Research on European capacity cost recovery mechanism and its experience to China’s power market construction

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Abstract. This paper makes an in-depth study of generation capacity cost recovery issues that have been, or are being faced, in European countries and summarizes its experience to China during the construction of competitive power markets. Firstly, the paper explains the idea and principle of capacity cost recovery mechanisms in EU, which are policy instruments to ensure adequate investment in generation capacity, then analyses the obstacles to the realization of capacity cost recovery in the energy-only market. Then, the paper divides the European capacity cost recovery mechanism into five categories: strategic reserve, capacity obligation, capacity auction, reliability option and capacity payment, and expounds the operation flow of the mechanisms respectively in detail. Thirdly, the paper studies the possible impact of the capacity cost recovery mechanism on the electricity market. Finally, the paper summarizes the practical experience of European capacity cost recovery mechanisms and lay a foundation for the design of generation capacity cost recovery mechanism in China.

1. The European Union on The Capacity Cost Recovery Mechanism
With a growing share of renewable energy installations, some EU member states are increasingly concerned that in the future the electricity market will not provide enough installed capacity to meet load demand, that is, the so-called long-term generation capacity insufficiency. Given the political sensitivity of power outages, some member states have intervened by introducing capacity cost recovery mechanisms to provide additional incentives for investors and to ensure that sufficient installed capacity is available in the market.

The purpose of a capacity cost recovery mechanism is to provide market participants with more effective incentives than energy-only electricity market: it can provide investors with a more defined source of income. However, to some extent, the capacity cost recovery mechanism will also make investors' income much higher than the income in the energy-only electricity market, which means that the capacity cost recovery mechanism may bring additional costs to consumers [1].

2. Capacity Cost Recovery in The Energy-Only Electricity Market
In an energy-only electricity market, the operating costs (such as fuel costs, start-up costs) and investment costs of generators can be recovered only through the market clearing price and the ancillary service fee. In most cases, it can be assumed that the available installed capacity in the power system is in excess of load requirements. In these times, assuming that the market is fully competitive and that
there is no limit to the fluctuation of the market clearing price, when the market is cleared, the market clearing price will tend to reflect the variable cost of the most expensive unit, namely the marginal unit, therefore, the base load and waist load units whose operating cost is lower than the market price can recover their variable operating cost, and their fixed cost can be recovered by the difference between the market price and the unit variable cost. At some point, however, the difference between available capacity and peak-load demand is small, that is, the supply is tight, and the price far exceeds the marginal operating cost. At this point, the price includes a ‘scarcity premium’. In this rare case of capacity shortage, the system will appear extremely high price, may reach the value of lost load (Voll). At these times, all the units will be able to recover certain fixed costs through high electricity prices [2].

In an energy-only electricity market, market designers expect frequent scarcity prices to attract new investment and prevent existing installed capacity from exiting the market. Otherwise, when scarcity prices occur less frequently, peak-load units may be withdrawn from the market without replacement capacity, which would result in a reduction in the available generation capacity, thereby increasing the frequency of scarcity prices. Through the price formation mechanism, the best economic installed capacity level is determined by the interaction between available capacity and demand. Therefore, in an ideal energy-only market, the adequacy level of installed capacity is determined by the market.

However, there are many problems in the application of the scarce electricity price mechanism. The most obvious one is the political unacceptability of high electricity prices, which directly promotes the intervention of EU member states, for example, by introducing a capacity cost recovery mechanism to reduce the frequency and level of price spikes.

3. Classification of Capacity Cost Recovery Mechanism
At present, many kinds of capacity recovery mechanisms have been put forward in the advanced countries of electricity market. Different capacity recovery mechanisms can be divided into the following five categories: strategic reserve mechanism, capacity obligation mechanism, capacity auction mechanism, reliability option mechanism and capacity payment mechanism [3].

3.1. Strategic reserve mechanism
In the strategic reserve mechanism, some generation capacity will be set aside to ensure the reliability of power supply in exceptional circumstances, which can be defined by the rise of market price to a certain threshold level in the day-ahead, day-ahead or balancing market. In the strategic reserve mechanism, it is often for the transmission system operators to decide how much capacity to reserve to meet the system's adequacy requirements, and to dispatch capacity resources when the system needs. The procurement of capacity resource is usually determined one year in advance, through bidding and at the consumers’ expense.

3.2. Capacity obligation mechanism
The capacity obligation mechanism is a decentralized mechanism whereby the final demand for capacity is determined by all market participants, rather than by transmission system operators alone. In the capacity obligation mechanism, large customers and load serving entities need to undertake and sign the capacity corresponding to their self-assessment of future power demand or power supply obligations. In contrast, when capacity demand levels are determined by an independent agency, large customers and load serving entities are required to sign up for capacity that is generally higher than the expected level of future demand or supply obligation. An obligor may perform its obligations through its own power plant, by signing a contract with a capacity resource, or by purchasing a tradable capacity certificate. The contracted power generator must provide the contracted capacity to the market during the period of capacity shortage, otherwise it may result in penalty. The capacity shortage is determined by the market operator separately or when the market price rises above the threshold level. In addition, a secondary market for the transfer of capacity certificates could be established to facilitate the transaction of capacity certificates between the generators and the obligors.
3.3. Capacity auction mechanism
Unlike the capacity obligation mechanism, the capacity auction mechanism is a centralized mechanism, in which the required total capacity is set by the market operator several years in advance, and the required capacity is obtained through the forward centralized auction. Capacity fees are charged by load serving entities from the consumers and the contracted capacity shall provide the required capacity support as required by the terms of the contract.

3.4. Reliability option
Reliability options can be understood as call options, in which the contract generator has to pay the difference between the wholesale market price (such as the spot price) and the pre-set reference price (that is, the exercise price), as long as the difference is positive. In exchange, the contractors receive fixed fees and more stable and predictable revenues. Under the reliability option mechanism, when the supply and demand is tight, the incentive for the generators to provide capacity comes from the high market price on the one hand, and on the other hand, if the contracted capacity is not available, generators have to pay the cost of the reliability option without any income from the market. The holder of the reliability option effectively controls the purchase price under the exercise price, because every time the market price rises above the exercise price, the excess will be offset by the reliability option payment. Depending on whether the scheme is purely financial or whether the contract generator should have and provide physical capacity when exercising the option, different forms of reliability options can be designed. In the latter case, the reliability option mechanism is similar to the capacity obligation mechanism.

It should be noted that the exercise price level of reliability option is usually much higher than the exercise price of the option contract that can be bought in the market and used to hedge the risk. Therefore, although the nature of the contracts are options contracts, but the use of reliability options and market options contracts are completely different.

3.5. Capacity payment mechanism
The capacity payment mechanism is to pay a fixed price for the available capacity of the generators. The fixed price is determined by the market operator and the amount of capacity supply is determined by the behavior of the market participants themselves.

4. The Application of Capacity Cost Recovery Mechanism in European Countries
At present, most EU member states implement capacity cost recovery mechanism at the national level based on their own actual conditions, among which Germany, Sweden, Finland, Belgium, Poland and other countries adopt strategic reserve mechanism, Italy, Portugal, Spain, Greece and other countries use the capacity payment mechanism, France and the United Kingdom use the capacity market mechanism. EU member states achieve different policy objectives through capacity cost recovery mechanisms, such as addressing flexibility, reducing investment risk and avoiding price volatility, in addition to ensuring system capacity adequacy. In addition, member states can use capacity cost recovery mechanisms to encourage demand response resource development [4].

5. The Influence of Capacity Cost Recovery Mechanism on Electricity Market
As with all policies and measures, the design or implementation of capacity cost recovery mechanisms may have an impact on electricity markets. First, the capacity cost recovery mechanism can affect the price in a short time, which has an impact on the power plant production decision-making and cross-regional competition. Second, in the long run, the capacity cost recovery mechanism may potentially affect investment decisions [5].

The opinion on the capacity market, issued to the Industry, Research and Energy Committee of the European Parliament by the European Union's Cooperation Agency for energy regulators indicates that ‘It is essential that any such capacity cost recovery mechanism be designed so as not to unduly disrupt or distort the operation of the electricity market and not to delay the realization of a pan-European
electricity market. In fact, it would be ideal if any market design designed to promote capacity adequacy or flexibility worked only if the electricity market did not provide sufficient incentives for investment, while minimizing the impact on electricity markets at other times.’. In this regard, a key factor in the design of capacity cost recovery mechanisms (including strategic reserves, capacity obligations and reliability options, etc.) is the exercise price.

In principle, the exercise price level can be used to judge the normal market situation and the serious shortage of power supply. It is clear that the exercise price should be set below the value of the load loss and well above the price level under normal market conditions, including moderate tight supply, i.e., well above the operating costs of the most expensive generator in the market. In theory, the exercise price should be set at the price level under the condition that the supply is seriously deficient and the further price level may reach the value of load loss. Given the political acceptability of very high prices, the exercise price should generally be set at the highest politically acceptable price level.

5.1. Short-term impact
Cross-regional competition and short-term distortions at the wholesale market may be affected when regional capacity-cost recovery mechanisms do not take into account or do not take sufficient account of installed capacity outside the region.

For example, the short-term distorting effect of capacity cost recovery mechanisms on the Finnish-Russian border. The Finnish and Russian electricity markets are connected by three 400 kV transmission lines (two DC lines and one AC line) with a total transmission capacity of 1400 MW. The capacity cost recovery mechanism in Russia was established when market liberalization began in 2006 and became fully operational in 2011, thus creating stable income for investors and helping existing power plant recover fixed cost. In order to recoup the total monthly capacity costs of about 200 euros per megawatt per day in the north-west of Russia, an additional charge is levied on all domestic demand and electricity exports during peak hours, so if the price difference between Russia and the Nordic Electricity Market (Finland) is less than the cost of the capacity, the electricity will not be exported. After 2011, when Russia’s capacity cost recovery rules to handle energy imports and exports came into effect, cross border electricity transactions from Russia to Finland fell by a third at some peak hours of the day. In addition, because the generation companies in the market with the capacity cost recovery mechanism get the capacity compensation, and the way to determine the compensation will affect the bidding decision of the generation companies in the electricity energy market, however, the uncompensated generators in the energy-only market will not be affected, which may make the competition environment of the generators in the two markets different.

5.2. Long-term impact
The research shows that once the capacity cost recovery mechanism is implemented, it will become the main driving factor for the investment of new generation capacity. In the strategic reserve or capacity obligation mechanism, the upper limit of market price is actually limited to the threshold price level. If the threshold price is set too low, the increase of market price will be limited and the scarce price signal of market supply will be hard to find. This has led to a reduction in the average revenue of power producers, which in turn has discouraged investment in power generation, which in turn has increased the scarcity of the market.

In addition, if capacity cost recovery mechanisms do not take into account the contribution of installed capacity across regions when addressing the issue of adequacy, they may lead to excess capacity and over-procurement, which may have a negative impact on consumers. Participation in capacity cost recovery mechanisms across regions does not necessarily require that cross-region capacity be set aside. However, there is a need for strong coordination of national power supply reliability policies and other conditionalities. One is the ability of the transmission system operator to monitor the actual availability of capacity resources committed by out-of-area generators over the term of the contract, moreover, the out-of-area power suppliers can meet the same standards as the local power suppliers in terms of reliability of power supply, in particular, within the time frame of the day-
ahead, intraday and balancing market; and third, the participating regions need to agree to the signing of contracts by regional power producers to ensure the reliability of electricity supply from neighboring member states, it also guarantees that the export of contracted generators will not be hindered. That is to say, when the regional power supply cross-regional capacity (especially when both sides are tight), transmission operators can not deviate from the rules to take care of the local market region.

6. Experience to China

China has been undergoing a whole new round of electricity system reform which began with the State Council No.9 Document entitled “Several Guiding Principles of Furthering the Reform of the Electricity Market” of March 2015. Like the power reforms and deregulations in other countries, one of the key contents of the electricity system reform is to establish a competitive electricity wholesale market and set up a mechanism in which the electricity prices are mainly determined by the power market. The goal of the electricity system reform is to establish an electricity market that managers the market risks through medium and long-term power transactions, discovers electricity prices in the spot market, and has variety of power transactions and complete market functions, and this market will help to improve electricity resource allocation efficiency, and ensure the electricity demand will be met in a safe, clean and reliable way in the future.

Since the beginning of the new round power system reform, the power market deregulation has achieved significant progress and the competitive market construction developed rapidly, among which the medium and long-term power transaction, which use a direct purchase contract specifying the volume and price of the electricity sold by a generation company and purchased by the grid company, retailer, or large customer, has increased dramatically in the previous years. At the same time, the power prices in most provinces (province-level municipalities, autonomous regions) have dropped significantly, comparing to the government pricing under the equal allocation dispatch scheme, as the whole electricity industry has been experiencing an overall power supply surplus during that time. At that stage, the generation units in most provinces (province-level municipalities, autonomous regions) were relying on non-market electricity generation and government pricing to compensate the cost of generating capacity. However, as the scale of market electricity continues to expand, the non-market electricity will become less and less, and it will be quite difficult to recover the cost of generating capacity through non-market electricity and government pricing for the generation companies, and therefore the normal operation of the generating units and power market will be affected. Hence, it is urgent for the policymakers to explore and establish a whole new generating capacity cost recovery mechanism.

On the other hand, electricity medium and long-term market transactions are energy-only market transactions, which cannot reflect the characteristics of real-time balance of electricity production, electricity supply and electricity demand. The energy prices formed by the competitive medium and long-term market will be constant for a certain period after the market clearing, which cannot show the generating cost difference of electricity production, as well as the value difference of electricity consumption at various time periods. However, different types of generation units provide differences productions and services for the power system, which require diversity in reasonable cost compensation mechanism for those generation units. But the above energy price mechanisms ignore the contribution differences for the system and give all unit the similar returns. On the power demand side, this price mechanism provides a flat price curve during a whole day and cannot incentive the end users to consume less power during peak hours.

Therefore, the electricity market with only medium and long-term power transactions is far from a real competitive and complete electricity market. Besides, this kind of market will meet its difficulties during further scale expansion, which cannot lead the power market to its sustainable development.

In order to promote the further development of the competitive power wholesale market, it is imperative to establish the power spot markets, which reflect the characteristics of real-time balance of electricity supply and electricity demand and are viewed as the key sticking point to improving power allocation efficiency and reducing emissions in the power sector. The spot markets allow exchange of energy on a day-ahead and real-time basis. Up to now, there have been 8 pilot projects for the
construction of power spot markets in China, most of which are provincial markets at this moment, and simulation trials have been carried out one after another lately. The accelerated construction of the electricity spot markets have made the requirement of establishing generation capacity cost recovery mechanisms more urgent in these pilot areas. According to the classical electricity spot market theory, the short-term marginal costs of power generation units are the main determinant factors when they participate in the spot market. However, the spot market price of electricity will bring about the lack of effective recovery mechanisms for the fixed cost of the marginal generation unit in the market, as well as more uncertainty of fixed cost recovery mechanisms for other generation units participating in the spot market.

In the case of China, it is particularly important to establish a long-term generation capacity guarantee mechanism to achieve the secure and stable electricity supply, in addition to secure access to fuels such as coal or natural gas and a well-developed electricity network infrastructure. Unlike those developed countries, whose electricity demand has entered a low-speed growth stage because of their saturation development, China's electricity demand is expected to maintain medium-to-high-speed growth, which can support the high-quality development of the national economy in the future. Although there is no shortage of secure generating capacity in China currently, the secure generating capacity available exceeds the demand for electricity have been written down at peak demand times even due to the relatively low demand for electricity resulting from the COVID-19. However, China's main incremental power generation sources are expected to be hydropower, nuclear power and thermal power over the next years, whose construction periods are generally longer. If there is no supporting long-term generation capacity guarantee mechanism, there will inevitably be a shortage of power supply.

In addition, with the rapid development of renewable energy that generally shows varying electrical generation, the number of utilization hours in a year of traditional power generation units will continue to decline year by year, which also declines the revenue and profits of traditional generation units form generation. The participation of renewable energy in the power spot market competition may further reduce electricity prices, which will further increase the difficulty of recovering fixed costs through the spot market for traditional power generation units in the power market. Therefore, when designing and constructing the power spot market, it is absolutely necessary and extremely important to plan and establish a supporting generation capacity cost recovery mechanism simultaneously, which will guide rational investment in power generation sources, and make certain that long-term sufficient power generation capacity shall be the case, as well as ensure the smooth progress of China's power market reform and long-term safe and stable power supply.

China’s power markets are developed on a province-by-province basis. Due to its vast size in territory, the economic development level, power mix, load characteristics, electricity supply and electricity demand conditions of each province show huge differences, hence it is very difficult to establish a simple and unified power generation capacity cost recovery mechanism. As shown above, there are many types of generation capacity cost recovery mechanisms crossing the European countries, including Strategic Reserve Mechanism, Capacity Obligation Mechanism, Capacity Auction Mechanism, Reliability Option and Capacity Payment Mechanism, etc., and they can provide a lot positive and significant reference for China to explore and establish its generation capacity cost recovery mechanisms those meet its own requirement and characteristics.

7. Conclusion
This paper studies the European capacity cost recovery mechanism, introduces the definition of capacity cost recovery mechanism in the European Union, and analyzes the reasons why the cost recovery of generation capacity cannot be guaranteed under the energy-only market. Subsequently, the paper investigates the design of five types of capacity cost recovery mechanism, and analyzes the impact of capacity cost recovery mechanism on electricity market in short-term and long-term. Finally, the paper summarizes the practical experience of European capacity cost recovery mechanisms and lay a foundation for the design of generation capacity cost recovery mechanism in China.
References

[1] Byers C, Levin T, Botterud A. Capacity market design and renewable energy: Performance incentives, qualifying capacity, and demand curves [J]. Electricity Journal, 2018, 31 (1): 65 - 74.

[2] Milligan M, Frew B A, Bloom A, et al. Wholesale electricity market design with increasing levels of renewable generation: Revenue sufficiency and long-term reliability [J]. Electricity Journal, 2016, 29 (2): 26 - 38.

[3] Olsina F, Garces F, Haubrich H J. Modelling long-term dynamics of electricity markets [J]. Energy Policy, 2006, 34 (12): 1411 - 1433.

[4] Heidarizadeh M, Ahmadian M. Capacity Certificate Mechanism: A Step forward toward a market based generation capacity incentive [J]. Energy, 2019, 172 (APR.1): 45 - 56.

[5] Bublitz A, Keles D, Zimmermann F, et al. A survey on electricity market design: insights from theory and real-world implementations of capacity remuneration mechanisms [J]. Energy Economics, 2019, 80: 1059 - 1078.