Prediction and analysis of smart substation equipment prices based on the assumption of "adaptive expectations"

Ming Fang *, Yi Liang

Guangzhou Power Supply Bureau of Guangdong Grid Co Guangzhou, China

* Corresponding Author Email: 25238188@qq.com

Abstract. Based on the actual situation of the development of smart substations in my country, the assumption of "adaptive expectations" and the relevant engineering cost theory, this paper analyzes the influencing factors of the equipment prices of smart substations, and uses the equipment price volatility as the benchmark to distinguish the different volatility conditions, adopting different forecasting methods to analyze the price change trend of smart substation equipment to improve the accuracy of forecasting prices. Finally, the hypothesis proposed in this paper is verified, and the price of smart substation equipment is most affected by technology and payback period, resulting in an overall stable price level.

Keywords: Smart substation; equipment price; adaptive expectation; technical factor; price prediction model

1. Introduction

Smart grid construction is a grid development method adopted to adapt to current and future social development according to the regional distribution characteristics of regional energy distribution and load consumption. Large-scale and efficient allocation of resources. The construction of China's smart grid has risen to the height of the national strategic level. From 2021 to 2025, the market demand capacity of China's smart substations is about 158.112 billion yuan, which is huge.

In terms of research literature, Liu Gang et al. [3] predicted the cost of power grid engineering equipment materials, selected multiple primary selection models from the preset model library, and selected at least one of the multiple primary selection models according to multiple preset indicators. A final selection model, judging whether the number of the at least one final selection model is greater than 1, and using the at least one final selection model to perform equal-weight combined calculation to obtain comprehensive price parameters of equipment and materials. Compared with the traditional price statistics method, the generated price parameter results are relatively more accurate, but the prediction method does not consider the impact of macro variables such as finance and market laws on prices. Lu Yanchao, Wen Weining, etc. [4] divided the factors affecting the price of power grid equipment and materials into policy factors, economic factors and corporate behavior factors, used the EMD-SVM model to predict the price of power grid engineering equipment. Wu Meiqiong [5] believed that the combined effect of production costs, industry factors and macroeconomics affects the price level of power materials and equipment.

In recent years, smart substation technology has been widely used, and the proportion of smart equipment in power grid engineering investment has gradually increased. Due to the various forms of intelligent equipment, the rapid technological update, the large differences in the quotations of different manufacturers, and the obvious fluctuation of equipment prices in different periods, these features greatly increase the difficulty of cost control for power grid enterprises, puts forward higher requirements for power engineering costs. From the existing literature, there are few studies on the factors affecting the price of smart substations, and the formation mechanism of the price of smart equipment has not yet reached a consistent conclusion. Therefore, it is particularly necessary to analyze the factors affecting the price of smart substation equipment and to study the trend of price changes that conform to the actual market laws.

Although the existing literature studies have acknowledged that macro factors have an impact on the price of power equipment materials, few studies have considered relevant macro variables in model construction and analysis. When the social and economic environment changes little, the forecast results are more reliable, but when the macroeconomic changes, the forecast results are less reliable. Therefore, this paper comprehensively considers macroeconomic factors, combines the relevant theories of engineering cost, establishes a prediction model for the price of smart substation equipment based on the assumption of "adaptive expectations" and makes relevant predictions, so as to provide relevant prediction information for enterprises and the market. The theory used in this paper and the prediction model can also provide an important reference for the follow-up research on the price of smart substation equipment.

2. Model construction and assumptions

At present, the commonly used forecasting models at home and abroad are divided into historical price forecasting models, forecasting models based on price influencing factors, and expert judgment methods. When the historical price data of equipment and materials is stable, the prediction based on the historical data model is selected. When the historical price data of equipment and materials is not stable, it is more appropriate to select a prediction model based on price influencing factors. When the dispersion of price data is too large, it is necessary to carry out predictive analysis based on expert experience judgment.

For the forecast of smart substation equipment, this paper first refers to the methods of relevant literature, puts forward relevant assumptions about macro-influencing factors, then calculates the fluctuation degree of historical prices, and determines whether to choose the forecasting method based on historical price or the forecasting method based on price influencing factors, and finally according to the analysis determines the correlation coefficient, and makes a reasonable prediction of the price according to the model. The article selects the volatility of the PPI index to measure the impact of macro factors on the price of related equipment.

According to the theory of adaptive expectations, the hypothesis H1 of this paper is put forward: the price is determined by supply and demand, the production of electricity manufacturers P_{t-1}determines the production volume of the current period according to the price level of the previous period, and the demand of commodities in the current period $Q_t$depends on the current period. The price level P_t is the supply function because of the manufacturer cannot expect the current $Q_t = f(P_t - 1)$fluctuation of the $P_t - P_{t-1}$PPI index, $P_t$which constitutes the impact of the price level on the manufacturer and causes the actual output to deviate from the equilibrium level when prices are stable.

The technical level of smart substation equipment production has been improved year by year, and the scale benefits of production enterprises have become more and more significant. The socially necessary labor time required for a unit product has been reduced, resulting in lower costs. However, the initial investment of smart substation equipment is relatively large, and the replacement speed is faster. The period investment recovery is relatively short, resulting in a high level of product pricing.

Therefore, the hypothesis H2 of this paper is put forward: the prices of smart grid equipment and materials remain relatively stable in each quarter.

3. Selection based on price fluctuation characteristics

3.1. Measurement basis for price fluctuations

In this section, referring to the practice of Liu Gang et al., in the two types of forecasting models, a preliminary selection of forecasting techniques is carried out to screen out suitable forecasting methods. The calculation of volatility needs to first obtain the standard deviation of the sample, and then obtain the volatility according to the actual number of equipment prices to measure the fluctuation of equipment prices. The greater the volatility, the greater the uncertainty of the price of the equipment, indicating that the price of such equipment is not suitable for the prediction model directly based on the price information of the past years. The specific classification is shown in Table 1:

Table 1. Choice of Forecasting Methods.

Volatility	in accordance with	method of prediction
<5%	Small price fluctuations and strong data correlation	Price based historical data forecast
5%-15%	High price volatility and weak data correlation	Price-Based Influencer Forecast
>15%	The price fluctuates widely and there is no obvious correlation	expert judgment

3.2. The volatility of smart substation equipment prices

Use the price data of Q2, Q3, Q4 in 2021 and Q1 in 2022 to calculate the price volatility of smart substation equipment. After the author calculate of the price of the smart substation equipment, Table 2 is obtained.

Table 2. Volatility of Power Engineering Equipment Prices.

Equipment	Voltage	price ratio standard deviation	Volatility
Equipment A	220kV	0.0571	2%
Equipment A	110kV	0.0789	3%
Equipment B	220kV	0.0000	0%
Equipment B	110kV	0.1027	3%
Equipment C	220kV	0.0000	0%
Equipment C	110kV	0.0000	0%
Equipment D	220kV	0.0337	1%
Equipment D	110kV	0.0000	0%
Equipment E		0.6525	22%
Equipment F		0.2978	10%
Equipment G	220kV	0.0000	0%
Equipment G	110kV	0.0000	0%
Equipment H		0.0448	1%
Equipment I		0.2470	8%

Data source: the author's calculation

As can be seen from the table, the volatility of most equipment prices is less than 5% and can be calculated using methods based on historical prices. The volatility rate of some data is 0, so it is considered that the price fluctuation of such data is not obvious, and the predicted price is the current price. A small number of prices have higher rates of change and require further analysis.

4. Intelligent substation equipment price forecast

This section divides equipment into 3 groups based on volatility and conducts price predictions separately.

4.1. If the volatility is less than 5%, the forecast is based on the historical price method

Table 3. Devices with less than 5% volatility.

Equipment	Voltage	price ratio standard deviation	Volatility
Equipment A	220kV	0.057	2%
Equipment A	110kV	0.079	3%
Equipment B	110kV	0.103	3%
Equipment D	220kV	0.034	1%
Equipment H	110kV	0.045	1%

Data source: the author's calculation

Due to the small amount of data in the sample items, the exponential smoothing method should be used for calculation, and the exponential smoothing method can more accurately reflect future changes. Since the existing balance index α is not take into account the impact of macroeconomic shocks, this paper constructs an equation considering the impact of price level changes on equipment prices based on theoretical analysis. The source of price level data is the National Bureau of Statistics of China. Since recent data has the greatest impact on future forecasting effects, this section uses data from four quarters of Q2, Q3, Q4 in 2021 and Q1 in 2022 for analysis.

Construct a price-adjusted one-time exponential smoothing forecast model: $S_t^1 = \alpha\left(\frac{P_t}{P_{t-1}} - 1\right)x_t + \alpha(1-\alpha)\left(\frac{P_{t-1}}{P_{t-2}} - 1\right)x_{t-1} + \cdots + \alpha(1-\alpha)^{t-1}\left(\frac{P_1}{P_0} - 1\right)x_1 + (1-\alpha)^t\left(\frac{P_0}{P_{-1}} - 1\right)S_0^1$

In order to further eliminate the influence of the initial value on the forecast, construct a price-adjusted quadratic exponential smoothing model: $S_t^2 = \alpha\left(\frac{P_t}{P_{t-1}} - 1\right)S_t^1 + \alpha(1-\alpha)\left(\frac{P_{t-1}}{P_{t-2}} - 1\right)S_{t-1}^1 + \cdots + \alpha(1-\alpha)^{t-1}\left(\frac{P_1}{P_0} - 1\right)S_1^1 + (1-\alpha)^t\left(\frac{P_0}{P_{-1}} - 1\right)S_0^2$

When the primary and secondary smoothed values are known, the prediction model is: $Y_{t+T} = a_t + b_tT$

Among them, $a_t = 2S_t^1 - S_t^2$, $b_t = \frac{\alpha}{1-\alpha}(S_t^1 - S_t^2)$

Among them: αis the smoothing index, P represents the price level, x represents the historical price level of the equipment, t represents the period, S_t^1 represents the first smoothing result, and S_t^2 represents the second smoothing result. Since the recent price has a greater impact on the current price than the long-term price, refer to relevant research (Wu Meiqiong, 2018) $\alpha = 0.9$

Table 4. Exponential Smoothing Values.

equipment	Voltage	One Exponential Smoothing Value				Quadratic Exponential Smoothing			
		2021Q2	2021Q3	2021Q4	2022Q1	2021Q2	2021Q3	2021Q4	2022Q1
Equipment A	220kV	15.18	13.42	11.03	13.59	15.31	13.32	10.98	11.75
Equipment A	110kV	5.92	5.45	4.21	5.86	5.87	5.12	4.39	5.08
Equipment B	110kV	4.91	4.56	4.38	4.8	4.93	4.41	4.36	4.69
Equipment D	220kV	3.64	3.18	2.97	3.38	3.59	3.07	2.88	3.02
Equipment H		4.78	4.53	4.42	4.66	4.69	4.52	4.39	4.32

Data source: the author's calculation

Table 5. Calculation of a and b values.

equipment	Voltage	2021Q2		2021Q3		2021Q4		2021Q1	
		a	b	a	b	a	b	a	b
Equipment A	220kV	15.05	0	13.52	0.9	10.36	-2.79	12.46	-1.89
Equipment A	110kV	5.97	0	5.78	2.97	4.03	-1.62	4.88	-1.94
Equipment B	110kV	4.89	0	4.71	1.35	4.32	-0.18	4.46	-0.09
Equipment D	220kV	3.69	0	3.29	0.99	2.42	-2.07	2.31	-1.99
Equipment H		4.87	0	4.54	0.09	4.25	-0.63	4.34	-0.98

Data source: the author's calculation

According to the prediction model parameters, the predicted price of the smart substation equipment is obtained.

Table 6. The predicted price of power engineering equipment (ten thousand yuan).

Equipment	2022Q2E	2022Q3E	2022Q4E	2023Q1E
Equipment A	11.98	11.64	11.42	11.39
Equipment A	6.08	5.93	5.69	5.63
Equipment B	5.13	5.08	4.93	4.84
Equipment D	3.16	3.11	3.05	2.97
Equipment H	4.86	4.84	4.76	4.75

Data source: the author's calculation

4.2. If the volatility is greater than 5% and less than 15%, the forecast based on price influencing factors shall be adopted

Table 7. Devices with volatility between 5%-15%.

Equipment	price ratio standard deviation	Volatility
Equipment I	0.2470	8%
Equipment F	0.2978	10%

Data source: the author's calculation

Among the factors affecting smart substation equipment, the core factors are technology, raw materials (steel) and labor costs. The macroeconomic impact is considered in the compilation of the steel price index, so there is no need to discuss the impact of the price index separately. In the prediction model based on price influencing factors, the multiple regression method is easy to understand and easy to calculate. The multiple regression method is selected for prediction, and the key influencing factors of intelligent substation equipment are the price of raw materials (steel price index), the R&D expenditure and labor cost of CR5 intelligent substation enterprises and the monetary policy index as independent variables to establish a multiple linear regression model. Since in the multiple regression method, the data of each period has an impact on the formation of the regression coefficient, the sample size needs to be larger, and because the technology of smart substations is replaced quickly, it is only necessary to moderately expand the sample size. This paper adopts 2020Q1-2022Q1, 9 quarters of price data for forecasting.

In 2019, CR5 accounted for 96% of the market share of smart substation equipment, and CR5 are listed company, and corporate financial data is easy to obtain. Therefore, this paper

Uses the total R&D expenditure of CR5 as an independent variable that affects the price of smart substation equipment.

As can be seen from the figure, the R&D expenditure of smart substation enterprises is showing an upward trend. The compound growth rate in 2020 and 2021 is 25.35%. The change in growth rate has a certain periodicity, and the R&D expenditure in the fourth quarter is obviously higher. In the first three quarters, the R&D expenditures in the second and third quarters were basically the same, and the R&D expenditures in the first quarter were the least. The detailed data are shown in Table 8.

Fig 1 Total R&D expenditure and year-on-year growth rate of CR5 smart substation equipment companies

Table 8. R&D expenditure of five smart substation equipment companies (unit: 100 million yuan).

Corporation	2020Q1	2020Q2	2020Q3	2020Q4	2021Q1	2021Q2	2021Q3	2021Q4	2022Q1
J	0.52	0.58	0.90	1.93	0.72	1.00	0.84	1.83	0.86
K	0.85	0.93	0.71	1.91	0.94	0.95	1.32	1.39	1.00
L	0.36	1.10	1.48	2.39	0.66	1.24	2.17	2.10	0.85
M	1.05	1.23	1.49	1.93	1.42	1.56	1.64	3.27	1.66
N	3.76	3.88	3.59	14.00	4.32	4.37	4.66	17.54	4.66
total	6.54	7.72	8.17	22.16	8.06	9.12	10.63	26.13	9.03

Data source: the author's calculation

In this paper, Stata15.0 statistical software is used to perform multiple linear regression, and the values of regression parameters are obtained, as shown in Table 9.

Table 9. Regression coefficients of smart substation equipment.

Equipment	Labor cost	Steel Price Index	R & D spending	constant value
Equipment I	-0.0097241	0.2300718	0.1556499	52.33763
Equipment F	0.0010427	0.1348699	0.0178029	-6.56785

Data source: the author's calculation

Enter the regression parameters in the above table into the multiple regression model to obtain the predicted value of the power equipment, see Table 10.

Table 10. The predicted price of smart substation equipment (10,000 yuan)

Equipment	2022Q2E	2022Q3E	2022Q4E	2023Q1E
Equipment I	29.67	32.78	30.45	31.24
Equipment F	19.08	21.53	18.43	19.22

Data source: the author's calculation

4.3. If the volatility is greater than 15%, consider the expert judgment method

The Smart Substation Equipment E has a volatility rate of 22%, which exceeds the volatility level of 15%. It is difficult to accurately predict the future price of the data with the existing prediction model. Expert judgment can be used, and industry experts can be consulted to obtain more information on equipment to predict price trends.

5. Conclusion

Through the above analysis, it is found that the expected price of the smart substation equipment price verifies the hypothesis H2, and the smart substation equipment is most affected by the advancement of technology and the investment payback period, resulting in the price of the smart substation equipment being basically stable from quarter to quarter, and the price of the smart substation equipment is basically stable between quarters. The changes are small. In general, the fluctuation level of equipment in smart substations is small, and historical data can well predict future price levels. Only a few has high volatility, and factor analysis can be used to perform multiple regression predictions. Specifically, equipment with volatility lower than 5% can use the price-adjusted exponential smoothing model for price forecasting; equipment with a volatility between 5% and 15% can use multiple regression methods to continue forecasting. Observing the regression coefficients can be found, the coefficient value of steel price index and R&D expenditure is the largest, and the coefficient value of labor cost is small, indicating that the price of bulk commodity steel and the level of R&D investment has a significant impact on the price level of intelligent substation equipment, and the impact of labor cost on the price is very small; Equipment with volatility greater than 15% can be forecast using expert judgment.

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