Research on Capacity Compensation Mechanism Based on Fixed Investment Cost of Power Generation Enterprises

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Abstract. With the increase of the proportion of renewable energy and the promotion of spot market, the fixed cost recovery of thermal power enterprises faces greater difficulties and the willingness to invest in power generation decreases, which brings risks to the safe and reliable operation of the power grid and the healthy and orderly development of the market. This paper proposes a capacity compensation method based on the fixed investment cost of power station, which can provide a simple and easy-to-operate compensation scheme for the fixed investment cost recovery of power generation enterprises. Since the revenue already earned by power enterprises is deducted from the capacity compensation cost, it can effectively avoid the problem of over-compensation to power generation enterprises and realize the linkage between capacity compensation revenue and real-time market revenue.

Keywords: capacity compensation · fixed investment cost · power station

1 Introduction

The current power supply and demand in China is in a phase of tightening trend. 2022 since the beginning of summer, many places with a record high electricity load, power supply security difficulties gradually highlighted. As the installed capacity of renewable energy further increases, the difficulty of power supply will be further increased due to the intermittent nature of its available power output and the outstanding power balance problem during peak hours of the system. 2021 Since the third quarter of the year, due to the increase in coal prices, coal power companies are having difficulties in operation and their willingness to generate electricity has decreased. During the "14th Five-Year Plan" period, the rise in carbon prices will further push up the cost of coal and electricity, coupled with the impact of financial institutions to withdraw loans and other factors, the contradictions of coal power development will be more prominent.

China's energy resources endowment to coal-based, installed coal power in the power supply to play a "basic plate" role. If the coal power large-scale, too fast out will give the power system security and stability and market construction and development of adverse

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effects, must take into account the security, promote transformation and other multiple factors for scientific planning, system design. The relevant government departments have been studying the development of capacity mechanisms related to policy rules, but in the framework of a unified market, for the near-term and medium and long-term capacity mechanism design is still lack of in-depth analysis and systematic research.

2 The Importance of Developing Generation Capacity Compensation

First, to promote the "double carbon" development, the near to medium-term coal power indispensable, the need to fully recover the fixed costs to ensure the security of power supply. Since the second half of last year, the global energy supply security problems, many European countries restarted nuclear power and coal power. China, as a major coal country, in the face of the unprecedented global changes, in the transition phase of green and low-carbon energy transition, we must continue to play the role of coal power safety and security of supply, and help coal power to recover the fixed costs, solidify the adequacy of coal power supply, to ensure the steady realization of the "double carbon" development goals, to build "Energy Power" to lay a solid foundation [1].

Second, the increasing penetration of renewable energy, the need to increase investment incentives for flexible regulation of power to ensure reliable supply [2]. China's installed capacity of renewable energy has been the world's first, the future in the "carbon peak, carbon neutral" national strategy guidance, renewable energy will continue to maintain high growth. Wind power, photovoltaic and other renewable energy output is affected by the characteristics of resources, with random, intermittent fluctuations and anti-peak characteristics. With the increase of the scale of renewable energy to the grid, the contradiction of insufficient peak and frequency regulation capacity of the system becomes increasingly prominent, and the difficulty of safe operation and balance regulation increases significantly. The demand for flexible regulation of the power system is growing, and must be satisfied in a reasonable way.

Third, the power generation and consumption plan is gradually liberalized, and the fixed cost recovery of power generation enterprises lacks stable expectations. With the deepening of the electric power system reform, coal-fired power plants on the grid benchmark tariff, the implementation of the "benchmark price + up and down floating" mechanism, both sides of the volume and price open degree greatly increased, the allocation of power resources from the plan to the market change. With the withdrawal of "planned power" and government pricing, the utilization hours of coal power in China have been declining significantly, and power generation enterprises have lost the relatively stable fixed cost recovery guarantee, which has significantly increased the investment risk and intensified the contradiction of insufficient regulatory power generation capacity.

Fourth, the spot market is accelerating, and the spot price based on short-term marginal cost is difficult to fully recover the fixed cost of thermal power. In accordance with the work requirements of the National Development and Reform Commission [3], the first batch of eight provincial spot market pilot has been carried out settlement trial run [4], the second batch of six spot market pilot is actively preparing for the first round of trial run work, spot pilot range gradually expanded. Based on short-term marginal

cost bidding to form the spot price, the long-term can not be complete recovery of all fixed costs. Especially with the rising share of wind power, photovoltaic, etc., short-term marginal cost of power generation continues to reduce, thermal power and other traditional power sources and renewable energy "on the same stage", further increasing the difficulty of fixed cost recovery.

Overall, in the context of global energy supply tension, power security requirements highlighted, with the renewable energy accounted for the increase in the proportion of electricity generation, electricity generation plan liberalization, spot market promotion, thermal power companies face greater problems of fixed cost recovery, power generation investment will be reduced, for the safe and reliable operation of the power grid, the healthy and orderly development of the market brings risks [5]. Therefore, China's power market construction should consider exploring the establishment of a capacity guarantee mechanism [6], fully recovering capacity costs, stimulating conventional thermal power investment and construction, and guiding thermal power enterprises' flexibility transformation, so as to guarantee the new power system's generation capacity adequacy, regulation capacity and operational safety, and promote the implementation of carbon peak and carbon neutral strategic goals.

3 Typical Experience of Foreign Capacity Guarantee Mechanisms

From the perspective of international countries and regions with electricity spot market, the generation capacity adequacy mechanisms implemented to solve the problem of difficult recovery of fixed investment costs of power generation enterprises mainly include capacity market mechanism (U.S. PJM power market), scarcity pricing mechanism (U.S. ERCORT power market), reliability option mechanism (Italy, Ireland), capacity compensation mechanism (Spain, Chile), strategic backup mechanisms (Belgium, Germany, Sweden), etc.

Since China's electricity users are mostly small and medium-sized users with low market awareness, they do not have the ability to hedge in the market of electricity finance and derivatives, and they are used to using electricity at a stable price level and are very sensitive to electricity price fluctuations. If the use of scarcity pricing mechanism will lead to large fluctuations in electricity prices, it is likely to cause a wide range of social opinion risk, affecting the promotion of electricity market reform. On the other hand, the strategic standby mechanism will reduce the willingness of old units to carry out flexibility transformation and participate in the market, and has a crowding-out effect on clean, low-carbon and efficient units, reducing the overall social benefits, so it is not suitable for China's development situation. In summary, combined with the rapid change of China's power supply structure and the main preference of each market player for low-risk cost recovery methods, we can consider starting with capacity compensation mechanism and gradually promoting the construction of capacity market in the future.

4 Generation Capacity Compensation Method

Currently, China's Shandong Province has implemented a capacity compensation mechanism for coal-fired generating units, renewable energy sources, and independent energy

storage participating in spot trading using the fixed cost method. By collecting capacity compensation funds from the customer side at a capacity tariff of 0.0991 RMB/kWh, and then sharing the compensation amount on the generation side based on available capacity. Considering the current economic downturn, recovering this cost from end-users will increase the operating pressure of commercial and industrial users if over-compensated to power generation companies, a new capacity compensation mechanism is proposed to calculate the capacity compensation cost. The core idea of this method is to exclude the costs already recovered by the power plant from the electricity energy market and the ancillary services market, and compensate only the unrecovered fixed costs of power generation. The energy market and ancillary services market include both market-based revenues and non-market-based revenues, such as participation in the Priority Generation Program or compensation under the two rules. The specific calculation formula is as follows.

$$\begin{aligned} &\textit{Total annual compensation cost} \\ &= \textit{Annual fixed costs to be recovered} - \textit{Annual operating income} \end{aligned} \tag{1}$$

$$\begin{aligned} &\textit{Annual fixed costs to be recovered} \\ &= \textit{Annual fixed investment cost recovery} + \textit{Annual fixed operating costs} \end{aligned} \tag{2}$$

$$\begin{aligned} \textit{Annual operating revenue} = {} & \textit{Annual energy revenue} \\ & + \textit{Annual ancillary services revenue} \\ & - \textit{Annual variable operating costs} \end{aligned} \tag{3}$$

$$\textit{Annual fixed investment cost recovery} = \frac{\textit{Unit fixed investment} \times \textit{Discount rate} \times (1 + \textit{Discount rate})^{\textit{Depreciation life}}}{(1 + \textit{Discount rate})^{\textit{Depreciation life}} - 1} \tag{4}$$

The calculation steps of the proposed method are as follows.

(1) Select the apportionment level year of the fixed costs of the recovered units and, after considering the depreciable life of the historical new units, obtain the starting year of the fixed investment costs of the historical new units to be apportioned.
(2) The fixed investment cost of each year of new units from the starting year to the apportionment level year is discounted to the apportionment level year and then added to the fixed operating cost of the apportionment level year to obtain the total annual fixed cost.
(3) Calculate the annual variable operating costs, annual electric energy revenue and annual auxiliary service revenue for the apportioned level year, and subtract the annual electric energy revenue and annual auxiliary service revenue from the total annual fixed costs plus the annual variable operating costs to obtain the total annual compensation cost (unrecovered fixed costs).
(4) Divide the total compensation cost by the electricity consumption of the marketed customer in the year, that is, to get the capacity compensation fee for the marketed customer in kilowatt-hour rate.

(5) After deducting the amount of thermal power generation that exceeds the depreciable life, the generation companies will be compensated according to the percentage of generation capacity.

5 Test Results and Discussions

Assume that the permitted rate of return for capacity recovery of thermal power units is 8%, the unit fixed investment cost is RMB 3722/kW, and the unit fixed operating cost is RMB 348.5/kW.

(1) Calculate the fixed cost to be recovered
Taking 2021 as the target year, the depreciable life is 19 years, so each new coal power installation from 2001 (including 2001) will have fixed investment cost recovery demand in 2021. Discounting the investment cost of all new coal power units from 2001 to 2020 to 2021 (31.372 billion yuan), plus the unit fixed operating cost (34.719 billion yuan), we get the fixed cost to be recovered in 2021, which is about 66.09 billion yuan.

(2) Calculate the total annual compensation cost.
The total revenue of thermal power enterprises in a pilot province participating in market-based trading of electricity energy, non-market-based trading and auxiliary service trading in 2021 is 15.445 million yuan, and the variable operating cost of thermal power in 2021 is 122.44 billion yuan, so the annual operating revenue in 2021 is 32.01 billion yuan. After deducting the annual operating revenue from the fixed costs to be recovered in 2021, the total annual compensation cost in 2021 is 34.08 billion yuan.

(3) Measurement of customer-side capacity cost standard
Assuming that the unrecovered fixed costs are shared among all marketed customers in 2021, after dividing the unrecovered fixed costs by the electricity consumption of marketed customers, we can get the customer-side capacity compensation unit cost of 0.109 yuan/kWh.

(4) Sensitivity analysis of core parameters
The permitted rate of return for capacity recovery of thermal power units has a great impact on the recovery of fixed costs by thermal power enterprises. The permitted rate of return for equipment recovery is 8%, the permitted rate of return for pumped storage capacity tariff approved by NDRC is 6.5%, and the permitted rate of return for cross-provincial and cross-regional special transmission projects is 4.9%, as stipulated in the financial decision indicators for quality investment in China's power industry. The following is a sensitivity analysis of the permitted rate of return on capacity recovery of thermal power units by taking values between 5% and 8%.

As can be seen from the Fig. 1 and Fig. 2, the total annual compensation cost and the customer's share of cost per unit of increase continuously as the permitted rate of return on unit capacity recovery increases. Therefore, when formulating the capacity compensation mechanism, each province needs to choose the appropriate unit capacity recovery permitted rate of return according to the affordability of price increase on the customer side of the province.

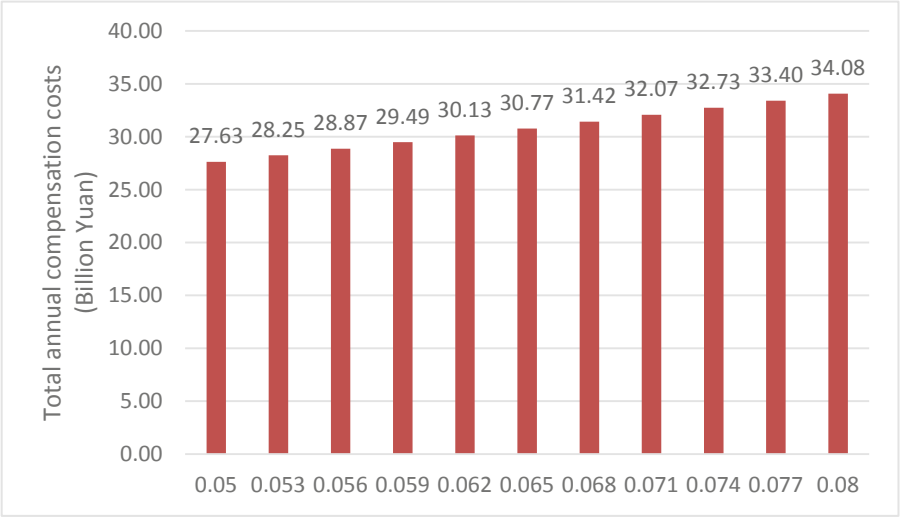

Fig. 1. Annual compensation expenses for different asset yields

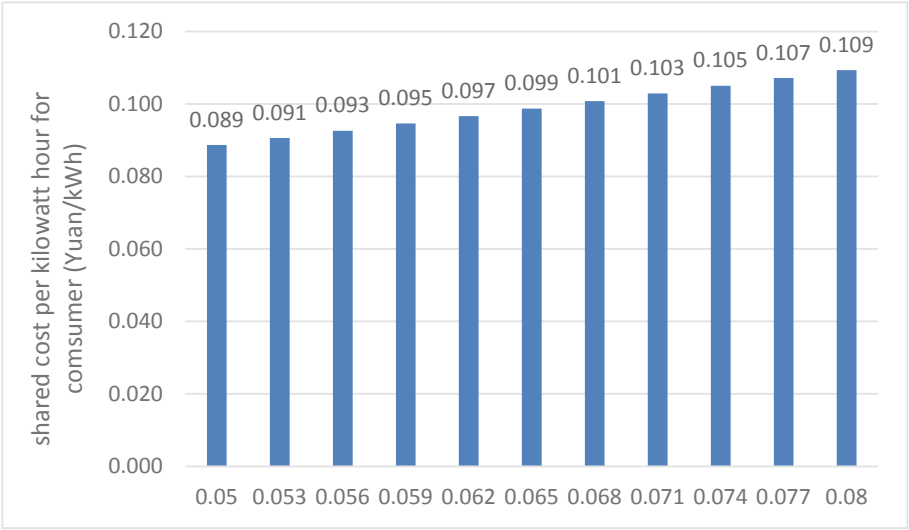

Fig. 2. Shared cost on consumer for different asset yields

6 Conclusion

The method proposed in this paper takes into account the fixed costs that have been partially recovered through the electricity energy market and auxiliary services market, and the capacity compensation cost only compensates the unrecovered part of the fixed costs, so the calculation results are more reasonable and can effectively prevent the increase of the customer's terminal electricity price caused by overcompensation. This

paper does not take into account the changes in discount rate during 2002–2020, and uses 8% as the uniform calculation. In fact, the risk-free interest rate, risk compensation, and inflation associated with the discount rate have fluctuated significantly over the past 20 years. In the future study, the average discount rate of the year in which the investment cost is incurred will be discounted separately in a reasonable manner to further improve the accuracy of the proposed method.

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