Forward Design of Financial Transmission Right Market in China

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Abstract. Financial transmission right (FTR) is a kind of financial instrument to avoid congestion cost risk caused by transimission congestion. Based on the development experience of foreign transmission right market, the paper designs the financial transmission right market in line with the operation characteristics of China's power system, including the design of transmission right product, transaction rules and settlement. Finally, the rationality and operability of the transmission right market design scheme are verified by an example calculation. The paper aims to provide theoretical reference for the construction of transmission right market in China.

1 Introduction

At present, China's electric power market reform is developing in depth. On the one hand, China should actively learn from the operation experience of foreign electric power market, on the other hand, China should strive to build an electric power market in line with China's national conditions. The target electricity market includes two parts: electricity spot market and electricity financial market. As a typical power financial instrument, financial transmission right(FTR) can avoid the risk of congestion cost for market participants.

The concept of transmission right was first proposed by Hogan in 1992 based on contract path model, which is used to allocate congestion cost and provide market participants with tools to avoid price risk. FTR market has been established in PJM, New York, Texas, California and other regional power markets in the United States. Scholars mainly do reserch on the experience summary, auction model, bidding strategy and market power of transmission rights. Lewis Evans and others analyzed the economy of FTR, including the impact of FTR on market participants' risk aversion and "free riding" reduction, the impact on transmission investment decision-making, the impact on market power of industry participants, the impact on auction and financing efficiency and equity. Richard P. O'Neill and others proposed a hybrid auction model of electric energy and transmission rights. Han zhongkuan analyzed the applicability of FTR market from the perspective of basic application conditions and selection of specific transaction varieties, and discussed the applicability of transmission right congestion management mechanism in China. Huake and others combined the distribution factor of AC transmission with the transmission right based on AC power flow, which explored a new way to realize the transmission right transaction under the AC model in China. Hua Yueshen,and others discussed the basis and feasibility of FTR application in East China power market. They designed the future transaction varieties, auction clearing model and income distribution mode of East China FTR market, analyzed the preparation, possible implementation routes and implementation rules of FTR introduction into East China market.

On the basis of previous research results and historical experience of the development of foreign FTR market, the paper sums up the general rules of the development of FTR market, and puts forward a comprehensive and systematic design scheme to adapt to the construction of China's FTR market.

2 Analysis of the demand for establishment of FTR market in China

FTR is a kind of financial derivative to avoid congestion cost risk for grid users. It can be used as a tool of congestion management. In addition, FTR can also be used to distribute congestion surplus. In the electricity market based on the node marginal price or regional marginal price, the transaction surplus will be generated when transmission congestion occurs. With the help of FTR transaction, the congestion surplus can be properly allocated to market participants.

Not all electricity markets are suitable for the establishment of the FTR market. The establishment of FTR market needs to meet certain applicable conditions: 1) competitive power market environment; 2) severity of congestion; 3) coordination of price mechanism of power market; 4) relatively stable grid structure.

3 Design of FTR Products for China

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Point-to-point FTR and FGR are two forms of financial transmission right, each of which has its own design rationality, and there is no exact reason to determine which is more effective. The selection of two forms of financial transmission right is as follows.

(1)Market maturity degree: The countries and regions with perfect market mechanism and relatively developed information infrastructure can adopt FGR, while FTR is easy to be implemented in the countries with imperfect technical force and market,.

(2)Congestion characteristics: If the power grid flow is relatively stable and the distribution of congested lines is concentrated on several main contact lines between regions, a set of highly fluid power flowgate can be defined for severely congested lines, and FGR can play a better role. However, the point-to-point FTR can cover all congested nodes in the market, which is more complete.

(3)Electric energy price mechanism: The electric energy market with node price is suitable for introducing point-to-pointFTR, the one with regional price is suitable for introducing FGR.

In addition, Willion W. Hogan, the main designer of FTR, and the Federal Energy Regulatory Commission of the United States, both proposed that at the beginning of the financial market, the responsible point-to-point FTR should be applied, and obligation point-to-point FTR should be considered introducing when the FTR market is more mature.

As for each application situation of FTR, it has been concluded in Fig. 1. Regional power markets in China can choose the corresponding reasonable FTR products according to the regions' own characteristics.

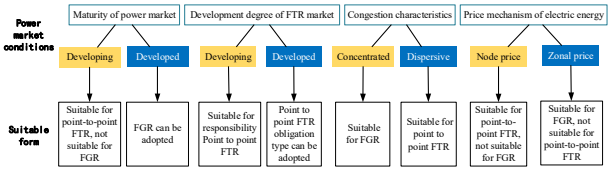

Fig. 1. The application situations of various FTR products

4 Design of FTR Transaction Rules for China

4.1 FTR Market Participants

The FTR market's organizer is the power trading center. The FTR market participants are the transmission users who pay for the transmission network tariffs, including electric customers, the power plants and costumers enjoying special transmission services. Other entities such as pure speculators and financial investment institutions can also participate in the FTR market. In principle, power trading centers, grid companies and distribution companies should not be allowed to participate in the FTR market.

4.2 Initial FTRs' Allocation

4.2.1 Initial piont-to-piont FTRs' Allocation

There are two ways of initial FTRs' allocation: initial auction and direct allocation.

Initial auction process: First, the trading center publishes FTR capacity, then the FTR buyers bid in the quotation. After the transaction is cleared, winning bidders shall pay market price for FTRs acquired in the acution to the grid company, which is used to compensate the investment cost of the transmission network. Under the condition of ensuring the reasonable construction and operation income of the grid company, the excess auction income of FTRs is used to reduce the transmission cost of the transmission users.

The operation mechanism of FTR market where initial FTRs are direct allocated: Transmission service users can be allocated initial FTRs due to rhe fact that they have paid transmission network tariffs; the market participants can buy and sell FTRs freely; after the operation of electric energy market, the congestion management surplus will be compensated to the FTR holders (or FTR holders pay fee).

Direct allocation process: Initial FTRs are directly allocated to the transmission users in the way of distributing auction revenue rights (ARRs). The users who obtain ARR can convert the ARR they hold into FTR and enter the FTR market to trade. This means that the transmission users have paid the transmission tariffs, which can guarantee the investment recovery of transmission network. However, direct allocation method is based on the network use by transmission users in historical years, which is likely to create barriers for new transmission network users. Therefore, direct allocation of initial FTRs is more applicable in the electricity market where the transmission network structure is relatively fixed and relatively mature. While in the early stage of the development of China's power market, initial FTRs should be allocated through auction .

Initial FTRs'direct allocation method design: The allocation principle is to guarantee the basic transmission demand of the transmission network users fairly and to minimize the transmission congestion risk of the power system. The allocation method should provide stable expectation for market participants and increase the flexibility of FTR transactions. The initial FTRs allocation should be based on the initial FTR application submitted by the transmission service user. The system operator conducts simultaneous feasibility test (SFT) on the initial FTR applications, and ensure that the initial FTR capacity of all applications does not exceed the maximum capacity of transmission lines.

The holders of the initial FTRs can keep FTRs to avoid the risk of transmission congestion cost; they can aslo participate in FTR auction markets and sell FTRs to obtain the FTR sales revenue.

4.2.2 Initial FGRs' Allocation

Initial FGRs' allocation process is depicted as: The system operator predicts the flowgates that may be blocked, and then release FGRs in the form of auction. Market entities such as generators, load integrators and

coustomers can participate in bidding for FGRs. Since FGRs are set for a small number of specific lines, the initial allocation of FGRs should be determined by auction.

4.3 Auction Models

FTR can be auctioned either unilaterally or bilaterally. The paper designs two auction models: 1) unilateral auction of FTR; 2) bilateral auction of FTR.

If the initial FTRs are allocated by auction, the transaction center is the only supplier of FTRs, then the unilateral auction model of FTR should be established.
The principle of the unilateral auction model is to maximize the total revenue of the FTR auction. Total revenue of the FTR auction equals the area between the bidders' quotation curve and the horizontal axis before clearing the price point. The schematic diagram of unilateral auction is shown in Fig. 2.

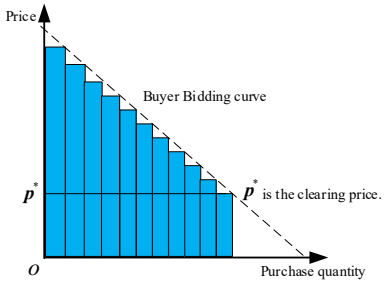

Fig. 2. Schematic diagram of unilateral auction

There are two constraints in the unilateral auction model: 1) The number of FTRs purchased by each bidder does not exceed the total amount of FTRs it needs, and the total amount of FTRs purchased by all bidders does not exceed the total supply of the market; 2) The impacts of FTR trading on power flow must meet the physical constraints of transmission lines. Power transmission distribution factors (PTDF) can be introduced to show the impacts of FTR trade on power flow lines. Unlike FTRs, FGRs' clearing price is the shadow price corresponding to transmission constraints. The auction model can output the winning bids' quantities and clearing price. It should be noted that the clearing price of reponsibility point-to-point FTRs can be negative while the price of obligation point-to-point FTRs is non negative. The clearing price of obligation FTRs is also the shadow price corresponding to the line constraint of auction model. The price of obligation FTRs should be greater than or equal to the clearing price of responsibility FTRs.

If Point-to-point FTRs or FGRs are traded by centralized bilateral bidding. The price declared by bidders and sellers is the difference between the corresponding injection and delivery node price of FTR. The principle of the bilateral auction model is to maximize the total revenue of the FTR auction. Total revenue of the bilateral auction equals the area between the bidders' quotation curve and seller's quotation curve before clearing the price point. The schematic diagram of bilateral auction is shown in Fig. 3.

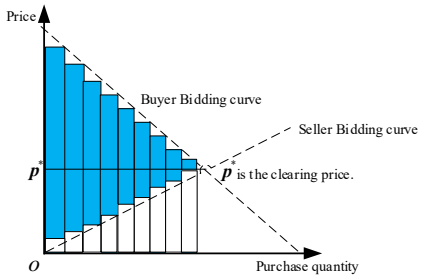

Fig. 3. Schematic diagram of bilateral auction

The constraints of the bilateral auction model is as same as the unilateral one.

5 Design of FTR Settlement Mechanism for China

5.1 Settlement mechanism of point-to-point FTR

The settlement of point-to-point FTR includes FTR transaction settlement and FTR contract settlement.

FTR transaction settlement refers to the settlement between FTR auction subjects. The settlement price of the same FTR type between the same injection and delivery nodes cleared at the same time is the same. Winning bidders pay market price for FTRs acquired in the auction; FTRs sellers are paid market price for the FTRs they surrender to the market.

FTR contract settlement refers to that the entities holding FTR contracts obtain the system blocking surplus compensation or liabilities according to the prices between the injection nodes and delivery nodes of the contracts.

For responsibility FTR holders, if the FTR contract direction is the same as the actual blocking direction, that is, when the price of the delivered node is higher than the injected node, the FTR holders will obtain the system blocking surplus allocation; otherwise, the FTR holders will be in debt. The target allocation of congestion compensation/liability cost of FTR holders is expressed by mathematical formula:

$$R_{FTR} = Q_{FTR} \times (p_{sink} - p_{sour}) \quad (1)$$

where, R_{FTR} is FTR holder' congestion compensation or liability cost, Q_{FTR} is FTR contract capacity, p_{sink} is the marginal node price of the energy sink node of contract, p_{sour} is the marginal node price of the energy source node of contract.

The same is true for the holders of obligation FTR, but when the direction of obligation FTR is opposite to that of congetion, they are neither income nor debt, their R_{FTR} is 0.

The compensation fund of FTR comes from the system congestion surplus.

5.2 Settlement mechanism of FGR

For the electricity trading that is fully covered by FGR contracts, the trader does not have to pay any congestion charges. For the electricity trading that is incompletely

covered by FGR contracts, the trader has to pay congestion charge in proportion to congestion "contribution" of the electricity trading to the line. The settlement price equals shadow price of the corresponding congested line. FGR holders can enjoy the economic compensation of grid congestion surplus after the real-time operation.

6 Example Calculation

The paper simulates the FTR trading and auction process designed above based on the standard IEEE-14 node system. The standard IEEE-14 node system topological structure is shaown in Fig. 4:

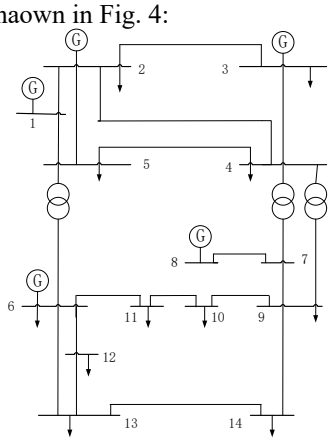

Fig. 4. The IEEE-14 node system topological structure

There are 20 lines in the node system. The upper limit of transmission capacity of each line is shown in Table 1. In order to provide decision-making basis for FTR traders, the paper also sets the prediction value of the price difference between the source and delivery nodes of each line.

Table 1. Transmission capacity and node price prediction of IEEE-14 node system

Line	Source-sink node	Transmission capacity （MW）	Price difference of source and sink node（￥/MWh）
1	1-2	±500	12.6
2	1-5	±470	45.4
3	2-3	±270	49.8
4	2-4	±240	35
5	2-5	±540	23.2
6	3-4	±300	26.1
7	4-5	±150	3.5
8	4-7	±230	21.9
9	4-9	±460	21.7
10	5-6	±340	6.3
11	6-11	±310	30.7
12	6-12	±120	43
13	6-13	±290	39.2
14	7-8	±470	-38.4
15	7-9	±240	29.7
16	9-10	±240	32.6
17	9-14	±290	42.1
18	10-11	±120	31.6
19	12-13	±170	36.6
20	13-14	±210	8.3

In order to facilitate the calculation, set the contract type limited to piont-to-piont FTR (including responsibility type and obligation type). Unilateral auction market is adopted with 50 bidders. The quotation information of market bidding is also simulated randomly.

Based on the simulated transaction data and unilateral auction model, FTRs' clearing result can be calculated. The clearing price of responsibility FTRs of each congested line is: 32, 36, 30, 20, 20, 17, 15, 18, 13, 11, 14, 12, 10, 10 (￥/MWh). The shadow prices of each congested line is: 32, 36, 30, 20, 20, 17, 15, 18, 13, 10, 14, 12, 10, 8, so obligation FTRs' clearing price of each congested line is: 32, 36, 30, 20, 20, 17, 15, 18, 13, 11, 14, 12, 10, 10 (￥/ MWh).

7 Conclusions

The paper designs FTR products that adapt to the China's electricity market, and design initial FTR allocation rules and auction mode correspondingly.At the last of the paper, an example is given to verify the feasibility of the design. The research aims at providing theoretical reference for the development of China's power financial market.

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