# Research on Hydropower Peak Regulation Market

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*Abstract*—In order to advance the instruction of the Smart Grid, resolve the peak regulation problem brought by new resources connected to the grid, and change the situation that hydropower peak regulationis regulated freely, analyzing the component of the hydropower peak regulation and indicating that the cost is mainly the opportunity cost which is produced by the change of water consumption rate in the process of regulation. By analyzing problems in our present hydropower peak regulationtrading mechanism, indicating the necessary of building hydropower peak regulation market in China, Based on the peak regulation right, proposing the building rules, option methods and pricing methods of the hydropower peak regulation market which is adapted to the present situation in our country. Example shows that building a hydropower peak regulation market can bring reasonable income for hydropower generating units, and then effectively improves the positivity for hydropower generating units to regulate, resolves peak regulation in the smart grid, improves ratio of energy utilization and realizing optimal allocation in resource.

*Keywords-electricity market; hydropower peak regulation; opportunity cost; peak regulation right*

## I. INTRODUCTION

The power peaking problems become more and more serious with the development of large-scale new resource brought into power grid. The focus attention is how to improve the positivity of hydropower peaking. At present, the research of hydropower peaking problem mainly focus on cost analysis, compensation method, peaking capacity, operation strategies etc. It is point out in paper1 and 2 that hydropower peaking is divided into basic peaking and paid peaking, the peaking cost is divided into fixed cost and opportunity cost, with the hydropower peaking cost, it is important to consider the opportunity cost in the process of adjustment, many kinds of compensation methods of hydropower peaking cost is proposed in paper 2 and 4, in paper 5 given out the conception of peak regulation right firstly, the research on peaking right trade rule is brought out from demanad management side and environment cost side separately in paper 6 and 7, paper 8 analyses the factors which affect the peaking capacity with hydropower unit, it is point out the  principle that hydropower replied to wind power peaking and solution of avoid waste water by hydropower brought by wind power combined into grid or the imbalance resolve, in paper 10, it is proposed the combined peaking operation strategy of  hydropower and wind power in day time at winter dry season. However, the research on hydropower peaking power markets is relatively few, nevertheless, it is a problem to be solved, otherwise, it will affect the enthusiasm of hydropower unit taking part in peaking, then the construct of the smart grid will be delay and the safe and stable operation of the whole power system will be hazarded. In paper 11 introduced the implement method and characteristics of ancillary service with the oversea power market and discussed the operation management and pricing mechanism of ancillary service, in paper12, which using principal -agent model to design model between power grid Corp and peaking power plant to achieve the maximize profits for the power grid, it established the optimal dispatching hydropower unit linear model under complete market conditions in paper 13. The above study has achieved certain results, but most of they just stay in the theoretical level, it did not brought out feasible scheme with hydropower peaking problem which is become more and more severe. To solve this problem, in this paper, by analyzing the successful experience of foreign assistance service market and China hydropower peaking service trading status, it proposed the design principle of hydropower peak market, procurement method and price method, which can mobilize the enthusiasm of hydropower plant effectively, solve the problem of grid-connected wind, improve the energy efficiency and optimize the allocation of resources.

## II. FOREIGN ASSISTANCE SERVICE MARKET

The western countries representation of Britain began electricity market reform in nineteen eighties, and established the ancillary service step by step, it is the rich successful experience worthy of our reference.

### A. Perfect Policies and Regulations

From the United State's Energy Policy Act, the British Electric Power Law, North Europe Energy Act and a series of policies in electric market, it is can see from the function acted in the establish and development assess that the power market legislation should go before the electric reform, the national policy especially the consummation of reform with power system management is the basic condition to establish perfect auxiliary service market.

## B. Power Market Norms

From the power system organization and trading mechanism of United States, Britain particular North Europe multinational trading transaction, it can see that the primary condition of the establish standard with ancillary service market is to constitute the electricity market norms. The ancillary service market will be water without source if no normative electricity market.

## C. Science Cost Analysis of Auxiliary Service

Although the ancillary service specific content of various countries and regions are different, the compensation method also different, it is usually divided into free and paid part, therefore, the correct analysis of auxiliary service cost, the reasonable definition of paid and unpaid boundary is the precondition of establishing ancillary services compensation mechanism and ancillary  service compensation. It is the only way to guide the activity of grid-connected power plant to provide high quality of ancillary service.

### III. ANALYSIS OF HYDROPOWER PEAKING COST

Reasonable analysis of hydropower peaking cost is the basis of hydropower peaking market pricing.

## A. Analysis of the Composition of Cost

It is the same with other commodities, the peaking service cost provided by generators is divided into fixed cost and opportunity cost(or alterative cost) parts, among them, the fixed cost refers to the mechanical loss due to peaking and various behavior requires cost in the process of peaking, it is has nothing to do with the generating capacity, the opportunity cost  is the loss of profits resulting from the less power generation because of regulating peak as in paper one.

The fixed cost of hydropower unit peaking is mainly refers to the mechanical losses caused by adjusting the output frequently, including the unit vibrate increase and shaft consumed badly. The expense has considered in unit depreciation cost usually, thus, it has not taken account into hydropower peaking cost as referred in paper 1.

 The hydropower peaking cost is mainly referred to the change of unit output caused the water consumption rate changed in the peaking regulation process, which cause the profit loss due to the generate output reduced as referred in paper 1. It is to definite that the abandon water cost of hydropower and hydropower standby cost all not part of opportunity cost, it is because the abandon water and standby are all owing to preparation, drive down output caused water loss which cause profit become low, it is the loss not happened in the peaking regulation process.

In summary, hydropower peaking cost is mainly the opportunity cost produced in the peaking process.

## B. Analysis of Opportunity Cost

For the hydropower unit, water consumption rate is an important parameter to characterize its efficiency, it refers to the consumption water of each KW output. The hydropower unit can cause the change of water consumption rate and efficiency.  Taken the hydropower unit average output as basement in fixed time, the loss water caused by the increase of water consumption at down peaking(using for loss load) is greater than upward peaking side(using for increase load), the water has chance to generation profits because of peaking, it is the opportunity water, if it convert the water into generation profit, it is named peak of the opportunity cost. Therefore, hydropower peaking opportunity cost is mainly represented the generation efficiency loss caused by backward peaking service refers to paper one, in the power market transaction, it reflected in the hydropower peaking power price.

### IV. POWER MARKET DESIGN OF HYDROPOWER PEAKING

## A. Design Principles

Our present power market is in the primary stage in this time, it has many steps to go in many aspects, the establish of hydropower peaking power market be on speaking terms and operation should adhere to the following basic principles:

1) Carried out provincial, regional, national electricity market gradually, the work can not be accomplished at one stroke.

2) It must obey the principle of open, fair, justice, all hydropower units in accordance with the terms of all the conditions can participate in the bidding, the competition is fair,

3) The transaction type is for contracts, it contracts is carried out by signing a contract of the sale of hydropower peaking power transaction between the two sides of hydropower parts, the trading price is determined by market competition, the term of the contract can be week, month, quarter, or year.

4) In order to ensure the full utilization of water resources, the hydropower peaking power market can begin after the short-term load forecasting or medium-term load forecasting.

## B. Purchase Method of Hydropower Peaking Power Market

In order to ensure the profits of the supply of hydropower peaking  with both sides, in this paper proposed the hydropower peaking power market trading mechanism based on the  transaction mechanism of peak regulation right

### 1) The Transaction Mechanism Of Peak Regulation Right

 The peak regulation rights is a downward  peak purchase option, it is not involve physical power trading, the peak regulation right purchasing part should have the right to shell the downward peak regulation capacity promised by the peak regulation right according to the quantity, in the terms of promised time, the buyers of peak regulation right can freely choose whether or not to buy the capacity from the peak regulation right sell side, but the peak regulation right side will not send back the purchase cost to the them in paper 5.

It is because the hydropower installed capacity is taken a small proportion of the total installed capacity in our most regional power grid of China, in the same while, the distribution is not symmetrical, which is means the rice is no adequacy for the people, therefore, through the establishment of peak regulation right transaction, on the one hand, it can

avoid the loss from buying side plant halt risk and power system operation instability caused by wind power connected into gird, on the other hand, it can enhance the ability and the positivity of peak regulation with the hydropower plant, through the sale of peak regulation right can obtain more benefits, finally to realize the stable operation of power grid and achieve a good win-win situation.

*2) Market Transaction Model*

The hydropower peaking power market will consider various practical constrains in the determination of the purchaser, and taken the total peaking cost minimum as goal. The objective function is as follows:

Objective function:

$$\min \sum_i (C_{rri}/10 + C_{rpi}) \times Q_i \quad (1)$$

Restriction

$$Q_i \leqslant Q_{imax} \quad (2)$$
$$Q_i \leqslant Q_{imin} \quad (3)$$

Among them, $C_{rri}$ is the peak regulation right price of plant i, it is generally five to ten percent of peaking capacity price, the peaking capacity of per peak regulation right corresponding to 10MW, $C_{rpi}$ is the peaking power bidding of plant i, is should be include the opportunity cost created in the process of hydropower peaking. $Q_i$ is the peak regulation capacity of purchased plant i. $Q_{req}$ is the peaking capacity the buyers need to purchase. $Q_{imax}$ is the maximum regulation capacity of plant i, $Q_{imin}$ is the minimum regulation capacity of plant i.

It can determine the successful unit through calculation, for these units, it can give a sequence of peak electricity price from low to high, the purchaser can use it with the sequence.

*C. Hydropower Peaking Power Market Pricing*

According to opportunity cost produced in the process of hydropower peaking, combined with the think of peak regulation right, in this paper proposed that the hydropower peaking service prices is composed of peak regulation right price and electricity prices parts.

*1) Peak regulation Right Price*

The peak regulation right price is determined by the quotation of bidding side, generally occupied 5 to 10 percent of the peak capacity price, the peak capacity corresponding to each peak regulation right is 10WM, the peak regulation right can trade multiple share at the same time referred in paper 5. After the transaction, the purchaser should pay the peak regulation right price to the bidder with cash immediately, whether or not the physical power trading occurred within the appointed time, the peak regulation right price will not be refunded. At the same time, the peak regulation right side should be compensated to the purchaser if it can not provide peaking power on schedule and with enough quantity.

*2) Peak Regulation Electricity Price*

The peak regulation electricity price is proposed by combined hydropower peaking opportunity cost and basic price. When participate in the bidding, it will be submitted to

peaking power market together with peak regulation right and peaking capacity. After strike a bargain and underwrite contract, the bargainor should transfer peak power to the buyer and capacity according to the contract within the fixed time, at the same time, the buyer should paid peak regulation electricity price to the bargainor according to the prescribed peak regulation electricity price and peak regulation capacity in practice based on contract.

*D. Hydropower Peaking power Market Clearing Way*

According to the biding market the hydropower peaking service successful in bid, its clearing consists of peak regulation right clearing and peak regulation power clearing. Among them, the clearing of peak regulation right at the end of the deal will paid to the peak regulation supplier according to the bargain on price and volume by the peak regulation purchaser after dealing, and this part of clearing funds will not be returned whether or not occurred hydropower peaking power physical trading in the future. Hydropower peaking power clearing will be executed with cash after physical transmission according to the bargain on price and physical bargaining amount.

*E. Hydropower Peaking Power Market Regulation Ward*

In order to ensure the deal is fair and equity, all the hydropower plant should undertake the peak regulation capability examination by power watch department before bidding, after the deal, the clearing will be finished under supervision with the relevant departments.

V. EXAMPLE ANALYSIS

Taken the single buyer hydropower peaking power market as an example, unit one, two, three, four, five, six participated in bidding market, it is the bidding peaking regulation capacity and quotation of each unit in table two. The demand load is 200MW at off-peak moment, the bidding session is one hour, it is supposed that the quotation and decision are rational.

TAB.1 BID DATA OF UNITS

| number | Peak regulation capacity （MWh） | Peak regulation share | Peak regulation price （yuan/piece） | Peak regulation electricity price （yuan/MWh） |
|---|---|---|---|---|
| 1 | 50 | 5 | 25 | 250 |
| 2 | 70 | 7 | 29 | 290 |
| 3 | 80 | 8 | 30 | 300 |
| 4 | 90 | 9 | 31 | 310 |
| 5 | 110 | 11 | 32 | 320 |
| 6 | 150 | 15 | 39 | 390 |

First of all, according to the constraints of the market trading model, can gained three kinds of trading model which can satisfy the load demand as follows, one composed of unit one, unit two and unit three, two is composed of unit one and six, the other is composed of unit four and unit five.

Then, can calculate the transaction cost with the three kinds of combination, which is 57368 yuan, 61690 yuan, 71710 yuan respectively. According to the objective function of market trading model can determine the combination of unit one, unit two and unit three can win the bid.

After bidding, the unit one, two and three can obtain the peak regulation right proceeds which is 125 yuan, 203 yuan and 240 yuan respectively. In the actual scheduling, when the peak regulation electricity transferred in the bidding process, the clearing can be carried through bargaining on price and the actual transmission power capacity of peak regulation.

It can be seen from example analysis that the established hydropower peak regulation electricity market based on the peaking regulation bargaining norm can obtained reasonable income for hydropower units, which ensure the behalf of the peak regulation business sides. The problem of allocation of grid resource and peak shaving can be effectively solved if it adapt to the distribution characteristics of our resources and the development situation of electricity power market.

## VI. CONCLUSION

It is based on the thinking of peak regulation right that put forward the peak regulation electricity establishment norm which adapt to our country present situation, purchases method and pricing manner. It can be seen from the example analysis that the establishment of hydropower peaking regulation market can brought abundant peaking regulation benefit for hydropower unit, and it is the efficient method to inspirit the hydropower unit actively participate in peak regulation.

In the future, with the development of our policy and the electricity power market, the hydropower peak regulation power market will become more deep in market and sufficiency, the hydropower peak regulation power market will be established with province scope, region scope and national scope, then the optimizing of resource configuration can be realized in the national electric power market.

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