
industry in Beijing.

The Holt-Winters method is similar with Double
Exponential Smoothing, which is suitable to predict the time
series with linear trend. The Holt-Winters method contains
of two smoothing coefficient, namely \( \alpha \) and \( \beta \) \((0 \leq \alpha, \beta \leq 1)\). The
time series after smoothing \( \hat{y}_{i} \) is shown as follows:

\[
\hat{y}_{i} = a_{i} + b_{i} \tau, \tau = 1, 2, 3 \cdots
\]  

(1)

Where, \( a_{i} \) represents the intercept and \( b_{i} \) represents the slope,
which are calculated based on the exponential smoothing.

The forecasting model based on the Holt-Winters method
can be expressed as follows:

\[
\hat{y}_{i+\tau} = a_{i} + b_{i} \tau, \tau = 1, 2, 3 \cdots
\]  

(2)

Where, \( T \) is the last data of the time series and \( \tau \) is the
predict cycles.

2.2. The Basic theory of co-Integration Theory

Co-integration was firstly put forward by Granger in 1981.
In this theory, if the linear combination of non-stationary
time series is stable, there must be a co-integration
relationship among these variables, namely these variables
keep a long-term equilibrium relationship each other. Since
the time series of economic and electric indicators are always
not smooth, the co-integration theory is put forward to
analyze the relationship between electricity demand and
economic development in Beijing. Based on the Stationarity
test and Johansen test, a long-term equilibrium model would
be established to analyze the relationship between electricity
demand economy. The specific steps are shown as follows:

(1) Stationarity test[7]

The ADF unit root test is a common method used to test
the stability of a time series. The time series variable model
is established as follows:

\[
\Delta y_{t} = \alpha + \beta y_{t-1} + \sum_{i=1}^{p} \beta_{i}\Delta y_{t-i} + \epsilon_{t}
\]  

(3)

Where, \( \alpha \) is constant, \( t \) is trend term, \( p \) is the optimal
lag order number, \( \epsilon_{t} \) is random error term. For a given
significance level, when the ADF test value is less than the
critical value, the time series is stable.

(2) Co-integration test[8]

Co-integration can be expressed as follows: if \( y_{t-1}^{d} \)
namely \( y_{t} \) becomes stationary after \( d \) times differencing,
there must exist \( \alpha = [\alpha_{1}, \alpha_{2}, \ldots, \alpha_{d}] \) makes

\[
Z_{t} = \alpha X_{t}^{d} \sim I(d - b) \quad (b > 0).
\]

On this basis, \( X_{1}, X_{2}, \ldots, X_{d} \) is co-integration of \( (d, b) \) order,
namely \( X_{t} \sim C_{l}(d, b) \), and \( \alpha \) co-integrated vector.

The JJ (Johansen and Juselius) co-integration test is always
used to test the co-integration for multiple variables. There
are two ways to test the co-integration: TRACE and MAX
are commonly two output results in this test.

3. Forecasting Model of Electricity
Demand in Each Sector

(1) The prediction model of electricity demand for the first
industry

The first industrial electricity consumption accounts for
less, and the influencing factors are unstable. Therefore, the
time series method is more suitable then the structural model
to forecast the electricity demand of the first industry, namely
the exponential smoothing method is adopted to infer the first
industrial utilization situation based on the past information.

(2) The prediction model of electricity demand for industry

Considering the characters of the industry production, the
value-added of industry (GDPg), industrial proportion of
heavy industry (Mz), electricity consumption intensity of the
industry (Eg) are the key factors affecting the electricity
demand of the industry electricity demand\((Q_{g})\) [9-10].
Therefore, based on the unit root test and co-integration test
of these four factors, the forecasting model is established as follows:

\[
\ln Q_{g} = 0.9955 \ln GDPg + 5.1338 \ln Eg - 2.8214
\]  

(4)

Since the coefficients of above forecasting model has been
through the inspection, there is a long-term equilibrium
correlation among\( \ln Q_{g} \), GDPg, Mz and Eg. From the
perspective of long-term equilibrium, when the added-value
industry increases 1%, the electricity demand increase
0.9955%; when industrial proportion of heavy industry
increase 1%, the electricity demand increases 0.033%; when
electricity consumption intensity of industry increases
1kWh/ten thousand yuan, the electricity demand increases
0.51338%.

(3) The prediction model of electricity demand for the
construction industry

The value-added of construction industry\(( GDPj)\),
construction power efficiency\((Ej)\) are the key factors
affecting the electricity demand of the construction industry
electricity demand\((Qj)\) [11]. Therefore, based on the unit
root test and co-integration test of these four factors, the
forecasting model is established as follows:

\[
\ln Q_{j} = 0.98 \ln GDPj - 0.04 \ln Efj - 1.96
\]  

(5)

Since the coefficients of above forecasting model has been
through the inspection, there is a long-term equilibrium
correlation among\( \ln Q_{j} \), GDPj and Ef. From the
perspective of long-term equilibrium, when the added-value
of construction industry increases 1%, the electricity demand increases 0.98%; when construction power efficiency increases 1%, the electricity demand decreases 0.04%.

(4) The prediction model of electricity demand for the tertiary industry

The value-added of the tertiary industry (GDP3), the level of the resident consumes (RCL) are the key factors affecting the electricity demand of the tertiary industry electricity demand (Q3)[12]. Therefore, based on the unit root test and co-integration test of these four factors, the forecasting model is established as follows:

\[
\ln Q3 = -3.9880 + 0.9991 \ln GDP3 + 19.2356E3
\]

Since the coefficients of above forecasting model has been through the inspection, there is a long-term equilibrium correlation among \( \ln Q3 \) and \( \ln GDP3 \). From the perspective of long-term equilibrium, when the added-value of tertiary industry increases 1%, the electricity demand increases 0.37%; when the level of the resident consumes increases 1%, the electricity demand increases 0.62%.

(5) The prediction model of electricity demand for the resident sector

The households (H), the level of the resident consumes (RCL), and the maximum temperature (HT) are the key factors affecting the electricity demand of the resident sector electricity demand (Qp) [13]. Therefore, based on the unit root test and co-integration test of these four factors, the forecasting model is established as follows:

\[
Qp = 0.39H + 0.003RCL + 0.67HT - 165.08
\]

Since the coefficients of above forecasting model has been through the inspection, there is a long-term equilibrium correlation among \( Qp \), \( RCL \), \( H \), and \( HT \). From the perspective of long-term equilibrium, when the households increase 1 unit, the electricity demand of resident sector increases 0.39%; when the level of the resident consumes increase 1 unit, the electricity demand of resident sector increases 0.003%; when the maximum temperature increase 1 unit, the electricity demand of resident sector increases 0.67%.

4. Forecasting the Electricity Demand of Each Sector in Hebei Province

4.1. The Development Situation of each Influencing Factors

According to the development planning of different sectors, the development situations of each influencing factors during the 13th Five-Year-Plan are shown as follows:

<table>
<thead>
<tr>
<th>Influencing factors</th>
<th>Year</th>
<th>Low situation</th>
<th>High situation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Industrial added value growth rate</td>
<td>2014-2020</td>
<td>5.00%</td>
<td>6.00%</td>
</tr>
<tr>
<td>Construction industrial added value growth rate</td>
<td>2014-2020</td>
<td>11.00%</td>
<td>12.00%</td>
</tr>
<tr>
<td>Tertiary industry added value growth rate</td>
<td>2014-2020</td>
<td>6.00%</td>
<td>7.00%</td>
</tr>
<tr>
<td>Growth rate of industry power consumption for per unit</td>
<td>2014-2020</td>
<td>-2.00%</td>
<td>-2.00%</td>
</tr>
<tr>
<td>Growth rate of power efficiency for construction industry</td>
<td>2014-2020</td>
<td>-2.00%</td>
<td>-2.00%</td>
</tr>
<tr>
<td>Level of the resident consumes</td>
<td>2014-2020</td>
<td>6.00%</td>
<td>7.00%</td>
</tr>
<tr>
<td>Growth rate of households</td>
<td>2014-2020</td>
<td>0.08%</td>
<td>0.10%</td>
</tr>
<tr>
<td>The highest temperature</td>
<td>2014-2020</td>
<td>38.2 c</td>
<td>38.2 c</td>
</tr>
</tbody>
</table>

4.2. The Forecasting Results of Electricity Demand in Each Sector

According to each industry and residents electricity consumption forecasting model, and the development situations, the various industries and residential electricity demand are calculated. The detail results are shown in the table6.

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>2015</th>
<th>2020</th>
<th>Average annual growth rate during 13th Five-year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Added-value (One hundred million yuan)</td>
<td>2015</td>
<td>2020</td>
<td>2015</td>
</tr>
<tr>
<td>Industry</td>
<td>2384.73</td>
<td>2453.52</td>
<td>3043.59</td>
</tr>
<tr>
<td>Construction industry</td>
<td>1018.15</td>
<td>1074.70</td>
<td>1639.74</td>
</tr>
<tr>
<td>Tertiary industry</td>
<td>10180.99</td>
<td>10471.86</td>
<td>13624.46</td>
</tr>
<tr>
<td>Electricity demand (million kWh)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First industry</td>
<td>22.52</td>
<td>22.52</td>
<td>31.49</td>
</tr>
<tr>
<td>Industry</td>
<td>337.41</td>
<td>367.83</td>
<td>402.22</td>
</tr>
<tr>
<td>Construction industry</td>
<td>27.18</td>
<td>28.66</td>
<td>40.11</td>
</tr>
<tr>
<td>Tertiary industry</td>
<td>447.44</td>
<td>460.02</td>
<td>596.09</td>
</tr>
<tr>
<td>Residents demand</td>
<td>178.27</td>
<td>185.71</td>
<td>218.00</td>
</tr>
<tr>
<td>Whole society electricity demand</td>
<td>1012.83</td>
<td>1064.75</td>
<td>1287.91</td>
</tr>
</tbody>
</table>
basis, the whole electricity demand in Beijing would during the 13th Five-year period, the electricity demand situation, in order to guarantee plentiful electricity supply investment and construction. Therefore, under the current improvement.

The characteristics of whole society electricity demand in Beijing during the 13th five-year can be obtained based on the analyzed results of five sectors:

1) The whole electricity demand will grow with a middle-low speed.

With the appearance of “new normal” and development of integration of Beijing-Tianjin-Hebei region, a large scale of industrial enterprises would be shift to other places, which will decrease the growth rate of electricity demand of industry. Moreover, with the strengthening of the energy saving and emission reduction in Beijing, the electricity consumption intensity decreased obviously. Therefore, on the basis, the whole electricity demand in Beijing would continue increasing with a middle-low speed. According to the forecasting results of electricity demand, the growth rate of the whole electricity demand would be 4.90%-6.00%, which will decline 1.5% comparing the rate in the growth rate during the 12th five-year.

(3) The electricity demand structure will change.

The integration of Beijing-Tianjin-Hebei region would transfer industries without capital function to other places. Therefore, the heavy industry enterprises and low-end services industry will be shifted. With the adjusting and optimizing of economic structure, the electricity demand structure would change. In the period of 13th five-year, although the demand structure will keep the mode of “third, second, first”, the proportion of the demand for tertiary industry will gradually rise, and the proportion of the second industry will decline. Meanwhile, the proportion of the first industry will keep stable proportion.

Acknowledgments

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5. Conclusion

Since the period between construction and production for the electricity project is very long, it is indispensable to make an accurate prediction for guiding a scientific planning, investment and construction. Therefore, under the current situation, in order to guarantee plentiful electricity supply during the 13th Five-year period, the electricity demand should be predicted exactly in Beijing, which is meaningful to promote the economic development and life standard improvement.

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Table 3. Prediction results of economic structure and electricity demand structure

<table>
<thead>
<tr>
<th>Scenarios</th>
<th>2015</th>
<th></th>
<th>2020</th>
<th></th>
<th>Annual proportion during 13th Five-year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Development speed</td>
<td>High development speed</td>
<td>Low Development speed</td>
<td>High development speed</td>
<td>Low Development speed</td>
</tr>
<tr>
<td>Proportion of industry electricity demand in the whole society demand (%)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First industry</td>
<td>2.22%</td>
<td>2.16%</td>
<td>2.45%</td>
<td>2.25%</td>
<td>2.36%</td>
</tr>
<tr>
<td>Industry</td>
<td>36.00%</td>
<td>35.99%</td>
<td>34.35%</td>
<td>34.35%</td>
<td>35.00%</td>
</tr>
<tr>
<td>Construction industry</td>
<td>44.18%</td>
<td>44.06%</td>
<td>46.28%</td>
<td>45.94%</td>
<td>45.46%</td>
</tr>
<tr>
<td>Tertiary industry</td>
<td>17.60%</td>
<td>17.79%</td>
<td>16.93%</td>
<td>17.46%</td>
<td>17.18%</td>
</tr>
<tr>
<td>Residents demand</td>
<td>2.22%</td>
<td>2.16%</td>
<td>2.45%</td>
<td>2.25%</td>
<td>2.36%</td>
</tr>
</tbody>
</table>

References


