Research on the Control Method of Short-term Transmission and Distribution Price Level

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Abstract. In order to ensure the orderly competition in the power market, through a variety of measures to reduce the electricity cost of enterprises and users, and improve the service quality of power enterprises, this paper puts forward the research on the control method of the total level of short-term transmission and distribution price. Combined with the principle of "three sets and five big", the power grid marketing system is established, the main responsibilities of customer service center are assigned, and the main factors affecting pricing are extracted by bird swarm algorithm. Combining the rate of return on investment with the price cap regulation mode, a growth type short-term total level regulation mode of transmission and distribution electricity price is constructed. Simulation results show that the proposed control method has high accuracy in forecasting electricity demand and can give full play to the role of market price regulation.

1. Introduction
To a certain extent, the transmission and distribution price reflects the ability of the government and power companies to negotiate prices and the degree of coordination of various interest groups. The short-term control of the overall level of transmission and distribution prices is significantly affected [1]. At the present stage, the electric power reform is not perfect, the main problems include slow progress, no clear goal, lack of supporting policies, etc., which seriously affect the construction of power grid and the normal operation of power grid enterprises. Therefore, it is necessary to take relevant measures to improve the scientific rationality of electricity price regulation mode [2-3]. In this mode, the authenticity of the cost report can not be guaranteed, and it is easy to make false cost reports.

Reference [4] divides short-term and long-term according to the change of transmission and distribution price, and establishes short-term cost-benefit evaluation model and long-term cost-benefit evaluation model respectively according to different accounting methods of total revenue, which verifies the objectivity and effectiveness of the evaluation model. Reference [5] proposes a scheme for setting sub-voltage power transmission and distribution prices based on bird swarm algorithm (BSA). The bird swarm algorithm is used to calculate the maximum load of each voltage level, and the peak load responsibility method is used to calculate the electricity price of each voltage level, which verifies the feasibility of the proposed method. However, the operating cost of the above research results has not been minimized, and the overall control effect is not high.

In view of the above problems, this paper studies the control method of the total level of short-term transmission and distribution price. This article combines the characteristics of the internal and external environment of power development, promotes the independence of public power, and breaks the monopoly system. The bird swarm algorithm is used to extract the main factors affecting the...
transmission and distribution price, and the transmission and distribution price adjustment mode is reconstructed, thereby achieving the balance of interests between producers and consumers. The method in this paper can guarantee the long-term stable supply of electricity.

2. Research on the control method of short-term transmission and distribution price level

2.1. Construction of short-term transmission and distribution price system
Because electric energy cannot be stored in large quantities and its substitutability is poor, its basic nature is quite different from that of public nature and ordinary commodities [6-7]. Therefore, the price is different, and its main feature is long-term stability. Because the electricity price is mainly set by government departments, it is less affected by the market in the short term, and the increase in electricity prices is directly related to the production cost of different industries and people's consumption expenditure. Therefore, the overall electricity price will not change significantly. Based on this, the transmission and distribution electricity price system structure is designed, and the transmission and distribution electricity price system structure is as Figure 1.

![Figure 1 Framework of transmission and distribution price system](image)

2.2. Extraction of main factors affecting short-term transmission and distribution price regulation
Combined with the designed framework diagram of transmission and distribution price system and the current situation of complex operation procedures of power market, it is proposed that the short-term transmission and distribution price regulation should follow the basic principles of establishing the thinking target mode of transmission and distribution price regulation, reasonably compensating the production cost of enterprises and paying attention to adjusting the market demand.

Based on the above principles, the bird swarm algorithm is used to extract the main factors affecting short-term transmission and distribution price control:

$$a = \frac{\cos(\omega + \varphi(t))}{\epsilon^2} \quad (1)$$

Among them, $\omega$ is the degree of influence on short-term transmission and distribution price control, $\varphi(t)$ influences the extraction of the main factor function of short-term transmission and distribution price control, and $\epsilon$ is the interference factor.

2.3. Propose short-term transmission and distribution price control methods

2.3.1. Combination of investment rate of return and price cap control mode
(1) Return on investment regulation model
In order to make enterprises obtain reasonable profits and help attract more investment, establish a corporate investment return rate management model [8-9]. If the power company only has one service, the investment return rate control model is expressed as:

$$R = C + r \times R_b$$  \hspace{1cm} (2)

In formula (2), \(R\) represents the income function of the enterprise, \(C\) represents the allowable costs and expenses, including raw material costs, wages and taxes, \(r\) represents the level of investment return specified by the relevant department, and \(R_b\) represents the base of the investment return rate, that is, the total capital [10].

\(r\) is the rate of return on investment set by the relevant department, usually using the average cost of capital after tax (\(WACC\)), which represents the weighted average of the principal profit rate and the debt rate. The calculation formula is as follows:

$$WACC = R_e \times \frac{E}{V} + R_d \times \frac{D}{V}$$ \hspace{1cm} (3)

In formula (3), \(R_e\) represents the after-tax asset return rate, which is equal to the sum of the risk-free return rate and the upper risk return rate. \(dR\) represents the interest rate of the debt market, \(DV\) represents the net value of equity and debt fixed assets respectively.

(2) Price cap control mode

Combining the bird colony algorithm to set the maximum price control of the control method is a direct management of the price level, and its model is expressed as:

If the company only has one product or service, the regulated price is:

$$P_{\text{reg}} \leq P_t (1 + R_{py} - X)$$ \hspace{1cm} (4)

If the company operates a variety of products, the price control model is as follows:

$$P = \sum W_i \times P_i$$ \hspace{1cm} (5)

In formulas (4) and (5), \(P_t\) represents the current price of the company, \(R_{py}\) represents the retail price index, \(X\) represents the percentage increase in production efficiency in a short period of time, \(P\) represents the weighted average price, and \(W_i\) represents the weight and price of the service, respectively.

2.3.2. Establish a growth-type short-term transmission and distribution price control method

Combining the above return on investment with the price cap regulation mode, and according to the current development situation of China's power grid, a growth type short-term transmission and distribution price regulation method is established. This method fully considers the control cost and accurately forecasts the profit level and the relationship between supply and demand. Under this method, the corresponding regulation model is improved, and the formulation process of electricity price model of power supply unit is as Figure 2.
Analyze the cost of power supply network

Fixed costs (depreciation, management)

Variable cost (operation and maintenance, etc.)

Comprehensive cost pricing

Marginal cost pricing

Using two part electricity price to get electricity price model

Analysis of power supply network characteristics

Company management cost analysis

Comprehensive cost pricing

Obtained the electricity supply company's regulated electricity price model

Integrated electricity price model

Figure 2 Flow chart of the formation of the electricity price model of the power supply unit

The improved control formula for the rate of return on investment is:

$$ R(P,Q) = Z + r \times R_a $$

(6)

In formula (6), $R(P,Q)$ represents the annual total income demand of the transmission and distribution enterprise, which is related to factors such as price and output, and $Z$ represents the annual depreciation.

The price cap control formula is as follows:

$$ P_{i+1} \leq C_s(1 + R_h - Y) $$

(7)

Among them, $Y$ represents the production efficiency growth rate set by the relevant department. Based on the above formula, it is determined that the short-term transmission and distribution price control model that is ultimately in line with China's power situation is:

$$ R_{s+1}(P,Q) = [C_s(1 + R_h - Y) + R_{s+1}(P,Q) \times r_s] \times S_d $$

(8)

In formula (7), $r_s$ represents sales profit, and $S_d$ represents the degree to which transmission and distribution can meet future demand. If an enterprise wants to increase the transmission power, it needs to increase investment and expand the transmission range to meet market demand.

If:

$$ r_s = \frac{r_s}{R(P,Q)} $$

(9)

$$ S_d = \frac{D_{s+1}}{S_0} $$

(10)

Then the regulated price $P_{s+1}$ for the next period is expressed as the total revenue $R_{s+1}$ divided by the electric power sold in the following period $Q_{s+1}$:

$$ P_{s+1} = \frac{C_s(1 + R_h - Y) \times D_{s+1} / S_0}{Q_{s+1} \times (1 - \frac{r_s}{R(P,Q) \times D_{s+1} / S_0})} $$

(11)

3. Experimental analysis

3.1. Experimental setup

In order to better illustrate the strong applicability of the proposed control method, it is further proved by specific calculation examples. Assuming that there are five power supply units in a province, the unit power supply cost is expressed as $C_i$ yuan, and the consumption level and price conversion coefficients are $\beta$ and $\beta_i$ respectively. Combining regional area, power supply and per capita power
consumption weight \( \omega_1 \), inflation rate \( \text{RPI}_i \), setting improved efficiency \( X_i \), and penalty factor \( \gamma_i \), the specific parameters are as Table 1. Among them, \( \gamma_i \) has two values, a positive value represents a reward for the power supply company by the relevant department, and a negative value is a punishment for the power supply company.

| Table 1 known data of a provincial power supply company |
|-----------------------------------------------|
| Unit 1 | Unit 2 | Unit 3 | Unit 4 | Unit 5 |
| \( C_i \) | 0.37 | 0.39 | 0.43 | 0.38 | 0.41 |
| \( \beta/\beta_i \) | 1.13 | 1.02 | 0.32 | 1.05 | 0.94 |
| \( \omega_i \) | 0.19 | 0.22 | 0.21 | 0.20 | 0.15 |
| \( \text{RPI}_i \) | 8.1 | 7.5 | 6.9 | 7.5 | 7.1 |
| \( X_i \) | 1.6 | 1.5 | 0.7 | 1.1 | 1.1 |
| \( \gamma_i \) | +60 | +50 | +50 | +70 | +50 |
|                   | -200 | -260 | -450 | -400 | -430 |

3.2. Data analysis

According to the regulation model established in this paper, the unit cost of electricity, the average cost of power supply unit \( \bar{C} \) yuan, the basic regulated electricity price \( P_1 \), and the price ceiling \( P_{\text{max}} \) can be obtained through calculation. If the real electricity price \( P_i \) of each power supply company is priced according to the data in Table 2, \( P_i \) will change over time because of seasonal influence. Therefore, it is necessary to assume that \( P_i \) is a fixed value in the same control period. The calculation results are shown in Table 2.

| Table 2 calculation results |
|----------------------------|
| Unit 1 | Unit 2 | Unit 3 | Unit 4 | Unit 5 |
| \( \bar{C} \) | 0.408 |
| \( P_1 \) | 0.351 | 0.391 | 0.458 | 0.381 | 0.432 |
| \( P_{\text{max}} \) | 0.385 | 0.415 | 0.492 | 0.402 | 0.452 |
| \( P_i \) | 0.35 | 0.392 | 0.457 | 0.381 | 0.431 |

Through the above analysis, it can be concluded that the unit price obtained by combining the regulation mode not only depends on its own cost and operation efficiency, but also depends on the cost of other power supply units, which effectively promotes the competition among units and helps to improve the efficiency.

Firstly, the simplified power flow diagram of the power grid is calculated, and then the transmission and distribution cost is apportioned according to the power flow distribution and the proportion of power or electricity source of each voltage level. After considering the two factors of power grid investment and power quality, the transmission and distribution prices before and after supervision are as Table 3.

| Table 3 Comparison of transmission and distribution price before and after supervision |
|-----------------------------------------------|
| Transmission and distribution price (yuan/ kW.h) |
| 220kV | 110kV | 20kV | 10kV | <1kV |
| Before control | 0.0179 | 0.0596 | 0.1189 | 0.1305 | 0.1452 |
| After control | 0.0165 | 0.0519 | 0.1039 | 0.1298 | 0.1305 |

It can be seen from table 3 that the transmission and distribution prices of all voltage levels have been reduced after the supervision. This is because the average level of power quality in the region is low under the condition of meeting the power demand. The government will punish the enterprises for
reducing and adjust the electricity prices, which is beneficial for the enterprises to improve the power quality in the future service, so as to achieve a satisfactory level of electricity.

3.3. Accuracy test

In this paper, the accuracy of the electricity demand in the proposed control model is tested. The commonly used method is the posterior difference test.

Assume residual: \( \varepsilon(k) = x_0(k) - \bar{x}_0(k) \). It is known that the variance of electricity sales is expressed as: \( S_1^2 = \frac{1}{n} \sum_{i=1}^{n} [x_0(k) - \bar{x}]^2 \), and the residual variance is \( S_2^2 \), and there is \( S_2^2 = \frac{1}{n} \sum_{i=1}^{n} [\varepsilon(k) - \bar{\varepsilon}]^2 \).

Therefore, the two main values of the posterior difference can be obtained, namely the posterior difference ratio \( C \) and the probability of small error \( P \):

\[
C = \text{sqrt}(\frac{S_1^2}{S_2^2}) = 0.2971 \quad (12)
\]

\[
P = P[|\varepsilon(k) - \bar{\varepsilon}| < 0.6745S_2] = 1 > 0.95 \quad (13)
\]

Through the calculation, it can be seen that under the control method proposed in this paper, the accuracy of power demand forecasting is higher, and the posterior error test results can reach the first level.

4. Conclusion

With the deepening of China's electric power reform, the transmission and distribution price gradually transits to the cost-benefit mechanism. This paper studies the control mode of the total level of short-term transmission and distribution price. First of all, this paper constructs a short-term transmission and distribution price system and configures the main tasks of key departments. Then, based on the basic principles of electricity price regulation, bird swarm algorithm is used to extract the main factors affecting the short-term transmission and distribution price regulation. Finally, based on the return on investment and price cap regulation model, a new short-term transmission and distribution price regulation method is proposed. Experiments show that the proposed method can maximize the social benefits of electricity, strengthen the control effect, and improve the cost accounting system of transmission and distribution in China.

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