Study on Electricity Business Expansion and Electricity Sales Based on Seasonal Adjustment

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Abstract. [1] proposed a novel analysis and forecast method of electricity business expansion based on Seasonal Adjustment, we extend this work to include the effect the micro and macro aspects, respectively. From micro aspect, we introduce the concept of load factor to forecast the stable value of electricity consumption of single new consumer after the installation of new capacity of the high-voltage transformer. From macro aspects, considering the growth of business expanding is also stimulated by the growth of electricity sales, it is necessary to analyse the antecedent relationship between business expanding and electricity sales. First, forecast electricity consumption of customer group and release rules of expanding capacity, respectively. Second, contrast the degree of fitting and prediction accuracy to find out the antecedence relationship and analyse the reason. Also, it can be used as a contrast to observe the influence of customer group in different ranges on the prediction precision. Finally, Simulation results indicate that the proposed method is accurate to help determine the value of expanding capacity and electricity consumption.

1. Introduction
As an important part of the Power Grid Company marketing business, business expanding can lead the future trends of electric selling market. With the economic development, the electricity sales and expanding electricity capacity are increasing yearly [2]. Also, the instinct advancement and uncertainty of business expansion pose challenges to forecasting method and technology. Therefore, improve the prediction accuracy and explore the antecedent relationship between business expanding capacity and electricity sales are key factors for marketing operations.

The relevant literature on electricity business expansion mainly focuses on the Long-term planning, including the perfection of management institutional and the improvement of the electricity market policy formulation [3], the entire process from customers’ applications of electricity consumption to the electricity is supplied to them [4-5], the formulation of business expansion decision-making [6], and the improvements in speed and service quality of electricity supply [7]. In [8], the author proposes a load forecast method which can improve the expansion accuracy of the electricity business in the next three years to five years, but it failed to suitable for the monthly analysis is not available. However, the marketing department of power Grid Company on utilisation ratio of electricity business
expansion data is still relatively lower. Few articles further study the antecedent relationship between the expanding electricity and electricity consumption on prediction method, mathematical model and optimisation algorithms [9]. In [10], author analyses the consumption speed of the monthly electric quantity of the entire industry since their electricity is supplied. However, the newly installed capacity is underutilised, a lot of the capacity has not completely converted into the electricity consumption’ growth. In [11], the author proposes modelling approach to forecast electricity business expanding capacity and electricity consumption of the entire society, but it does not consider the growth of business expanding is also stimulated by the growth of electricity sales. In [12], authors discuss the current situation and problems of the newly installed capacity of wind turbines in China, but they failed to provide detailed solutions.

This paper extends previous work to include the effect the micro and macro aspects, respectively. From micro aspect, this paper adopts load factor to forecast the stable value of electricity consumption of a single consumer after the installation of new capacity of High-Voltage Transformer (HVT). From macro aspects, this paper analyses the antecedent relationship between business expanding and electricity sales based on Seasonal Adjustment (SA). We select the data of electricity expanding capacity and electricity sales of Shandong Power Grid Company as the test evidence. Simulation results indicate that the proposed method is accurate to help determine the value of expanding capacity and electricity consumption.

The remainder of this paper is organised as follows. In Section II, we propose the method and theory of electricity business expansion. In Section III, we design the calculating programs for the stable electricity consumption forecasting of consumers after the installation of the new capacity of HVT and the antecedence of business expanding and electricity sales. In Section IV, analyse simulation results. Finally, conclusions are drawn in Section V.

2. Theory and Method

Because of the newly installed capacity will not be fully utilised, a lot of the capacity has not completely converted into the electricity consumption growth. It will increase the difficulty to forecast the electricity consumption of the single new customer before it reaching a stable state. To solve this problem, we introduce the concept of Load Factor (LF). The load factor in a power system refers to the ratio of the actual electricity consumption to the maximum demand of the equipment, and assume that it is continuously utilised within a given period. Without considering the time effect, the load factor is calculated from the ratio of the average load in a given time to the maximum value [13]. Therefore, the load factor of the customer group can be calculated as follows.

\[ F = \frac{\sum_{i=3}^{\Delta Q} (\sum_{i=3}^{E_{new}} \times 24 \times 30)}{\sum_{i=3}^{E_{new}} \times 24 \times 30} \]

(1)

Where, \( F \) is the load factor of the customer group, \( \Delta Q \) is the change of electricity consumption of the customer in twelve months after the installation of new capacity, \( E_{new} \) is the newly installed capacity of customers, \( S \) includes all typical customers of the customer group who have finished the high-voltage newly business.

The load factor varies with different customer groups. For a closer customer type to the customer group, (2) is more suitable to calculate the load factor change of the new customer. For the new customer who needs to install the capacity of HV thermal power (units), his change in load factor is

\[ F = \frac{\Delta Q}{E_{new} \times 24 \times 30} \]

(2)

The electricity consumption of the customer in 12 months after the installation of new capacity when his electricity consumption reaches a stable state can be obtained by calculating \( F \times E_{new} \).

3. Designing and Calculating Program

3.1. Stable Electricity Consumption Forecasting of Consumers after The Installation of the New Capacity of HVT
Based on [1], we adopt load factor to forecast the stable value of electricity consumption of consumers after the installation of the new capacity of HVT. First, the change value of load rate of the customer group can be derived according to the electricity consumption of the typical customer and newly installed capacity. Then, calculate the stable value that the electricity consumption of new customer can achieve according to the newly installed capacity of HVT customer. The flow chart of the stable electricity consumption forecasting of consumers after the installation of the new capacity of HVT is shown in Figure 1.

![Flow chart of the stable electricity consumption forecasting of consumers after the installation of the new capacity of HVT](image)

**Figure 1.** Flow chart of the stable electricity consumption forecasting of consumers after the installation of the new capacity of HVT.

**Figure 2.** The release rules of the newly installed capacity of HVT.

**Figure 3.** Flow charts of electricity sales forecast.

3.2. The Antecedent Relationship between Business Expanding and Electricity Sales

To explore the antecedent relationship between business expanding and electricity sales, we use electricity sales to forecast expanding capacity, and the corresponding flow chart is shown in Figure 2. Conversely, we use expanding capacity to forecast electricity sales, and the corresponding calculation program is shown in Figure 3.

4. Simulation Results

We use the same data in [1] as the test example, and we analyse these data from two aspects: the stable value of electricity consumption forecasting of consumers after the installation of new capacity of HTV, and the antecedent relationship between business expanding and electricity sales.

4.1. Stable Electricity Consumption Forecasting of Consumers after the Installation of New Capacity of HVT.

Because different industry subdivision of different cities significantly affects the load factor, the customer group must be classified. Therefore, in this section, we select the manufacturing industry of large-scale industrial electricity in A city of Shandong province as customer group. First, we screen out all the typical customers who have applied for the high-voltage newly installed business during May 2011 - May 2014. Then, we input the time series data of the monthly electricity consumption of all customers after season adjustment. Finally, we only retain their TC to eliminate the effect of seasonal changes and random factors in the releasing process of expanding capacity.

The data in the TC of electricity consumption that does not conform to the law of the growth curve is eliminated. Namely, the time series that corresponds to the TC of electricity consumption of the typical customers is selected, and the TC is sustainable growth after the installation of new capacity.
We record the electricity consumption of 12 months and take them as the electricity consumption change value $\Delta Q$ and the corresponding newly installed capacity $E_{\text{new}}$ of the customers who have applied for the high-voltage newly business.

The consumption of the newly installed electricity of some customers is not increasing month by month in the initial stages, but it decreases after several months, and finally it steadily recovers following the approximate growth curve. A possible reason is that the customer is affected by other factors (such as policy changes, economic factors, weather, et al.) during the commissioning period, and leads them to cut production temporarily. The capacity will return to the state of normal growth after the commissioning phase. Figure 4 illustrates the electricity consumption of the typical customer belonging to the research customer group. Although the initial power electricity consumption growth is not zero, it can be calculated according to the monthly electricity consumption with increasing values in terms of time series. Thus, the electricity consumption change value $\Delta Q$ of the customer is

$$\Delta Q = Q_3 - Q_0 = 247.25 - 41.15 = 206.10 \text{(10^4 kWh)}$$

Because this type of customers encounter temporary difficulties after the installation of new capacity when the difficulties are solved, the electricity consumption growth trends are similar to the electricity supply during the initial period. Hence, this type of customers should be retained, and the time series should be separately normalised. Thus, we can avoid eliminating large customers of the newly installed larger capacity units, and improve the accuracy of calculation results.

The load factor of the customer group according to (1) is $F = 41.76\%$

If there is a typical customer with newly installed transformer capacity of 400kVA in the customer group, his electricity consumption after it reaches a stable state can be obtained using (2), and the TC of the electricity consumption can reach the following value.

$$\Delta Q = F \times E_{\text{new}} = 41.76\% \times 400 \times 24 \times 30 = 120260.1 \text{(kWh)}$$

The TC of the actual electricity consumption after it reaches a stable state is $Q = 124995.7 \text{(kWh)}$. Therefore, the calculation error of the electricity consumption forecast using the proposed method is

$$\sigma = (Q - \Delta Q) / Q = (124995.7 - 120260.1) / 124995.7 = 3.79\%$$

The calculation error is less than 4%. So the forecasting results are more accurate.

Finally, the growth rule of electricity consumption of the customer group [1] is applied to the new customer, and the change of electricity consumption is calculated according to the percentage of stable electricity consumption per month after electricity is supplied. The results are shown in Table 1.

**Table 1. Changes in electricity consumption of the new customer**

| Month | Forecasting electricity | Actual electricity | Calculation error |
|-------|-------------------------|-------------------|------------------|
| 1     | 13769.78                | 14626.41          | 5.86%            |
| 2     | 19229.59                | 20767.2           | 7.40%            |
| 3     | 26373.04                | 27609.21          | 4.48%            |
| 4     | 35392.54                | 33954.28          | 4.24%            |
| 5     | 46191.9                 | 43279.2           | 6.73%            |
| 6     | 58398.3                 | 55378.59          | 5.45%            |
| 7     | 71290.18                | 67728             | 5.26%            |
| 8     | 83989.64                | 79312.76          | 5.90%            |
| 9     | 95654.87                | 90834.59          | 5.31%            |
| 10    | 105696.6                | 101212.5          | 4.43%            |
| 11    | 113886.3                | 111042.2          | 2.56%            |
| 12    | 120260.1                | 124995.7          | 3.79%            |

As shown in Table 1, the calculation error is less than 6% except in May. So you can see that the proposed method can accurately predict the growth rule of the electricity consumption of new customer after he is supplied electricity from the newly installed HVT.
4.2. The Antecedence of Business Expanding and Electricity Sales
Considering electricity sales is also one of the main influence factors of electricity business expansion. So it is necessary to analyse the antecedent relationship between business expanding and electricity sales. First, forecast electricity consumption of customer group and expanding capacity, respectively. Second, contrast the degree of fitting and prediction accuracy to find out the antecedence and analyse the reason. It can also contrast the electricity sales forecasting accuracy in a different range of customer groups.

4.2.1 Expanding capacities forecasting based on electricity sales. Take D city with the maximal proportion of monthly expanding capacity as an example. We use the expanding capacity to forecast the electricity sales. Similarly, the same method to forecast expanding capacity based on electricity sales. First, the monthly expanding capacity and electricity sales are statistically analysed to obtain the time series ED and QD, respectively. Then, the seasonal adjustment proposed in [1] is performed to obtain the two trend cycles ED-TC and QD-TC, two seasonal factor ED-SF and QD-SF, and the irregular component ED-IR and QD-IR, as shown in Figure 5 and Figure 6.

We use the Grey Correlation Analysis (GCA) method to calculate the Correlation Degree (CD) of these two trend cycles, and the CD reaches peaks when the trend cycle of electricity sales lags for two months, as show in Table 2. Compares with the CD of the entire industry mentioned in [1], this correlation degree is smaller as the scope of customers group become smaller. It also can be seen from Figure 7 and Figure 8, both the TCs of expanding capacity and electricity sales appear obvious fluctuations for many times, so the correlation is decreased obviously.

Table 2. Correlation degree of TCs. of expanding capacity and electricity sales in D city

| Month | CD  |
|-------|-----|
|       | -3  | -2  | -1  | 0   | 1   | 2   |
|       | 0.623| 0.614| 0.604| 0.582| 0.572| 0.601|

The regression analysis is carried out with $QD_{TC}(0)$ as the independent variable and $ED_{TC}(2)$ as the dependent variable, and the formula (6) can be obtained by selecting the inverse function curve with the highest degree of fitting, the degree of fitting of the regression model is $R^2 = 0.503$, so it can be used to fit the relationship between two variables. The Sig. of F test is 0, which is smaller than 0.05, so the result is significant.

$$ED_{TC} = 9.454 - 1.53 \times 10^6 / QD_{TC}(2)$$ (6)

The forecast values of the expanding capacity of D city can be obtained by adding the seasonal factor to the fitted values of trend cycle of the expanding capacity of D city. Then, compare forecast values with the actual values, the results are shown in Figure 7. The expanding capacity obtained by adopting the above fitting method on Aus. 2014 is 97,400 kWh, the actual expanding capacity is 123,900 kWh, and the difference is 21.39%. Visibly, the prediction error is bigger, so the proposed method is not very well to complete the prediction of expanding capacity.
Also, as seen from figure 7, the CD of two curves is not high, but their turning point is consistent, which illustrates that it is basic feasible using the electricity sales to forecast the turning point of expanding capacity. However, electricity sales are not the decisive factor for forecasting expanding capacity as expanding capacity has high randomness. The random factors obviously influence on expanding capacity, so it is difficult to forecast the total expanding capacity.

\[ QD_{TC} = 0.103ED_{TC(5)}^3 - 35.09ED_{TC(5)}^2 + 3256ED_{TC(5)} + 190800 \]  

(7)

The forecast values of electricity sales of D city can be obtained by adding the seasonal factor to the fitted values of the trend cycle of electricity sales of D city. Then, compare forecast values with actual values, the results are shown in Figure 8. The electricity sales obtained by adopting the above fitting method in Aus. 2014 is 2,460,000 kWh, the actual expanding capacity is 2,490,000 kWh, and the difference is 1.25%. Although the CD of two curves is not high, the turning point is consistent. Also, the formula (7) is derived from fitting data of all the months, and use it to forecast TC of electricity sales in Aus. 2014. So it is acceptable although the coincidence degree is not high enough.

4.2.2 Electricity sales forecasting based on expanding capacity. On the other hand, we uses expanding capacity to forecast electricity sales. The CD of these two trend cycles can be obtained using GCA method, and the correlation degree reaches peaks when the trend cycle of electricity sales lags for five months. As shown in Table 3.

**Table 3. Correlation degree of TCs of expanding capacity and electricity sales in D city**

| Month | -1 | 0  | 1  | 2  | 3  | 4  | 5  | 6  |
|-------|----|----|----|----|----|----|----|----|
| CD    | 0.572 | 0.582 | 0.604 | 0.614 | 0.623 | 0.653 | 0.672 | 0.667 |

Similarly, the regression analysis is carried out with \( ED_{TC}(5) \) as the independent variable and \( QD_{TC}(0) \) as the dependent variable, and the formula (7) can be obtained by selecting cubic curve with the highest degree of fitting. The degree of fitting of the regression model is \( R^2 = 0.503 \), so it can fit the relationship between two variables better. The Sig. of F test is 0, which is smaller than 0.05, so the result is significant.

The forecast values of electricity sales of D city can be obtained by adding the seasonal factor to the fitted values of the trend cycle of electricity sales of D city. Then, compare forecast values with actual values, the results are shown in Figure 8. The electricity sales obtained by adopting the above fitting method in Aus. 2014 is 2,460,000 kWh, the actual expanding capacity is 2,490,000 kWh, and the difference is 1.25%. Although the CD of two curves is not high, the turning point is consistent. Also, the formula (7) is derived from fitting data of all the months, and use it to forecast TC of electricity sales in Aus. 2014. So it is acceptable although the coincidence degree is not high enough.

Unlike the example analysis in [1], this paper analyses the customer group of D city rather than the entire industry, it can be used as a contrast to observe the influence of customer group in different ranges on the prediction precision. It can be seen that the fluctuations of TC of customer group increase with the decrease of customer group range, this means that if you need more precision analysis, the fluctuations of expanding capacity will be more visible.

Compares the above two parts, it can be seen that the effect of using expanding capacity to forecast electricity sales is more obvious than using the electricity sales to forecast expanding capacity. It not only reflects on the prediction precision but also on the correlation degree. The correlation degree of trend cycles of expanding capacity and electricity sales is obvious high when electricity sales forecasting is lagging expanding capacity, and the correlation degree reaches peaks when trend cycle of electricity sales lags for five months, which reflects that electricity sales’ change lags expanding
capacity for about five months. In contrast, the stimulation of electricity sales’ growth for expanding capacity is a long-term process. Also, because of the construction process, it will take at least several months for electricity supply after customers submit their application to Power Supply Company. Under the limitation of the amount of existing data, if the seasonal adjustment is implemented to forecast electricity sales lagging expanding capacity, it will need at least three years of data. On the contrary, if the seasonal adjustment is implemented to forecast expanding capacity lagging electricity sales, it will need about one year of data. This leads to the overlapping time less than three years. Thus the analysis result may be not accurate. If you want to analyse further the stimulation effect of electricity sales’ growth on expanding capacity, it will be necessary to adopt other method or collect earlier data of business expanding. Therefore, business expanding is the antecedent indicator for electricity sales, it can use the change of expanding capacity to better analyse the potential change of future electricity sales market structure and the potential growth points of electricity sales

5. Conclusions
This paper explores the correlativity between expanding electricity capacity and electricity sales from the micro and macro aspects, respectively.

From micro aspects, we introduce the concept of load factor to forecast the stable value of electricity consumption of consumers after the installation of the new capacity of HVT. The simulation results show that the load factor method can accurately predict the growth rule of the electricity consumption of a newly installed HVT customer after electricity transmission.

From macro aspects, considering the growth of business expanding is also stimulated by the growth of electricity sales, we analyse the antecedent relationship between business expanding and electricity sales from two aspects: using expanding capacity to forecast electricity sales and using electricity sales to forecast expanding capacity. The simulation results prove that the effect of using expanding capacity to forecast electricity sales is more obvious than using electricity sales to forecast expanding capacity. Therefore, business expanding is the antecedent indicator for electricity sales, we can use the change of expanding capacity to better analyse the potential change of future electricity sales market structure and the potential growth points of electricity sales

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