Designing a National Inertia Trading Market with Chinese Characteristics

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Abstract. The rapid development of new energy has led to insufficient rotational inertia, putting significant challenge on the safe and stable operation of the power system. As the world's largest energy consumer and carbon dioxide emitter, China is making commitment to realizing its dual carbon goals. The national inertia market, as an innovative tool to deal with the problem of large-scale new energy in the power system, will play a key role in promoting the low-carbon transformation of China's energy economy. This paper focuses the following questions: What is the inertia market? Why is it necessary to build a national inertia market? What kind of inertia market does China need to establish? How to build an inertia market with Chinese characteristics? A national inertia market is a difficult task that cannot be completed in a single day due to the complexity of the difficulties involved. The incomplete contractility and uncertainty of new energy sources make the demand for power system change more and faster than the traditional power system. For their prices to more properly reflect the value of resources to system reliability, inertial markets can have appropriate price formation processes that deliver more rapid and accurate price signals.

Keywords: Dual Carbon Goals, Energy Economy, National Inertia Market, Power System Reform

1 Introduction

Large-scale grid connection of new energy sources may lead to insufficient rotational inertia of the power system, putting great pressure on the safe and stable operation of the large power grid.[1] The innovation in electricity auxiliary service market can be an important policy instrument to deal with the problem of power system instability caused by new energy sources.

In the traditional electricity auxiliary service market, the principle of payment for auxiliary services such as frequency regulation and standby are to pay for the reserved capacity to compensate for the corresponding operating costs and opportunity costs. This payment method is based on the assumption of "same capacity same quality", that is, the same capacity provides the same auxiliary service performance. However, as the share of renewable energy increases, the uncertainty of the system increases,

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and the proportion of traditional auxiliary service providers on the grid decreases, making it difficult for the regulation capacity of the existing FM and standby service resources to meet the reliability requirements of the system, which requires the introduction of new resources while incentivizing the auxiliary service providers to improve the performance of the auxiliary services provided. The addition of new varieties of high-performance ancillary services is an important incentive.

ERCOT (Electric Reliability Council of Texas), on the other hand, is conducting a Fast Regulation Response Service (FRRS) pilot to promote the integration of energy storage resources with stronger incentives. The Fast Ramp Product (FRP) is a new auxiliary service proposed by California in response to the ramp demand caused by large-scale PV generation.

Unlike traditional auxiliary service products, the demand and specifications of this product are not based on the state of the system at one point in time, but on changes at two points in time. California estimates the probability of power imbalance with a certain number of flexible ramp products (estimated by historical data)[2], and then multiplies the probability of power imbalance by the value of load loss to obtain the demand curve for the flexible ramp product.

The U.K. electricity market has also recently tested a variety of new auxiliary services, including a service called Super SEL (Stable Export Limit), which is utilized to directly decrease the sum of the minimum MW level or SEL of generators synchronized to the system by lowering the minimum generating level at a generator synchronized. The Super SEL providers are supposed to deliver a maximum notice period of 6 hours before SEL reduction, as well as a minimum of 10MW of Footroom. It is a worthwhile way to tap into the system's peaking potential as the share of renewables grows.

As the largest developing country and carbon emitter around the world, China is facing increasing international pressure to reduce emissions as its carbon emissions continue to rise[3], driven by medium to high economic growth. Therefore, it is imperative to promote the transformation of energy structure[4]. The inertia market, as an innovative mechanism to solve the problem of new energy grid stability using market-based instruments, will play a key role in promoting the low-carbon transformation of China's energy economy[5]. This paper answers the following questions: What is the inertia market? Why is it necessary to build one? What kind of inertia market does China need to establish? How to build an inertia market with Chinese characteristics?

2 The importance of establishing an inertia market

2.1 New energy expansion

The spread of new energy sources, especially solar energy, presents a significant challenge to the power system[6]. Due to the rapid increase in solar output during the day, the net load on the system becomes very low from 12:00 p.m. to 3:00 p.m., when there is a very significant risk of overloading. However, around 3:00 p.m. to 7:00 p.m., the net system load increases rapidly because the solar power output decreases

rapidly, and the system once more runs the risk of not having enough resources to meet the increase in power output. Such a large change in net load within a day fully illustrates the need for the power system to have very flexible resources to adapt to fluctuations in wind and solar power promptly. The national inertia market allows for the flexibility to buy and sell inertia quotas to address the uncertainty of upward or downward changes in power system.

2.2 Promoting stable power system operation

The national inertia market is a crucial innovation for promoting stable power system operation. The development of the national inertia market demonstrates China's concentration on using market tools to address power system issues caused by new energy. Market instruments are typically preferable to financial and administrative instruments because the widespread use of financial subsidies will increase the financial burden placed on the government and is ultimately unsustainable, while the marginal cost of implementing administrative instruments is rising while the marginal benefit is decreasing. The creation of a national inertia market can, on the one hand, ensure the steady operation of the power system and, on the other hand, offer power generators effective incentives for using new energy through inertia trading, encouraging them to integrate low-carbon concepts into their production, operation, and investment decisions. In addition, the implementation of data monitoring, reporting and verification systems (MRV) and effective penalties for non-compliance by power generators will drive the effective development and implementation of industry bench-marking standards.

2.3 Realizing the dual carbon goal

The national inertia market is a vital mechanism to meet the dual carbon goal. As China is the world’s largest energy consumer and carbon dioxide emitter, the future trajectory of its carbon emissions will play a crucial part in global mitigation plans[7]. Early in the negotiation process of the Paris Agreement in 2015, China submitted its NDCs targets on GHG emission reduction to the United Nations, pledging to peak its emissions before 2030 and cut its CO2 emissions per unit of GDP by 60-65% from 2005 level by 2030, which is a preliminary dual goal of carbon emission intensity reduction and total emissions peak. Subsequently, President Xi Jinping has pledged at the UN General Assembly in September 2020 that China would become carbon neutral by 2060. The national inertia market can considerably promote the construction of a new energy-based power system, and ensure that the dual carbon targets are met and put into practice via market mechanisms.

3 The core idea of the overall solution design of the inertia market

At the initial stage of operation, the national inertia market quota allocation method mainly adopts the free quota allocation based on the inertia benchmark of the power generation industry and the actual participation of the department energy in power generation, i.e. the benchmark method, which can be expressed as equation (1). Where IN represents the inertia quota available to power generation enterprises, BA represents the inertia baseline value of the power generation industry, and EN represents the corresponding new energy actual activity level. The number of industry baselines and the baseline values are unified by the relevant state departments.

$$IN=BA\times（1-EN） \tag{1}$$

The inertia market is essentially a multi-enterprise performance standard for tradable inertia use. The cost or benefit of allowances for a firm or unit can be expressed as equation (2). where NR is the net revenue associated with the firm's allowances, FIN is the firm's use of inertia, and PA is the price of allowances. If the enterprise's inertia is higher than the industry benchmark, it will have a shortage of quota and will need to purchase an equivalent amount of quota over the initial quota to meet the compliance requirement. NR < 0, which is equivalent to taxing enterprises below the industry inertia use level to ensure the stable operation of the power system. And the inertia use is lower than the industry benchmark value, which will generate a surplus of quota and can obtain excess revenue by selling quota, at which time NR > 0, which is equivalent to subsidizing enterprises above the industry inertia use level requirement.

$$NR=（BA-FIN）\times（1-EN）\times PA \tag{2}$$

Under the above bench-marking method, the total amount of allowances in the national inertia market (i.e., the total amount of emissions without considering default) can be expressed as equation (3) where BA is the benchmark value of the power industry, Qi is the actual output of the power generation industry in province i. The industry benchmark value is often determined in practice based on the distribution of rotational inertia usage data of power generation companies, and it is necessary and essential to consider the technical feasibility and fairness thoroughly. The total inertia market quotas shown in equation (3) are aggregated using a "bottom-up" approach.

$$CAP=\sum BA \times Qi \tag{3}$$

China's dual carbon goal is a commitment to the world, and the establishment of the national inertia market is highly aligned with the achievement of the dual carbon goal. The establishment of the national inertia market in China is to achieve stable operation of the power system in the context of vigorous development of new energy with minimal social cost. Therefore, it is important to clarify the relationship between national and local dual carbon goals and national inertia market construction.

The inertia market determines the price of inertia clearing and the winning bids of different generators. Initially, the market organizer confirms some basic information: the inertia constants and installed capacity of each generating unit, the frequency variation rate requirements of the power system and the corresponding inertia requirements, and the trading frequency. The generators offer and quote their volumes to the market organizer. The quoted quantity is the maximum amount of inertia that the generator can provide to the power system. The price quoted is the minimum fee that the generator requires for providing inertia. The final offer that is cleared determines the clearing price of the inertia market. This clearing price is paid in RMB/s as a unit price to all the generators that are cleared. The generators that are successfully cleared receive a corresponding payment for the amount of inertia that they provide.

4 The fundamental principles of inertia market establishment

The key issues of how to set the inertial aggregate, distribute inertial quotas, assess the effectiveness of national inertial market operation, balance efficiency and political acceptability, interact well with other different policies and mechanisms, and foster international cooperation for markets must all be addressed clearly in the design of inertial markets in China.

4.1 The judgment of inertia market effectiveness

In order to protect the environment, it ought to encourage the development of new energy sources, which will aid in achieving emission reduction targets in China. For the stable operation of the power system, it might efficiently distribute resources to reduce costs and maximize societal welfare, assuring the stability of the power system at the lowest feasible cost. Political acceptance should be quite high, the wealth distribution effect brought about by the operation of the inertia market is fair among a variety of emission reduction subjects, industries, and regions, the numerous stakeholders are able to agree on the establishment of the national inertia market, and there is less resistance to policy implementation. It can cooperate and coordinate with macroeconomic policies and other measures targeted at reducing emissions, in comparison to other policies. Internationally, inertial markets across different regional and international markets can link, interact, and trade to promote the overall effort to address climate change.

4.2 The trade-off between efficiency and political acceptability

The promotion of new energy development may be hampered by a total quota that is set too high, while the instability of the power system may result from a total quota that is set too low. The original purpose of the inertia market establishment cannot be fulfilled, and performing so will come at a significant cost to society's resources.

The inertia market will function significantly differently in each location depending on the economic structure, level, and energy use characteristics of each place. To reflect regional fair development rights, the inertial market creation process must take into account factors like population, GDP, and other variables. The fairness principle, however, is likely to alter market incentives and lessen the effectiveness of how the inertia market functions. The widely varying abatement costs across industries and firms also raise the question of efficiency and fairness in the allocation of abatement targets (Pang and Duan, 2016). In order to reduce the controversy over the fairness of covered and uncovered companies in the national inertia market, as many companies as possible should be covered.

Both the grandfather technique and the benchmark approach can be used to allocate quotas; the grandfather method is based on the company's historical inertia consumption data, whereas the benchmark method is based on industry benchmark numbers. Each method has pros and cons. The grandpa approach is quite practical, but it has a problem with incorrect allocation brought on by unexpected changes in the economy. Although the benchmark technique can address the issues, it has high data requirements and issues with difficult data acquisition, high acquisition costs, and inconsistent data quality (Groenenberg and Blok, 2002; Quirion, 2009).

4.3 The trade-off between efficiency and political acceptability

Future policymakers and academics will be more and more interested in connection solutions for the global inertia market as they model and evaluate the effects of connectivity on power system stability, the impact of new energy sources, and the economic ramifications. Political obstacles and technical restrictions make inertial market connectivity a difficult and contentious topic. On the one hand, inertia market connectivity will have an asymmetric impact on the economic development and industry competitiveness of countries through changes in equilibrium inertia plus one, which in turn will affect international trade patterns and changes in national welfare. This is due to the differences in power system structure, new energy development, and emission reduction targets between countries and regions. On the other hand, in order to accomplish the whole connectivity, a variety of inertia markets' designs must be coordinated to ensure the compatibility.

5 Conclusions

This article conducts a thorough analysis of what a national inertial market is, why one should be built, and how to build one with Chinese characteristics. It also elaborates on the significance and fundamental logic of establishing an inertial market and offers strong theoretical support and practical recommendations for the development of a national inertial market.

One of the most important functions of the inertia market is to balance supply and demand through timely, accurate, and effective price signals. The incomplete contractility and uncertainty of new energy sources make the demand for power system

change more and faster than the traditional system. For their prices to more properly reflect the value of resources to system reliability, the national inertial markets can have appropriate price formation processes that deliver more rapid and accurate price signals. This encourages the market to respond quickly when the system requires it.

A national inertia market is a difficult task that cannot be completed in a single day due to the complexity of the difficulties involved. To reach the objective of carbon peaking by 2030, it is imperative to actively participate in the development of the national inertia market in the near term. Then, it is important to set the total number of inertia quotas and establish the inertia benchmark value in the national inertia market, and further enhance the status and function of the market construction in achieving the carbon peak target and carbon neutral vision.

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