Joint Decision-Making Model of Power Manufacturer Participation in Green Certificate Market and Medium - and Long-Term Power Market

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Abstract: To effectively guide power manufacturers in the medium and long-term market and green certificate market trading behavior. This paper firstly constructs the model of power manufacturers' participation in the green certificate market and the model of participating in the medium and long-term market of power, and establishes the coupling constraint of power manufacturers' participation in the power market and the green certificate market. Secondly, considering the speculative behavior of power manufacturers and using conditional value-at-risk to depict the profit risk of electricity generation due to the uncertainty of market price, the optimal comprehensive benefit considering the annual expected profit and risk of power manufacturers is taken as the decision-making objective, and the joint decision-making model of power manufacturers participating in the green certificate market and the medium and long term power market is established. It is helpful for power manufacturers to make trading decisions in medium and long-term market and green certificate market.

1. Introduction

The implementation of quota system and green certificate exchange system will help to solve the problems of power generation, Internet access and market absorption faced by renewable energy in our country. The trading system of green certificates aims to promote the development of renewable energy by replacing financial subsidies through the income of renewable energy in the market, which is an important means to achieve the goal of "carbon peak carbon neutrality". There is a complex interaction between the green certificate market and the power market, which will have an important impact on the management decisions and interests of power manufacturers. For power manufacturers under the new background, they should consider the operation decisions in both the green certificate market and the power market to maximize their own interests [1-3]. This paper takes the one-year performance period of the green certificate market as the optimal decision-making cycle, and considers the speculative behavior of power manufacturers in the green certificate market, proposes a joint decision-making model of power manufacturers' participation in the green certificate market and the medium and long-term power market based on conditional value-at-risk [4-7].

2. Power Manufacturers Participate in Green Certificate Market and Power Medium - and Long-term Market Decision-making Framework

At present, in our power market, power manufacturers' main income comes from the medium and long-term power market. At present, power manufacturers' participation in the power market and green certificate market is mainly focused on the power manufacturers' participation in the power spot market, without considering the medium and long-term power market. Therefore, in the power market, this paper mainly focuses on the decision-making behavior of power manufacturers in the medium and long-term power market, including participating in the medium and long-term annual transaction and monthly transaction. The joint decision-making model of power manufacturers' participation in the green certificate market and the medium - and long-term power market proposed in this paper can be divided into two parts: annual decision-making and monthly decision-making. The decision-making process is shown in Figure 1. When making annual decisions, the medium - and long-term annual contract price of electricity is regarded as the known quantity. power manufacturers first predict the medium - and long-term monthly trading price of electricity and the market price of green certificate in each month of the next year, and formulate the annual trading plan and monthly trading plan of the next year with the

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optimal comprehensive benefit of expected profit and risk in the whole performance period as the decision-making objective.

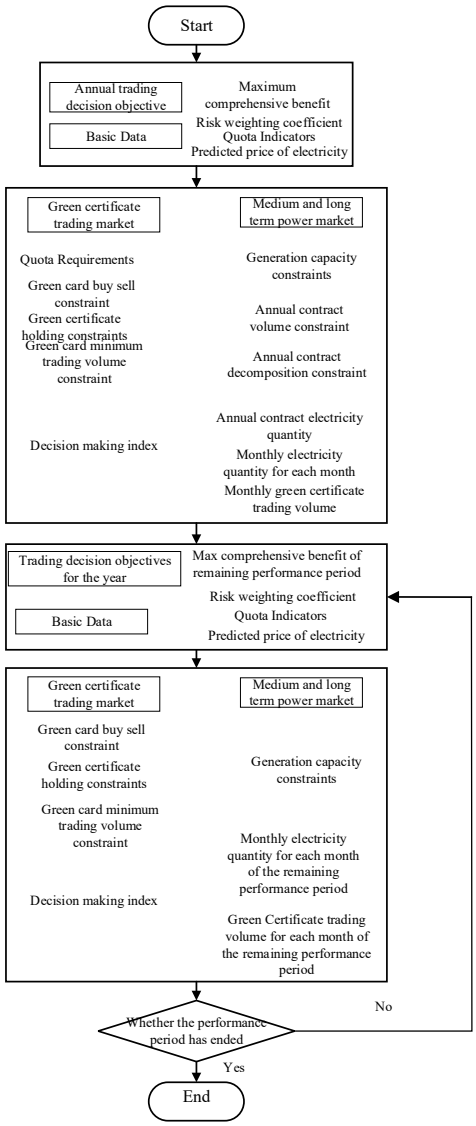

Fig.1 Decision making process

In the decision-making part of the year, power manufacturers re-forecast the monthly trading price and green certificate price of the future months according to the implementation of the contract and the latest market information of each month, and decided the medium and long-term monthly trading plan and green certificate trading plan of the future months with the optimal comprehensive benefits in the remaining performance period as the decision-making objective. This will be used to make rolling decisions every month until the end of the performance period.

3. Joint Decision-making Model of Power Manufacturer's Participation in Green Certificate Market and Power Medium and Long-term Mark

3.1 Decision of the year

3.1.1 Objective function

CVaR is used to measure the risks of power manufacturers in the performance period. The optimal comprehensive benefit of expected profits and risks in the performance period is the decision-making objective. The objective function is:

$$R_e=\sum_{i=1}^{12}\left(\left(P_y-c_r\right)Q_y+Q_i^r\left(p_i^r-c_r\right)-P_{c,i}Q_{c,i}\right) \quad (1)$$

$$\begin{aligned} & R=\eta-\frac{1}{N(1-\alpha)}\sum_{\omega=1}^{N}S_\omega \\ & \text{s.t} \\ & \eta-\left(\left(P_y-c_r\right)Q_y+Q_i^r\left(p_i^r-c_r\right)-P_{c,i}Q_{c,i}\right)\leqslant S_\omega \\ & S_\omega\geqslant 0\forall\omega \end{aligned} \quad (2)$$

Where, R represents the comprehensive income of power manufacturer, R_e is the expected profit of power manufacturer, and R_α is the profit risk of power manufacturer. The $\alpha\in(0,1)$ is the risk weight coefficient, which represents the power manufacturer's preference for risk. P_y is the annual contract electricity price, which is regarded as a known quantity in this paper Q_i^r, $Q_{c,i}$ Monthly transaction electricity of each month of the next year and the purchase amount of green certificate of each month of the next year, where $Q_{c,i}$ is positive, denotes the purchase of green certificate, and negative, denotes the sale of green certificate; $P_{c,i}$ is the purchase or sale price of the green certificate in each month of the next year, and c_r is the power generation cost of the power manufacturer.

3.1.2Green certificate market trading model

According to national policies, the renewable energy quota Q_c that power manufacturers need to complete in the current year will be verified. Since the power generation enterprises discussed in this paper are power manufacturers, all their quotas will be made up by purchasing green certificates.

Monthly purchase and sale restriction power manufacturers must not buy more than a certain percentage of green certificates allocated by the government and sell more than the total number of green certificates currently held.

When $Q_{c,i}\geqslant 0$,equation (X) needs to be satisfied.

$$Q_{c,i}\leqslant\mu Q_c\ \forall i=2,3,\mathrm{L},12(\mathrm{X}) \quad (3)$$

When $Q_{c,i} < 0$,equation (X) needs to be satisfied.

$$-Q_{c,i} \leqslant \sum_{t=1}^{i-1} Q_{c,t} \ \forall i = 2,3,\mathrm{L},12 \quad (4)$$

In the formula, μ is the purchasing upper limit coefficient of monthly green certificate trading, which is determined by the regulator. When $i = 1$, $\sum_{t=1} Q_{c,t}$ is 0.

To prevent excessive speculation by power manufacturers, the regulator has set a limit on the number of green certificates issued by e-commerce companies. The number of green certificates held by power manufacturers must not exceed the prescribed limit.

$$\sum_{i=1}^{i} Q_{c,i} \leqslant Q_c K^* \ \forall i = 1,2,\mathrm{L},12 \quad (5)$$

Where, K^* is the green certificate holding coefficient stipulated by the green certificate trading institution.

Green certificate trading institutions usually specify the minimum trading volume of green certificate. If $Q_{c,i} \neq 0$, then there is:

$$\left|Q_{c,i}\right| \geqslant r \ \forall i = 1,2,\mathrm{L},12 \quad (6)$$

Where, r is the minimum trading volume of carbon quota, usually 1.

3.1.3 Medium - and long-term market trading model for electricity

The amount of electricity a power producer can generate each month is limited by its capacity for that month.

$$\begin{aligned} Q_{y,i} + Q_i^r &\leqslant Q_{\max} \quad \forall i = 1,2,\mathrm{L},12 \\ Q_{y,i} &\geqslant 0 \quad \forall i = 1,2,\mathrm{L},12 \\ Q_i^r &\geqslant 0 \quad \forall i = 1,2,\mathrm{L},12 \end{aligned} \quad (7)$$

Where, $Q_{\max}$ "is the monthly maximum power generation plan of the power manufacturer, and $Q_{y,i}$ is the monthly decomposition amount of the annual contract, which is affected by the coal storage amount and unit maintenance plan of the power manufacturer.

Power trading institutions encourage market entities to sign long-term contracts, and the annual contracted quantity of power manufacturers shall not be less than a certain proportion of the total quantity of medium - and long-term contracted quantity.

$$\lambda \sum_{i=1}^{12} \left(Q_{y,i} + Q_i^r\right) \leqslant Q_y \quad (8)$$

Where, the quantity of electricity under the annual contract for λ accounts for the influence of the total coal storage amount under the medium and long term contract, unit maintenance plan and other factors.

When power manufacturers trade in the green market, the net trading value of the green certificate at the end of the performance period should be greater than the quota set by the government.

$$\sum_{l=1}^{12} Q_{c,i} \geqslant Q_c \quad (9)$$

3.2 Decisions during the Year

3.2.1 Objective function

As the January trading plans were decided before the year, the decisions for the year only need to roll over the trading plans for February to December, according to the best combined benefits of expected profits and risks for the remaining period, T-January (t⩾2) decision trading plans for months t to December, RESULTS: But only the decision result of month t is implemented, and the objective function is:

$$\max R = (1-\alpha)R_e + \alpha R_\alpha \quad (10)$$

$$R_e = \sum_{i=1}^{12} \left(\left(P_y - c_r\right) Q_{y,i} + Q_i^r \left(p_i^r - c_r\right) - P_{c,i} Q_{c,i} \right) \quad (11)$$

$$\begin{aligned} & R = \eta - \frac{1}{N(1-\alpha)} \sum_{\omega=1}^{N} S_\omega \\ & \text{s.t} \\ & \eta - \left(\left(P_y - c_r\right) Q_y + Q_i^r \left(p_i^r - c_r\right) - P_{c,i} Q_{c,i} \right) \leqslant S_\omega \\ & S_\omega \geqslant 0 \forall \omega \end{aligned} \quad (12)$$

It should also satisfy constraints similar to those associated with the annual decision.

4. Conclusion

With the proposal of the two-carbon target and the launch of the green certificate market, this model is helpful for power manufacturers to take into account the risks and benefits, and provides some guidance for power manufacturers to participate in the green certificate market and the medium - and long-term power market at the same time. This paper mainly draws the following conclusions:

(1) According to the joint decision model proposed in this paper, power manufacturers can comprehensively consider the conditions of the power market and the green certificate market, and flexibly decide the trading behavior in the power market and the green certificate market according to the different degree of risk preference, which can obtain greater comprehensive benefits than the traditional model.

(2) The profit risk of power manufacturers can be described by the expected value of benefits outside the confidence, which can avoid the problem of constructing loss function when the benefit function is used in CVaR calculation.

(3) In order to better guide power manufacturers to clean and low-carbon transformation, measures such as limiting the number of green certificates held by power manufacturers and limiting the range of price changes of green certificates can be taken to restrain the speculative behaviors of power manufacturers, so that the renewable energy quota can be transmitted to power manufacturers as far as possible.

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