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Development and Enlightenment of Performance-based Transmission and Distribution Price Regulation Method

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Abstract. Transmission and distribution price regulation methods in the United States and Europe are now evolving from the cost-based regulation, the cap-based regulation to the performance-based regulation. The performance-based regulation method has already been implemented in the UK, the United States, Denmark and many other countries, which can provide valuable experiences. Firstly, mechanisms and incentives of the cost-based regulation, the cap-based regulation and the performance-based regulation are reviewed and discussed. Then, key modules of the performance-based regulation are discussed from aspects like regulation targets determination, evaluation indices design, performance standards setting and incentive mechanism selection. Thirdly, the UK RIIO model is selected as an ideal example to discuss in detail on how to design the model framework, how to design performance indices, and how to determine permitted revenue under the performance-based regulation. Finally, based on the status quo of transmission and distribution price regulation in China, the opportunity and challenge for utilities in China are discussed.

1. Introduction

Due to the natural monopoly characteristics of the transmission and distribution network, the electricity price must be determined under the government regulation. Domestic and foreign transmission and distribution price regulation methods are constantly developing and evolving. Literature [1] discusses the practice and experience of transmission and distribution price regulation theories in United States and Europe, and divides those methods into three categories: guaranteed cost-recovery regulation, maximum cap incentive regulation, and results-based incentive regulation. Economist Alfred Kahn believes that all regulation is incentive regulation. Regardless of the mode of regulation, when the restraint is imposed on regulated objects, it will also exert an influence on its mode of operation, and incentive regulated objects to choose the action that is most beneficial to themselves to maximize its own interests. In view of this, through the analysis of domestic and foreign status quo, this paper divides the transmission and distribution price regulation methods into the cost-based regulation, the cap-based regulation to the performance-based regulation.

Since October 2014, the National Development and Reform Commission and the National Energy Administration have studied and formulated the “Measures of the Supervision for the Pricing Costs of Transmission and Distribution” and the “Measures of the Pricing for the Transmission and



Distribution Price of Provincial Power Grid” on the basis of the pilot projects in Shenzhen and Mengxi in accordance with the reform thoughts “piloting first and generalizing later”. The NDRC and the NEA guide the provincial price authorities and relevant institutions to promote the reform of transmission and distribution price of provincial power grid in three batches in an orderly manner, and comprehensively completes the reform [2]. China's transmission and distribution price regulation method has evolved from the traditional method of being determined by the difference between purchase and sale price to that of “permitted cost plus reasonable revenue”.

In the background of global energy transformation and marketization, the operation of transmission and distribution corporations will face more uncertainties and undertake the task of supporting sustainable energy development. Considering the importance of transmission and distribution price regulation methods for the operation of corporations, this paper analyzes the latest developments in transmission and distribution price regulation, focusing on the latest performance-based regulation methods, aiming to provide information to support the operation of transmission and distribution corporations.

This paper is organized in the following order: Section 1 reviews the latest developments in transmission and distribution price regulation methods. Section 2 sorts out and analyzes the elements of the performance-based regulation methods. Section 3 takes the British RIIO model as an example to clarify the principles and methods for the formulation of transmission and distribution prices under the performance-based regulation. Sections 4 and 5 combine the status quo in China to discuss the opportunities and challenges with which the transmission and distribution investment is faced.

2. Existing transmission and distribution price regulation methods

2.1. Cost-based regulation

The application of the cost-based regulation in the development of transmission and distribution price has been for a long time. Based on a particular review of investment and operating expenses, the regulator aims to verify fair and reasonable access revenue for grid corporations.

In this regulation mode, the revenue is allowed to set the permitted revenue level of the corporation based on the measured cost and cost-benefit ratio of grid corporation cost in the base period, and then price transmission and distribution service [3].

$$RVN^* = RB^* \times RoR + OE^* \quad (1)$$

where RVN^* (Revenue) is the permitted revenue, RB^* (Rate of) is the rate of return measured in the base period, RoR is the permitted rate of return, OE^* is the measured operation and maintenance cost.

The average transmission and distribution price R can be expressed as:

$$R = RVN^* / S^* \quad (2)$$

where S^* is the measured transmission and distribution electricity.

In this pricing mechanism, if permitted rate of return is higher than loan rate, in order to obtain more permitted revenue, regulated objects tend to increase investment in fixed asset and operational cost. Due to the existence of information asymmetry, Averch-Johnson effect will be triggered [4].

In addition, the setting of permitted revenue is only used to determine the level of transmission and distribution price, and the real revenue and profit of regulated objects depend on the transmission and distribution electricity and cost in reality.

The real revenue of regulated objects is as follows:

$$RVN = R \times S \quad (3)$$

where RVN is the real revenue, and S is the transmission and distribution electricity and cost in reality.

The real profit of regulated objects is as follows:

$$P = R \times S - E - T \quad (4)$$

where E is the real cost of regulated objects, and T is the tax payment for regulated objects.

Based on formula (3)-(4), it is easy to know that the incentive guidance of the cost-based regulation to regulated objects is to reduce cost or increase sales during the regulation period. On the one hand, the incentive to reduce cost has no problem in theory, but there is a lower limit for cost reduction. Exceeding the lower limit will affect the quality of service of regulated objects. Regulation generally also sets standards of service quality, and regulated objects will be punished if it is below certain standards. On the other hand, more transmission and distribution electricity means more revenue, and regulated objects tend to increase the electricity, which makes against the development of distributed generation and the improvement of energy efficiency. The literature [1] pointed out the shortcomings of the cost-based regulation method, including superfluous investment at the early stage, insufficient incentive for energy-saving on the demand side, and excessive regulation cost.

2.2. Cap-based regulation

The motivation for the cap-based regulation is to solve the problem of information asymmetry in the cost-based regulation method, aiming at improving the operational efficiency of natural monopoly regulated objects. Unlike the cost-based regulation, regulators in the cap-based regulation will set a permitted revenue cap or a price cap. The fundamental difference between the two is that the permitted revenue of regulated objects has nothing to do with its cost. This method provides a strong incentive for regulated objects to improve their operational efficiency on the premise of ensuring reasonable revenue, and also reduces the difficulty of regulation in the process of cost supervision [5]. Take the permitted revenue regulation as an example:

$$RVN_{t+1} = RVN_t \times (1 + I - X) \pm Z \quad (5)$$

where RVN_t is the permitted revenue in the base period, I (inflation) is the relevant indicator that reflects the inflation level, X is the target of operational efficiency improvement, Z is used to describe the estimated impact of factors except inflation and operational efficiency on the cost.

By setting a gradually decreasing revenue cap, it is possible to simulate the cost reduction incentive faced by regulated objects in a competitive market environment. In this regulation mode, regulated objects have a strong incentive to reduce its own cost. In addition, the input variables of the cap-based regulation model are pre-predicted parameters, and there is no need to verify the cost of regulated objects, which greatly reduces regulation cost.

In the cap-based regulation mode, the value of X determines the intensity of the incentive for the operational efficiency of regulated objects. However, how to determine the appropriate value is the main difficulty of this method. On the one hand, regulated objects are short of a competitor which makes it lack of reference value. On the other hand, historical data may also have large deviations in the description of the future environment in which regulated objects are located.

According to the practical experience of the cap-based regulation, the main problem is that it is unilateral to emphasize the incentives to reduce costs, and those for the regulated objects to promote technological innovation, achieve public policy goals, and improve consumer satisfaction are insufficient.

2.3. Performance-based regulation

In the context of global power transformation, grid corporations, as managers of transmission and distribution segment, will face more social responsibility requirements. This means that in addition to safe and efficient operation, regulators need to design more comprehensive assessment indices, which will shift the regulations and incentives of costs to the assessment of operational performance, and determine the revenue and profit of regulated objects based on performance outputs.

The performance-based regulation has been widely used in the regulation of power grid corporations in the United States and Europe. The most influential regulation models include the British RIIO (Revenue = Incentives + Innovation + Outputs) and the REV (Reforming the Energy Vision) in New York. In addition, similar practices have been carried out in other countries such as Denmark, Mexico and South Africa. The performance-based regulation aims to align the economic interests of regulated objects with the interests of society. Different from the cost-based regulation to encourage investment in fixed asset, or the cap-based regulation to pay too much attention to economic benefits, the performance-based regulation will reward or punish regulated objects based on whether they achieve their performance targets, accordingly to determine their real revenue level [6].

The design and implementation of the performance-based regulation method is described in detail in the next section.

3. Elements of the performance-based regulation for transmission and distribution prices

Due to the wide differences in systems, policies, and structures between countries and regions, there is no universal regulation method, while there are still rules to follow in the design and implementation. The literature [7] sorts out the general procedure of the implementation of the performance-based regulation on power grid, as shown in Figure 1.

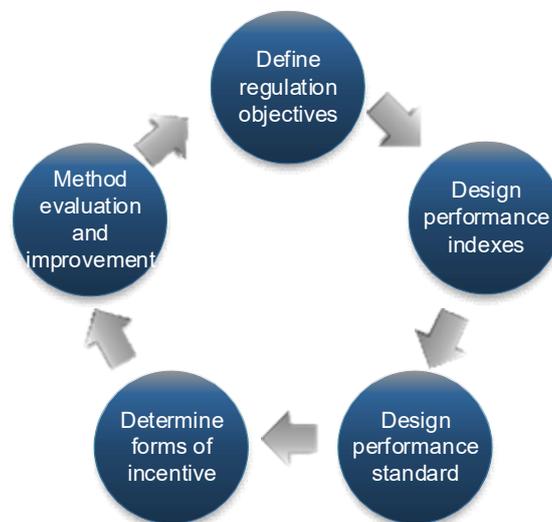


Figure 1. Procedure of power grid performance-based regulation.

It should be pointed out that in the specific implementation process of the performance-based regulation on power grid, there are still a lot of details to be paid attention to, such as ensuring the transparency of the design and the ease of operation. These contents are beyond the scope of this paper and will not be repeated here.

3.1. Determine regulation targets

The first step in implementing the performance-based regulation is to determine targets. Generally, the guiding goals are determined according to the macro policy orientation. Based on this, the directional

incentives and coordinated operational incentives are selected, and the specific measurable performance standards are finally set.

The guiding goals are the macro guidance for regulation, which generally does not include specific measurable performance standards, but the targets must be clear, such as reducing environmental impact, improving economic efficiency, and promoting energy conservation and emission reduction. Targeted incentives set specific and measurable performance standards based on guiding goals. For example, the operational targets include the proportion of renewable energy consumption, and the increase of several percentage points in user satisfaction. In coordination with guiding goals and targeted incentives, the operational targets focus on operation and management, ensuring that the operational level of power system while achieving the guiding goals and targeted incentives. Among them, the measurable performance standards that match the goals and incentives are the benchmarks for judging whether the regulation targets are achieved.

3.2. Design performance indices

Targeted incentives and operational incentives provide measurable performance standards to assess whether the given targets are achieved, and performance indices are the media through which they are evaluated. In other words, performance indices are quantitative assessment indicators used to assess the extent to which regulated objects have achieved the given targets. Literature [7] sorts out performance indices with monitoring and reporting conditions from multiple dimensions (as shown in Figure 2).

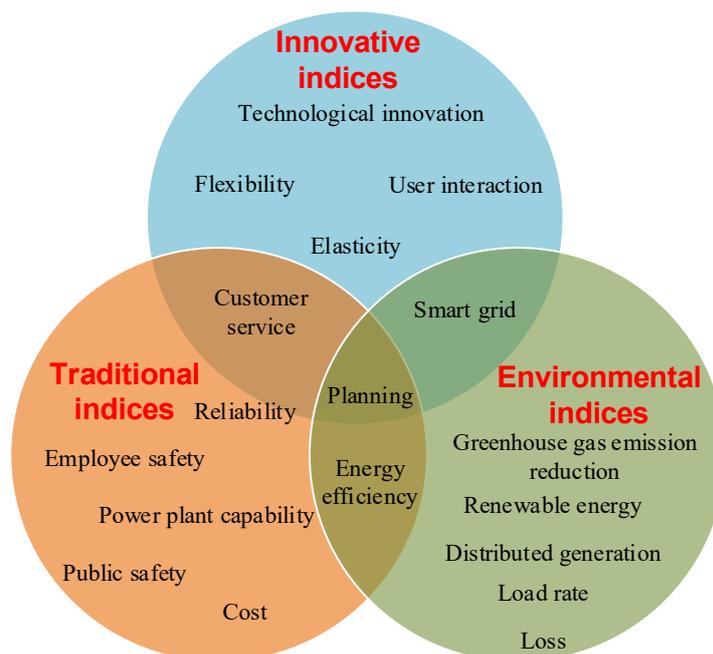


Figure 2. Multiple dimension of performance-based regulation indices.

Traditional indices include power system reliability, employee safety, public safety, power supply costs, etc. Innovative indices include user interaction level, power system flexibility, elasticity, technological innovation, etc. Environmental indices include the access ratio of renewable energy, the reduction level of greenhouse gas emission, etc. There are also overlapping indices in different dimensions, such as planning level, energy efficiency level.

A good performance indices system should have the following characteristics: clearly determined and closely related to regulation targets; ensuring that data is reliable and accessible; ensuring that indices are objective and unambiguous; ensuring that they are within the control of the objects.

3.3. *Setting performance standards*

The performance standards will define the level of performance indices that regulated targets expect to achieve in a given time period. Regardless of whether the performance appraisal results are linked to economic rewards and penalties, the monitoring and publication of performance indices can play a role in stimulating regulated objects.

The setting of performance standards needs to follow some basic principles: compatible with the regulation targets, realistic and feasible, being able to coordinate costs and benefits, and can cope with the impact of uncertainty.

Common methods for setting performance standards include: setting base values based on historical data of regulated objects and data from industry peers. Both methods rely on objective data and are measured using statistical and measurement methods, which is easy to be understood and accepted by the public. In addition to the above-mentioned two methods, there are more complicated engineering calculation methods, such as Frontier Analysis, but they are not widely used due to complicated calculations and large influences on the results.

3.4. *Determine the form of incentives*

Once the performance standards are set, the regulator can determine the incentives and strengths to guide the target to achieve the given performance standards. While other non-economic incentives can also have similar guiding effects (such as publicly releasing performance information to highlight the social responsibility of regulated objects), this section merely focuses on economic incentives (economic rewards and penalties).

The setting of economic incentives needs to be paid attentions: selecting the appropriate incentive calculation formula (linear function, quadratic function, step function, etc.), ensuring that the incentive calculation method is consistent with the performance targets, ensuring reasonable incentives, and avoiding incenting operational effects outside the control range of regulated objects.

4. Typical performance-based regulation method of transmission and distribution price — British RIIO Model

The UK has been at the forefront of power system reform. Since the UK proposed the power market reform in the 1980s, it has completed two rounds of power market reforms so far, having established the Pool mode of the electricity market (1989) and power trading mechanism model (the New Electricity Trading Arrangements (NETA) model in 2001 and the British Electricity Trading Transmission Arrangements (BETTA) model in 2007) [8]. In July 2011, the Department of Energy officially released the White Paper on Power Market Reform (2011), which began to conceive a new round of power market reforms with the promotion of low-carbon generation development. The main contents are as follows: the mechanism of combining fixed electricity price and contract for price difference is introduced for low-carbon generation, performance standards of carbon emission are established for new generator sets, and capacity mechanism is constructed [9].

The British transmission and distribution pricing method is advanced with the electricity reform process. In 1990, the RPI-X cap-based regulation method was implemented. The main purpose is to encourage transmission and distribution operators to improve operational efficiency and reduce power supply costs while ensuring reliability of transmission and distribution. After 20 years of implementation of the RPI-X method, the Office of Gas and Electricity Markets (Ofgem) believes that in those new situations, RPI-X is insufficiently motivated for the sustainable development of power system in the future. Since 2010, based on RPI-X, the new RIIO (Revenue = Incentives Innovation Outputs) model has been adopted for energy network business regulation, and it was officially implemented in 2013.

The RIIO regulation model was proposed to improve on the basis of the RPI-X model in the following areas:

(1) RPI-X pays too much attention to the incentives to reduce costs, resulting in insufficient attention of transmission and distribution operators to operational performance.

(2) Five-year regulation cycle of RPI-X is relatively short and cannot support transmission and distribution corporations to plan long-term transmission and distribution investment decisions.

(3) RPI-X lacks adaptability to rapid technological innovation and needs additional measures to encourage transmission and distribution corporations to actively carry out technological innovation and support the transformation of low-carbon generation.

By implementing the RIIO model, Ofgem hopes to guide the regulated objects to give full play to the role of promoting sustainable energy development.

4.1. Model framework

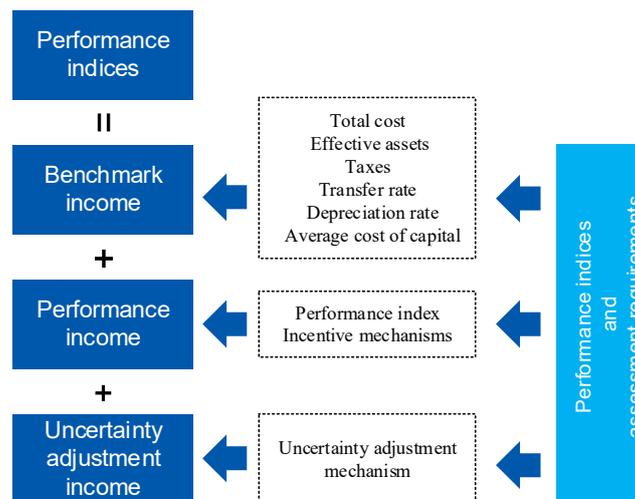


Figure 3. Core factors of RIIO model.

The core factors of the RIIO model [10] are shown in Figure 3, including:

(1) Revenue, which sets the revenue level of regulated objects beforehand, aims to ensure a safe and efficient supply of electricity, to provide a stable cash flow for regulated objects, to ensure transparency and predictability and to balance current and future costs.

(2) Incentive, which incents sustained high-level performance outputs, focus on long-term performance by setting an eight-year price regulation in advance, provides economic incentives based on performance completion and use uncertainty response mechanisms to address uncertainties during price regulation period.

(3) Innovation, which encourages innovation in technology and business models, provides targeted additional economic incentives for technology and business model innovation.

(4) Output, which means an incentive mechanism motivates regulated objects according to performance outputs, enhances the transparency of price regulation, and encourages stakeholder participation by prioritizing performance assessment indices and targets.

4.2. Performance indices

In the RIIO model, six types of performance indices are mainly evaluated:

- (1) Customer experience, which means meeting the requirements of user satisfaction;
- (2) Public safety, which means meeting the requirements of public safety.
- (3) Environmental impact, which means direct or indirect impacts on the environment, such as carbon footprint, low carbon generation and other pollution emission levels, etc.
- (4) User access, which means meeting the timeliness of the generation side and the demand side to access the grid.
- (5) Power supply reliability, which means improving the reliable operation level of power system, such as the duration and the frequency of power outages.

(6) Social responsibility, which means meeting Ofgem's requirements for social responsibility of regulated objects.

4.3. Permitted revenue

Under the regulation of the RIIO model, the permitted revenue of transmission and distribution corporations consists of three parts: the basic revenue, the performance revenue, and the uncertainty adjusted revenue in the regulation period (as shown in Figure 4):

(1) Basic revenue, which means the annual basic revenue in the regulation period based on estimated total cost, transfer rate, return on assets, assets depreciation rate, taxes, etc.

(2) Performance revenue, which means rewards (or penalties) based on the completion of performance indices during the regulation period.

(3) Uncertainty adjustment revenue, which means the amount of revenue adjustment for uncertainties in response to the changes in factors outside the control of regulated objects (such as inflation rate, debt cost, labor cost, etc.).

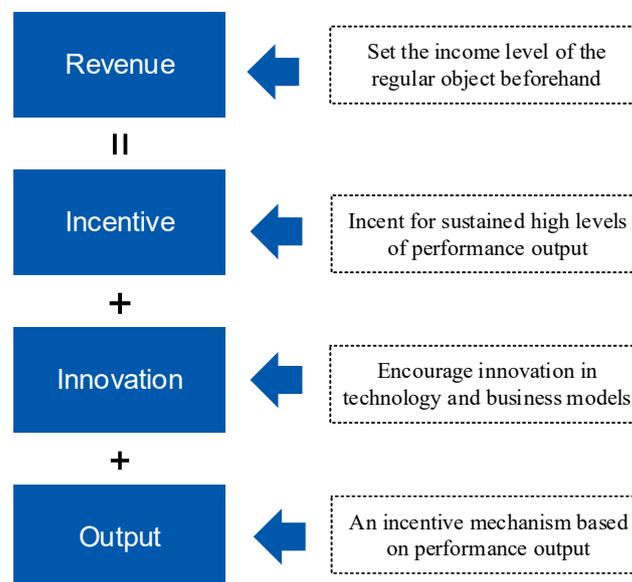


Figure 4. The formation of allowed revenue.

4.4. From RIIO-1 to RIIO-2

The first regulation period of the RIIO model (RIIO-1 for short) will expire in 2021 (RIIO-T1 for transmission companies) and 2023 (RIIO-ED1 for distribution corporations). As of 2018, RIIO-1 has fulfilled its given mission in terms of its real operation results. In the condition of better control of investment level, the performance outputs of transmission and distribution corporations have significantly improved. However, there are still some problems: the rate of return of the transmission and distribution segment is still high, and the transmission and distribution costs still account for a large proportion in the entire power supply value chain [11].

In response to solve the existing problems and meet the requirements in new situations, Ofgem convened stakeholders in March 2018 to conduct consultations and discussions on how to reasonably set the level of profitability, capital cost, and regulation cycle, and began planning the regulatory regime for the second regulatory period of RIIO (RIIO-2 for short) and the RIIO-2 regulatory scheme was announced in July 2018 [12]. Among them, the main revisions include adjusting the regulation cycle from eight years to five years, further enhancing user participation, driving innovation and efficiency, simplifying the price regulation process, and providing a reasonable return on capital.

It can be seen that in order to adapt to the uncertainties introduced by the power system transformation, the regulation method of power grid performance is also evolving. Grid corporations need to closely follow and participate in the formulation of regulation methods to achieve the given regulation targets.

5. China's current situation of performance-based regulation method of transmission and distribution price

In the background of the new round power system reform, China verifies the transmission and distribution price based on the principle of "permitted cost plus reasonable revenue". According to the "Measures of the Pricing for the Transmission and Distribution Price of Provincial Power Grid", the average power transmission and distribution price (including VAT) of the provincial power grid = permitted revenue (including VAT) \div transmission and distribution electricity of common power grid, of which, permitted revenue = permitted cost + permitted profit + tax within the price. Figure 5 shows the detailed measurement method for the average transmission and distribution price.

In the aspect of form, China's transmission and distribution price verification method belongs to the category of the cost-based regulation. Based on the verification mode of transmission and distribution price of "permitted cost plus reasonable revenue", the grid corporation will be protected from coal price fluctuation and market competition, obtain relatively stable transmission and distribution revenue, and ensure the sustainable development of the power grid. However, different values of pricing parameters such as depreciation rate, operation and maintenance rate, line loss rate, and return on equity will significantly affect the operating efficiency of grid corporations [13].

In the aspect of design, China's transmission and distribution price verification method also leaves space for performance evaluation. The "Measures of the Pricing for the Transmission and Distribution Price of Provincial Power Grid" states: "Regions with appropriate conditions shall establish the adjustment mechanism of transmission and distribution price for assessing the reliability rate of power supply and service quality of grid corporations. Government price authorities can appropriately adjust the permitted revenue for the next regulation cycle based on the assessment results of government energy authorities. If the reliability of supply and the quality of service exceed the level of the prescribed standards, the permitted revenue for the next regulation cycle may be appropriately increased. If the prescribed standard is not met, the revenue in the next regulation cycle shall be decreased."

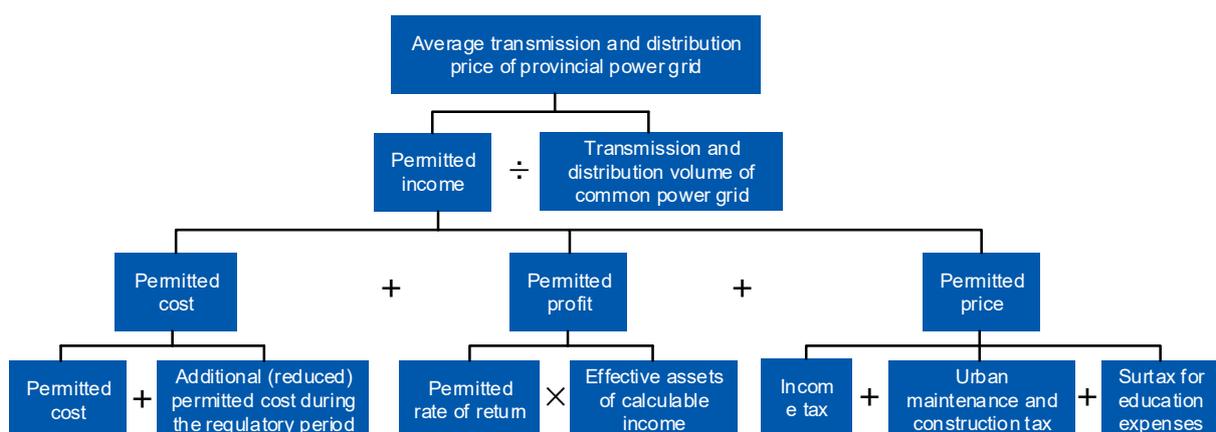


Figure 5. Calculation method of average transmission and distribution price for province-level power grid.

6. Conclusion

Internationally, there has been a shift for transmission and distribution price regulation methods from the reduction of costs and the improvement of efficiency into multi-target performance-based regulation to meet the challenges faced by the power industry in the context of energy transformation. User satisfaction, safety, reliability, environmental impact, and social responsibility have become the emphases of regulation of transmission and distribution corporations in the United States and Europe.

In the context of the new round of power system reform, China verifies the transmission and distribution price based on the principle of “permitted cost plus reasonable revenue”. On the basis of the cost-based regulation, the elements of the performance-based regulation are incorporated, and it is probable that it will gradually convert into the performance-based regulation in the future.

The performance-based regulation encourages transmission and distribution corporations to consider long-term development and helps them to consider sustainable development goals. In terms of transmission and distribution investment, in order to provide management and technology reserves in advance for the performance-based regulation of transmission and distribution prices, it is necessary to expand the time scale for assessment, consider the uncertainties in related fields, and comprehensively evaluate the investment benefits from the aspects of safety, reliability, economic efficiency, green and low-carbon to improve the long-term competitiveness of transmission and distribution corporations.

Acknowledgments

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