Research on Electricity Transmission and Distribution Price Calculation under Electricity Regulation

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Abstract. The new round electricity system reform leads to changes in electricity supervisory environment. Further, the reform on electricity transmission and distribution price has new objective. Under such background, this paper establishes scientific and reasonable electricity transmission and distribution price calculation model, collects data and carries out electricity transmission and distribution pricing. Based on calculation results, this paper carries out parameter sensitivity analysis on electricity volume (uncertain regulatory parameters) and main regulating parameters, and gets sensitivity ranking of each pricing parameter of electricity transmission and distribution. Through study, the electricity transmission and distribution price calculation model and sensitivity analysis model for price influence factors under new electricity supervision are formed, providing ideas and opinions for electricity transmission and distribution price calculation.

1. Introduction

After the new round electricity system reform, the electricity supervision starts full coverage supervision from electricity generation in enterprises to electricity consumption in households. The defects of fragmented and dependent supervisory institution and functions are shown. In the new electricity supervisory environment, the reform on electricity transmission and distribution price has new objectives. The key section is the verification method for electricity transmission and distribution price, including electricity composition, calculation basis and calculation method.

2 Electricity transmission and distribution price calculation model

The objective of electricity transmission and distribution price reform is to formulate scientific and reasonable electricity transmission and distribution price, recover attribute of electricity commodity, and promote electricity market development. The current electricity transmission and distribution price adopts the cost-based regulation method, i.e., allowed cost + reasonable benefits. In accordance with the Provincial Power Grid Transmission and Distribution Price Confirmation Method (Trial),
Average electricity transmission and distribution price of provincial power grid (including VAT)

\[ \text{Allowed income recovered at electricity transmission and distribution price (including VAT)} = \frac{\text{Public electricity transmission and distribution volume of provincial power grid}}{} \]

According to the pricing method, the calculation formula of allowed income shall be:

\[ \text{Allowed income} = \text{Allowed cost} + \text{Allowed earnings} + \text{In-price tax} \]

Apparently, the composition elements of electricity transmission and distribution price shall be: allowed costs, allowed earnings, in-price tax and electricity transmission and distribution volume.

The allowed income \( I_i \) in the \( i^{th} \) year during the calculation period shall be:

\[ I_i = C_i + R_i + T_i \] (1)

(1) Allowed cost calculation

The pricing method regulates that the allowed costs are comprised of depreciation expense and operation and maintenance fee; the allowed cost during the benchmark period and newly added (decreased) allowed cost during the regulatory period will be calculated respectively. Therefore, the calculation model of allowed cost is as follows:

\[ C_i = C_0 + \Delta C \] (2)

In the formula, \( C_i \) is the allowed cost in the \( i^{th} \) year of the calculation period, \( C_0 \) is the allowed cost during the benchmark period, and \( \Delta C \) is the newly added (decreased) allowed cost during the regulatory period.

The allowed costs are comprised of depreciation expense and operation and maintenance fee; since operation and maintenance fee is predicted based on historical data in the previous years of the regulatory period, the operation and maintenance fee rate \( O_{M,i} \) in the \( i^{th} \) year is introduced.

\[ C_{0,i} = F_{A0} \times r_{p,i} + F_{A0} \times O_{M,i} \] (3)

\[ \Delta C_i = F_{Ai} \times \alpha_i \times (r_{p,i} + O_{M,i}) \] (4)

In the formula, \( F_{A0} \) is the original value of fixed assets in the end of the the year (benchmark period) before the regulatory period which depreciation may be withdrawn in the first year of the regulatory period; \( F_{Ai} \) is newly added investment in fixed assets in current year; and \( r_p \) is the comprehensive pricing depreciation rate. The calculation model of the allowed cost shall be:

\[ C_i = (F_{A0} + F_{Ai} \times \alpha_i) \times (r_{p,i} + O_{M,i}) \] (5)

(2) Calculation of the allowed earnings

The calculation model of the allowed earning \( R_i \) in the pricing method shall be:

\[ R_i = A_{A,i} \times W_{AAC} \] (6)

\( A_{A,i} \) is the effective assets which could be withdrawn in the \( i^{th} \) year of the regulatory period; \( W_{AAC} \) is the allowed rate of return; in which, the effective assets which earnings could be withdrawn are comprised of effective asset \( A_{A,0} \) during the benchmark period and newly added (decreased) effective asset during the regulatory period:

\[ A_{A,i} = A_{A,0} + \Delta A_i \] (7)

Except net value of fixed assets, the effective assets also contain other assets during the benchmark period; introducing proportion coefficient \( \rho \) of other assets to net value of fixed assets, and according to operation capital no higher than 10% of main business income, the net value of fixed assets in each year shall be net fixed asset value in the previous year and net fixed asset value converted from newly increased investment, less corresponding depreciation.

\[ A_{A,i} = \left( F_{AN} + F_{A,i-1} - F_{A0} \times r_{p,i} - F_{A,i-1} \times \alpha_{i-1} \times r_{p,i-1} \right) \times \left( 1 + \rho \right) + I_{i-1} \times 10% + F_{A,i} \times \alpha_i \times \left( 1 - r_{p,i} \right) \] (8)

In the formula, \( F_{AN} \) is the net value of fixed assets during the benchmark period, and \( I_{i-1} \) is the allowed income in the previous year of the prediction year.

\( W_{AAC} \) is the allowed rate of return, comprising equity capital rate of return \( R_{e} \), debt capital rate of return \( R_d \) and asset-liability ratio \( A_{LRO} \):

\[ W_{AAC} = R_e \times (1 - A_{LRO}) + R_d \times A_{LRO} \] (9)
Calculation model of the allowed earnings shall be:

\[ R_i = \left[ (F_{AN} + F_{Ai} - F_{AR} \times r_{pj} - F_{Ai} \times \alpha_i \times r_{pj} + 1) \times \left( 1 + \rho \right) + I_{i} \times 10\% + F_{AR} \times \alpha_i \times \left( 1 - r_{pj} \right) \right] \times \left[ R_e \times (1 - A_{LR0}) + R_d \times A_{LR0} \right] \]  

(10)

(3) In-price tax calculation

The annual in-price tax shall be calculated by effective assets and allowed income as base number estimated in current year multiplying corresponding tax rate. The in-price tax \( T_i \) in the \( i \)th year shall be:

\[ T_i = T_{1,i} + T_{2,i} \]

\[ = \frac{A_{Ai} \times (1 - A_{LR0}) \times R_e}{1 - r_3} \times r_1 + [(C_i + R_i) \times r_2] (r_3 + r_4) \]  

(11)

The in-price tax calculation formula is given by equation (11), where \( T_{1,i} \) is the income tax in the \( i \)th year, and \( T_{2,i} \) is the urban maintenance and construction tax and educational surtax in the \( i \)th year. \( r_1, r_2, r_3, r_4 \) are respectively income tax rate, VAT rate, urban maintenance and construction rate, and educational surtax rate.

(4) Electricity transmission and distribution price calculation model

In accordance with the pricing method, the provincial power grid transmission and distribution pricing model shall be:

\[ P_i = \frac{I_i}{Q_i} \]  

(12)

In the formula, \( P_i \) and \( I_i \) are respectively the electricity transmission and distribution price and allowed income in the \( i \)th year; \( Q_i \) is the pre-cost electricity volume predicted in the \( i \)th year of the regulatory period; the relationship with the electricity volume \( Q_0 \) in the year prior to the regulatory period shall be \( Q_i = Q_0 (1 + Q_{AGR})^i \), in the formula, \( Q_{AGR} \) is the electricity volume growth rate predicted by authorized department of competent provincial government.

3. Electricity transmission and distribution price calculation results

The original data of certain provincial company from 2016 to 2018 is collected to carry out electricity transmission and distribution price calculation. The original statement analysis shows: from 2016 to 2018, the mean value of \( O_{Aj} \) is 8.68%, \( a \) is set as 75% according to requirements in electricity transmission and distribution pricing method; the mean value of \( r_{pj} \) is 2.5%, and mean value of \( \rho \) is 0.77%, mean value of \( A_{LR0} \) is 56.05%, mean value of \( \Delta P \) is 6.04%, and mean value of \( Q_{AGR} \) is 4.81%. Moreover, \( R_e \) is the 5-year national bond interest rate in 2014 (5.41%, totally 5 terms), plus 4%, equaling to 9.41%; \( R_d \) is the loan interest rate for five or more terms in 2017, 6.15%. Supposing the electricity volume increases 3% every year, the newly added investment amount will be predicted by GM(1,1) according to history data. Inputting value of parameters into price calculation model above, the provincial public network transmission and distribution electricity price and value of each pricing value can be seen from 2019 to 2021 can be seen in Table 1.
Table 1 Public electricity transmission and distribution price and value of pricing parameters of provincial power grid

| Type  | F_{An}/ Billion | α_{i}/% | r_{p}/% | O_{AI}/% | F_{AN}/ Billion | ρ/% | R_{c}/% | R_{d}/% | A_{AI0}/ % | ΔP/% | Qui/(TWh) | Pi/(Yuan/TWh) |
|-------|-----------------|----------|--------|----------|-----------------|------|--------|--------|-----------|-------|-------------|-----------------|
| 2017Y | 453.81          | 75%      | 6.25%  | 2.50%    | 5018.0         | 0.77 | 9.41%  | 6.15%  | 60.25%    | 6.04% | 4930.58     | 0.298065        |
| 2018Y | 493.81          | 75%      | 6.25%  | 2.50%    | 5831.9         | 2    | 0.77%  | 9.41%  | 6.15%    | 6.04% | 5078.50     | 0.276227        |
| 2019Y | 578.32          | 75%      | 6.25%  | 2.50%    | 6777.8         | 6    | 0.77%  | 9.41%  | 6.15%    | 6.04% | 5230.85     | 0.275457        |
| 2020Y | 710.81          | 75%      | 6.25%  | 2.50%    | 7877.2         | 3    | 0.77%  | 9.41%  | 6.15%    | 6.04% | 5387.78     | 0.275457        |
| 2021Y | 903.61          | 75%      | 6.25%  | 2.50%    | 9154.9         | 1    | 0.77%  | 9.41%  | 6.15%    | 6.04% | 5549.41     | 0.275455        |
| 2022Y | 1192.3          | 75%      | 6.25%  | 2.50%    | 10639.84       | 4    | 0.77%  | 9.41%  | 6.15%    | 6.04% | 5715.89     | 0.275456        |
| 2023Y | 1632.6          | 75%      | 6.25%  | 2.50%    | 12365.62       | 6    | 0.77%  | 9.41%  | 6.15%    | 6.04% | 5887.37     | 0.286863        |
| 2024Y | 2387.0          | 75%      | 6.25%  | 2.50%    | 14571.32       | 32   | 0.77%  | 9.41%  | 6.15%    | 6.04% | 6063.99     | 0.306716        |
| 2025Y | 3723.4          | 75%      | 6.25%  | 2.50%    | 16702.35       | 35   | 0.77%  | 9.41%  | 6.15%    | 6.04% | 6245.91     | 0.341442        |

Table 1 shows the comprehensive influence of each parameter on electricity transmission and distribution price. According to Table 1, the electricity transmission and distribution price from 2019 to 2020 is rising. Based on aforesaid formula, the growth of allowed income is faster than that of electricity volume under influence of each parameter. Table 1 also reflects different influence degrees of each parameter on electricity transmission and distribution price level. Therefore, the sensitivity study of each parameter is carried out below.

4. Sensitivity analysis of main influence factors for electricity transmission and distribution price
In order to disclose influence degrees of each parameter on electricity transmission and distribution price level, this paper selects electricity volume (uncertainty supervisory parameter) and main regulatory parameters to carry out parameter sensitivity analysis. The electricity transmission and distribution price in 2018 shall be RMB 0.2316/kW·h; after changes in parameters, the electricity transmission and distribution price shall be PR, and change amount ΔP = P - RMB 0.2316/kW·h, sensitivity coefficient is AP/ (RMB 0.2316/kW·h). The calculation results can be seen in Table 2. The parameter sensitivity comparison chart is drawn for absolute value of sensitivity parameters, as shown in Fig.1.

Table 2 Sensitivity factors of electricity transmission and distribution price

| Param. | Growth rate of electricity purchase amount | Line loss rate | Depreciation rate | Operation and maintenance fee rate | Rate of return on equity capital |
|--------|------------------------------------------|---------------|------------------|-----------------------------------|--------------------------------|
|        | Electricity price change amount | Sensitivity coefficient | Electricity price change amount | Sensitivity coefficient | Electricity price change amount | Sensitivity coefficient | Electricity price change amount | Sensitivity coefficient | Electricity price change amount | Sensitivity coefficient |
| -0.1   | 0.0002         | -0.70         | -0.0003         | -1.23         | -0.0008         | -3.06         | -0.0005         | -2.10         | -0.0002         | -0.87         |
| -0.2   | 0.0004         | 1.75          | -0.0006         | -2.29         | -0.0015         | -5.96         | -0.0010         | -4.03         | -0.0004         | -1.56         |
| -0.3   | 0.0007         | 2.71          | -0.0008         | -3.35         | -0.0022         | -8.85         | -0.0015         | -5.96         | -0.0006         | -2.25         |
| -0.4   | 0.0009         | 3.67          | -0.0011         | -4.40         | -0.0029         | -11.75        | -0.0010         | -7.89         | -0.0007         | -2.95         |
| -0.5   | 0.0011         | 4.63          | -0.0013         | -5.46         | -0.0036         | -14.64        | -0.0024         | -9.82         | -0.0009         | -3.64         |
| -0.6   | 0.0014         | 5.50          | -0.0016         | -6.51         | -0.0043         | -17.50        | -0.0020         | -11.75        | -0.0011         | -4.34         |
| -0.7   | 0.0016         | 6.56          | -0.0019         | -7.56         | -0.0050         | -20.43        | -0.0034         | -13.68        | -0.0012         | -5.03         |
| -0.8   | 0.0019         | 7.53          | -0.0021         | -8.61         | -0.0057         | -23.33        | -0.0038         | -15.61        | -0.0014         | -5.73         |
| -0.9   | 0.0021         | 8.50          | -0.0024         | -9.65         | -0.0065         | -26.22        | -0.0043         | -17.54        | -0.0016         | -6.43         |
| -1.0   | 0.0023         | 9.47          | -0.0026         | -10.69        | -0.0072         | -29.12        | -0.0048         | -19.47        | -0.0017         | -7.12         |

According to Table 2, the lower growth rate of predicted electricity sales amount will drive electricity transmission and distribution price to increase; lower growth rate of other parameters makes electricity transmission and distribution price lower. The electricity amount growth rate is predicted by competent provincial authorized department; the parameters regarding uncertainties are related to the balance account. In pre-forecast in 2017, Q_{TAGR} is 4.81%; the actual amount is actually 3.81%, 1% lower than the predicted value when the regulatory period ended in the end of 2017; then, Q_{i} =
QT2(1+QTAGR)(1-ΔP) = 1768.12 GW·h × (1+3.81%) × (1-6.04%) = 172.462 GW·h. The corresponding reasonable electricity transmission and distribution price shall be RMB 0.2487/(kW·h); however, the electricity transmission and distribution price is still charged as per RMB 0.2316/(kW·h). In this way, the power grid enterprises could not acquire the allowed income of 172.462 GW·h × RMB 0.0023/(kW·h) = RMB 397 million. Thus, the “deficit” shall be reckoned to the balance account in the form of “negative number”.

The line loss rate is a regulatory attribute parameter for incentive decision making variant; in pre-forecast in 2018, ΔP is 6.04%; the actual amount is actually 5.04%, 1% lower than the predicted value when the regulatory period ended in the end of 2017. The corresponding reasonable electricity transmission and distribution price shall be RMB 0.2438/(kW·h); but the electricity transmission and distribution price is still charged as per RMB 0.2316/(kW·h). According to the pricing method, the risk that line loss rate during actual operation exceeds the verified value shall be undertaken by the power grid enterprise; the line loss rate lower than the verified income shall be shared by power grid enterprises and power users 50% respectively. Then, the added value of power grid enterprise incomes is about: 174.124 GW·h × RMB 0.0026/(kW·h) × 50% = RMB 230 million.

![Sensitivity factors of electricity transmission and distribution price](image)

Fig.1 Sensitivity factors of electricity transmission and distribution price

According to Fig.1, the sensitivity degree of electricity transmission and distribution price on each pricing parameter are respectively from high to low: depreciation rate parameter, operation and maintenance fee rate, line loss rate parameter, electricity volume growth rate parameter, and rate of return on equity capital, in which, the influence effect of the former two on electricity transmission and distribution price is respectively 3 and 2 times; thus, they are significant influence parameters; the influence effect of the middle two is about 1 time, and they are common influence parameter; the influence effect of the last factor is smaller than 1, and it is a weak influence parameter.

### 5. Conclusion

Based on the objective of new electricity transmission and distribution reform, this paper establishes a scientific and reasonable electricity transmission and distribution price calculation model with factors of allowed costs, allowed earnings, in-price tax and electricity transmission and distribution volume. Then, the original data of certain provincial company from 2016 to 2018 is collected to carry out electricity transmission and distribution price calculation. Results acquired are as follows: the electricity transmission and distribution price from 2019 to 2020 is rising; the growth of allowed income is faster than that of electricity volume under influence of each parameter. The calculation results also disclose different influence degrees of each parameter on electricity transmission and distribution price level. Therefore, this paper selects electricity volume (uncertainty supervisory parameter) and main regulatory parameters to carry out parameter sensitivity analysis, and the sensitivity degree of electricity transmission and distribution price on each pricing parameter are respectively from high to low: depreciation rate parameter, operation and maintenance fee rate, line...
loss rate parameter, electricity volume growth rate parameter, and rate of return on equity capital. Through study, this paper forms an electricity transmission and distribution price calculation model and acquires influence degrees of different factors on electricity price calculation, providing ideas and opinions for electricity transmission and distribution price calculation.

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