Preliminary Exploration of Establishing a Spot Quotation Alliance for Cascade Hydropower Stations

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Abstract: For the spot electricity market, the quotation combining the hydropower stations is more resistant to uncertainties of runoff and spot price in market bidding. Therefore, it is of great significance to set up a spot quotation system for these hydropower stations. The paper first studied the fundamental characteristics of hydropower stations at different tiers, based on which the establishment of a quotation system of hydropower stations at different tiers and the bidding procedures were proposed. In addition, the paper investigated the joint bid model suitable for hydropower stations at different tiers based on cooperation between bidding stations. Finally, the paper established a coordinated management model and conflict-solving model for the quotation system of hydropower stations at different tiers, providing theoretical support for the system to take part in the spot electricity market and improve its marketing capabilities.

1. Introduction

Since the new round of reforms of China’s power system in 2015, there have been some studies on how cascade hydropower stations participate the market. For example, Zhang Lizi [1] and his team studied the clearing model of the day-ahead market for downstream power stations as price recipients, and discussed the influence of water flow delay on the operation of power stations. Mo Dong [2] et al. proposed to decompose the annual base electricity into the spot market in equal proportion based on the generating capacity. Though these studies have made important progress, they mainly focused on the design of the spot system [3], market clearing model, bidding strategy [4], medium and long-term power decomposition [5] and so on.

In current market, power stations either bid alone or work with other power stations for bidding. Under the cascade development mode, individual bidding would cause conflicts, raise the cost, thus affecting the coordinated operation of hydropower stations at different tiers and harming their overall interests. The establishment of a spot quotation system of cascade hydropower stations is essential to the information sharing, coordinated management and improved competency of power stations at each tier. A proper mechanism serves as a significant influencing factor affecting the long-term stability of the spot quotation system, a topic that has hardly been studies. Therefore, the paper analyzed the fundamental characteristics of the cascade hydropower stations and their bidding behaviors, and investigated the establishment of a spot quotation system and coordination system, providing solid support for hydropower stations to participate in the spot power market and improve marketing.
2. Fundamental Characteristics of Cascade Hydropower Stations

2.1. Mutually beneficial symbiosis
Symbiosis is widely found in ecosystems, which refers to the coexistence and development of organisms (including animals, plants or other combinations) in a specific environment [6]. The symbiotic system consists of five basic elements: organism, substrate, medium, environment and energy. That is, a specific type of symbiotic system was formed by organism on the symbiotic substrate via a specific medium. Hydropower stations at different tiers share natural hydropower resources, thus causing both conflicts and interdependence between upstream and downstream hydropower stations in the development and utilization of water resources. The hydropower stations are interdependent, mutually restricted and competing with each other, which is similar to the dynamic symbiosis, survival competition and evolution of the nature. Therefore, there is a mutually beneficial symbiotic relationship between hydropower stations at different tiers, as shown in the following figure.

![Mutually Beneficial Symbiotic Relationship between Hydropower Stations]

2.2. A complicated adaptive system
The system of cascade hydropower stations features sophistication, complication and adaptation. The mutually beneficial symbiotic system of cascade hydropower stations involves the adaptation, exploration and dynamic evolution of members. The geographical features, spatial planning, and natural ties between hydropower stations have formed complicated correlations and coupling effects between power stations. Therefore, members of the system need to adjust and optimize the water resources based on geographical features and location of the site as well as utilization of water resources among other power stations. The system involving various tiers of hydropower stations needs to exchange information of the power market via various channels. The problems include trade policies, hydraulic interaction, electricity generation, production and operation, distribution, safety of the power grid, power demand, and complicated and dynamic non-linear targets restricted by the electricity consumption law. With the development of the power market and the combination of multiple factors, the connections and coupling effects are increasingly sophisticated and extending to a higher level. The mutually beneficial symbiotic system of the cascade power stations would further complicate the actual operations.

3. Bidding Behavior of Cascade Hydropower Stations
Power transactions have gradually become market-oriented since the power reform. The cooperation of cascade power stations has positive significance for taking advantage of cascade joint regulation, enhancing market competitiveness, reducing operation performance risks and preventing excessive internal competition. Therefore, cascade power stations are willing to form a collaborative quotation
alliance.

3.1. The form of the collaborative quotation alliance
The collaborative quotation alliance of cascade hydropower stations refers to the phase-based coordination of hydropower stations who share the interests and risks and make a full use of each other’s strengths for resource sharing, market expansion and stronger competency. It is categorized into equity-based collaborative quotation alliance and contract-based collaborative quotation alliance.

(1) Equity-based collaborative quotation alliance, which is characterized by close cooperation and coordination among members. It can be further categorized into “equal possession” (such as joint venture) and “mutual shareholding” (like taking equity). The joint venture allows members to remain independent and equal to each other, while taking equity of other member power stations facilitates long-term coordination in different fields.

(2) Contract-based collaborative quotation alliance, which has no equity adjustment. With only limited restrictions of the members, it features greater flexibility and freedom, wider application and higher economic efficiency than the equity-based collaborative quotation.

Generally, the equity-based collaborative quotation alliance is more stable than the contract-based one. However, diversified investment entities of the cascade power stations with independent owners and separate equity make it difficult to coordinate the entities via setting up joint ventures or holding each other’s equities. On the other hand, the cascade power stations are equal and independent in the market, suggesting the possibility of horizontal cooperation. Given the diverse needs of the market and uncertainties of the policy, the flexible and adaptable contract-based collaborative quotation alliance is more suitable for cascade power stations. In the contract-based model, this paper studied factors like hydraulic connection, electric power connection, power station ownership and utilization of hydropower resources, and categorized the formation of collaborative quotation alliance into the following situations:

(1) Formed by power stations of sole ownership
(2) Formed by hydropower stations of phase-based adjustment and downstream hydropower stations without adjustment.
(3) Formed by cascade hydropower stations in the same network
(4) Formed by cascade hydropower stations that supply power to the same destination

3.2. Procedures of collaborative quotation
The collaborative quotation model of the cascade power stations in the spot market involves the overall financial assessment of the member stations as a whole. A bidding price and several bid volume are offered and properly matched to win the bid, thus maximizing the overall profits and optimizing utilization of water resources. The collaborative quotation allows cascade power stations to integrate resources. In this way, the members will have a more accurate understanding of market demands and distribute water resources more efficiently, thus meeting the needs of all parties while maintaining the position as an independent competitor in the power market. The mechanism has proved an effective tool to improve the overall profits and efficiency, and lower the cost of users. The procedures of collaborative quotation of cascade power stations are shown in Figure 2.

(1) Carry out survey and investigation of the rival bidding scheme and the current power market, based on which cost analysis of member power stations were made to determine the general strategy and optimal scheme for individual power station.

(2) Determine the bidding strategy. The cost of power generation and the bidding scheme of each member power station are used to analyze the supply and demand of power as well as competitors. Then, the coordination, resource distribution and the overall bidding strategy are determined. All member power stations offer a unified bidding price and different bidding volume.

(3) Power generation. Based on the general bidding strategy, the collaborative quotation is performed, and member stations win the unified bidding price and bidding volume, with the specific power generation tasks being implemented by each member station according to the rule.
(4) Profit assessment and settlement. The contribution and economic benefit of member power stations are assessed based on their performance in the tasks, which determines profit distribution among them.

Finally, before the next round of bidding, the member power stations will decide whether to continue the collaborative quotation based on their level of satisfaction with the profit distribution and the power market. If the collaborative quotation continues, each member power station will repeat the above bidding procedures; if not, the hydropower stations will look for partners to form a new quotation group and repeat the above procedures.

![Diagram of Procedures of Collaborative quotation for Cascade hydropower stations](image)

4. The Bidding Mechanism of Cascade Hydropower Stations

4.1. Cooperation model

(1) Leader-dominated cooperation. Based on the "rights" of power stations, it can be divided into meta-dominant cooperation and cooperation based on mutual supervision.

Meta-dominant cooperation. A core meta member of collaborative quotation alliance could promptly and accurately obtain information from the market and inside the group, thus being able to promote cooperation and regulate production activities, operation and coordination of the members. When a member is strong in marketing, financing and R&D, it is more acute in grasping business opportunities and the trend of the market. Also, other members would be more reliant on it in one or more aspects. In this situation, the other members didn’t participate in key production links or R&D. Then, the strong one will take the leading role, which is beneficial to the coordination and decision making.

Cooperation based on mutual supervision. Under this model, no member has absolute dominant control, and the cooperative management organization composed of each member station has the highest authority, which represents the interests of all members and supervises the decision-making and program implementation of the leading member. This model features greater democracy.

(2) Equal cooperation. This is a model that highlights equality and cooperation, which is suitable for entities of equal market, economic and technical power. Based on organizational structures, it can be divided into joint operation model and federated cooperation model.

① Joint operation model. All entities are in an equal position and cooperate to formulate operation rules and expand the market. Each member contributes its core strength and creates more profits for the team while remaining independent.

② Federated cooperation model. Based on the joint operation model, a cooperative management organization composed of member stations is established, which is responsible for carrying out coordinated management to optimize resource distribution within the team. This cooperation model features flexibility and tight organization, which is an ideal and practical cooperation model.
(3) **Cooperation between Agents.** The third-party management team investigates the market, identifies business opportunities, sets up the collaborative quotation alliance for hydropower stations, coordinates with and manages the member stations as a partner with the members. It supervises and restricts the cooperative behaviors of members. The introduction of broker management team can provide market information and decision-making references for small and medium-sized enterprises, and prevent large leading enterprises from taking absolute control. However, China is still in the early stage of power market reform, with few professional broker management teams. Therefore, this model is not practical at this stage.

The distinctive features of the power industry weaken the foundation of leader-dominated cooperation as power stations are close in strength and could exert influence and restrictions on each other. Therefore, this study believes that the federated cooperation model is more suitable for the collaborative quotation alliance of cascade hydropower stations.

### 4.2. Federated Quotation Alliance (FQA)

The Federated Quotation Alliance (FQA) sets up common goals, promote trust and information sharing while securing business confidentiality. As to the common goals, the member stations start from their own interest and form alliance with other power stations to optimize their marketing strength and resource utilization. It is the common goal of the alliance to profit from collaborative quotation. Also, the FQA would examine the candidates before they join in the alliance to form a just, equal and open collaborative management committee (CMC) to secure trust, information sharing and business confidentiality. The committee consists of professionals from each member station, who are responsible for the operation, coordination and supervision of the alliance. This paper intended to establish a coordinated management system based on information sharing and coordinated management. By integrating each member station, the system would be more coordinated and efficient. The paper divided the structure of FQA into three parts: information system service, core power generation service and power marketing service, in which the core power generation service is essential to the cooperation among members while the other two play an assisting role. The structure is shown in Figure 3.

![Figure 3 Structure of the FQA](image)

The construction of FQA can be divided into the following seven steps:

1. **Seek partners of power generation.** The members participating in collaborative quotation need to meet conditions like installed capacity, market power, and reservoir regulation capacity.

2. **Ensure agreement on operational decisions.** Establish relevant management systems to ensure consistency in operation activities and other relevant decisions of power generation.

3. **Determine the cooperation model.** In this step, the organizational structure should be established. This paper adopted FQA, where power stations jointly generate electricity, operate as an entity, and coordinate management via CMC.

4. **Design the collaborative quotation system.** It is necessary to plan and design a collaborative quotation system for coordination and improving revenues.

5. **Apply for administrative approvals.** Apply for administrative approval of the projects and
submit an application to the administrative departments in time so as to obtain the license of establishing the bidding system.

(6) Operating the bidding system. Set up a system management organization, and formulate operation procedures and coordination mechanisms of the bidding system as a preparation for the bidding and cooperative power generation activities.

(7) Improve the bidding system. Check the performance of each member regularly to identify and solve problems in time. And upgrade the system regularly to ensure stable, efficient and continuous operation.

5. Coordination Mechanism of the Spot quotation Alliance
The dynamic coordination mechanism of the FQA is divided into the coordination management model and conflict resolution model. In the early stage of FQA's establishment, it is necessary to put in place a basic model of coordination management for future operation activities. When the FQA matures, a conflict resolution model needs to be established to track and handle conflicts among member stations. Finally, it is also important to combine the dynamic coordination and feedback mechanism of FQA.

5.1. Coordination management model of FQA
This paper divided the coordination management model of FQA into three levels and two levels of management support. Based on the technical support of the integrated information platform and guarantees of the contract and agreement, the CMC organizes and manages the alliance from three levels. The detailed coordination and management model is shown in Figure 4.

a. Coordination at the decision-making level. Formulate the goals, principles and major policies of the alliance, and assess the overall situation for decision-making based on the overall interests. It mainly includes: how to facilitate interactions between FQA and the external market, allocate internal resources of FQA, establish the entry and exit mechanism, formulate the scheme of profit distribution and conflict resolution, and propose measure of target control and correction.

b. Coordination at the executive level. The coordination at this level focuses on attainment of the common goals, the task allocation and schedule control, and the coordination of power generation tasks and business procedures, including the response to power demand and customer service complaints, coordination of bidding strategies, power generation, power distribution and business schedule.

c. Coordination at the information level. Coordination at this level focuses on data collection, information sharing and information feedback, including integrated processing of internal and external information, transmission and sharing of information among members, tracking and feedback of business information, etc.

d. Coordinate management support. It plays a significant supporting role in the coordination and management at all levels: the integrated information platform focuses on technical support, aiming at providing a physical channel for member stations to share information and communicate efficiently.
The coordination guarantee mechanism focuses on contractual constraints, providing an effective guarantee and a good cooperation atmosphere for the cooperation of member power stations.

5.2. Conflict coordination model of FQA

In the actual operation of FQA, CMC will collect information through the integrated information platform, and integrate, check, process and analyze relevant data. When abnormal data or deviation is identified in data analysis, it is considered an internal contradiction or conflict. Subsequently, CMC traces the sources of conflicts according to the data results, analyzes the causes and chooses appropriate strategies to solve the problem until the system returns to normal. However, the absence of business opportunities and powerful negative impacts on the collaboration would cause the collapse of the alliance. When there are emerging opportunities, power stations will start a new round of collaborative quotation based on the demands, environment, policies and mechanism of the market. See Figure 5 for the detailed conflict resolution model of FQA.

6. Conclusions

This paper studied the bidding strategies of cascade hydropower stations in the spot market, explored the establishment of collaborative quotation alliance based on the characteristics of cascade hydropower stations, and concluded:

1. Under the market environment, the cascade hydropower stations are mutually beneficial and interdependent on each other, a relationship featuring active adaptation and learning as well as dynamic evolution.

2. As to the forms of quotation alliance, the flexible and adaptable contract-based quotation alliance is more suitable for cascade hydropower stations.

3. In terms of the cooperation model between cascade hydropower stations, the federated cooperation model is more suitable for cascade hydropower stations, as it can actively cater to market changes compared with the leader-dominated cooperation model.

4. The paper designed a coordination management model and a conflict resolution model for the quotation alliance, which allows the organic combination of dynamic coordination mechanism and dynamic feedback mechanism, thus ensuring the stability of the alliance.

Fund project

This work is supported by State Grid Corporation of China (No. DZ71-20-014).
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