Quantitative Evaluation Method of Contract Execution Deviation Risk in Power Spot Market

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Abstract: In the power spot market, the price risk is the biggest among the power purchase schemes under multiple time scales. Equipment failure, scheduling affairs, external policy adjustment and market fluctuation may cause the deviation of contract execution. This paper analyzes the uncertain risk degree of random variables by identifying risk factors. The probability density of the random variable is analyzed, and the conditional risk-value function of the random variable is established. Finally, based on monte carlo stochastic simulation, risk indicators are used to quantitatively evaluate the risk of power purchase and sale.

1. Introduction

Quantitative risk assessment is the numerical calculation of risk indicators. At present, risk indicators mainly include standard deviation, standard deviation coefficient, value at risk (VaR), conditional value at risk (CVaR), etc. Among them, the market subject pays more attention to the risk that the revenue from electricity purchase and sale is less than the expected revenue. The standard deviation and standard deviation coefficient cannot describe the direction of the risk, and the value at risk does not meet the consistency and additivity.

In the current research on the risk of spot power market, in order to promote the optimization of resource allocation, it is necessary to form the electricity price signal that reflects the physical operation characteristics of the power system. Some experts and scholars adopt credit evaluation system for risk early warning management \cite{1}. For the user side, one kind of research focuses on the analysis of over-sensitive influence of prediction accuracy, resource characteristics of the user side and cost on the control of real-time deviating electric quantity of the selling company \cite{2}. In the other category, the user similarity calculation method is adopted to automatically identify the required parameters and achieve the optimal clustering effect \cite{3}. However, the evaluation results of these two methods are highly influenced by subjective factors. Therefore, conditional risk value based on objective probability data is used as risk index. It is more helpful for the selling companies to avoid the risk of contract execution deviation in the electricity spot market and improve their profitability \cite{4-5} to evaluate the electricity purchase and sale risks of the main players in the electricity retail market with the highest profit and the lowest risk \cite{6}.

Because the mean and standard deviation of day-ahead clearance price have a strong correlation with day-ahead market load, it can be expressed by a unitary linear regression equation with day-ahead
clearance price as the dependent variable and day-ahead market load as the independent variable. Therefore, in this paper, the risk condition function of income is constructed to minimize the risk of electricity purchase while striving for the maximum income.

2. Analysis of Contract Deviation Factors in Power Spot Market

For electricity sales revenue, the capacity electricity price, electricity price and peak, flat and valley time periods of the price package shall be determined by the power selling company and power users through bilateral independent negotiation; the real-time load of power users is a random variable, which can be divided into two parts: planned load and random load error. Among them, the planned load is caused by the change of electricity users' production and living behaviors, which is manifested as the change of the overall trend of the daily load curve, with a long cycle and a large range of changes; random errors of load are caused by unpredictable daily changes, which are shown as small fluctuations under a certain daily load curve with short period and small range. The planned load corresponds to the annual and monthly medium and long-term risks of the load, and the random error of the load corresponds to the day-ahead and real-time short-term risks of the load.

For the electricity purchase cost, the contracted power is decomposed according to the standardized contract curve, and the contract price is independently negotiated by the selling company and the user, both of which are determined variables: day-ahead bid winning load, day-ahead clearance price and real-time clearance price are all random variables. In the day-ago market, the number of electricity selling companies is large and the market share is scattered. Generally, there is no market monopoly. It is approximately believed that a single electricity selling company and electricity users cannot affect the clearance price, that is, the electricity selling company and electricity users are price receivers. Therefore, it is believed that the uncertainty of day-ahead bid-winning load, day-ahead clearance price and real-time clearance price is caused by the non-monopoly position of the selling companies and users in the market and the unpredictability of other market players' trading strategies.

Most customers of the power retail package are enterprises, which have the characteristics of large power consumption, complex electrical equipment, small power demand elasticity, and sensitive to the influence of market policies. Therefore, the deviation of the user's contract execution mainly comes from two aspects: the lack of internal control and the change of the external environment.

Equipment failure may cause deviation in contract execution. After signing the power consumption contract with the selling company, the time period and load of power consumption may be restricted by the contract. In the case of failure or even aging of electrical equipment, the load is likely to change uncontrollably. When the equipment is out of service or the power consumption increases sharply, it is possible to break through the agreed scope of the contract and cause deviation in the execution of the contract.

Scheduling transactions may cause deviations in contract execution. The contract performance of power users is closely related to the production scheduling plan. Scientific and reasonable scheduling plan can effectively balance the power demand curve and make the demand of electricity characteristic load contract. If the plan for electricity use is not reasonable, and the electrical appliances run over schedule, resulting in a large amount of load demand within a short period of time or the total power exceeds the limit of the contract, the contract implementation deviation will be caused.

External policy adjustment may cause deviation of contract execution. As an uncontrollable factor in contract execution, policy adjustment often affects power consumption characteristics of large industrial enterprises. In the period of environmental rectification, production inspection, policy shutdown, etc., the factory cannot carry out production according to the established plan, and most of the load stops working, and the scheduling cannot foresee such events, so it is difficult to make timely adjustments to meet the requirements of the contract.

Market fluctuation may cause deviation of contract. The market fluctuation is the most significant factor affecting the electricity contract. In order to cope with the possible increase in market demand, the general industrial production users will reserve inventory in advance. However, when the market is
saturated, work stoppages will occur, and the electricity load will fall to a lower level, which will bring a big deviation to the monthly contract execution.

3. Quantitative Risk Assessment
Conditional value-at-risk is the expectation that the loss is greater than the value-at-risk under a certain degree of confidence. The conditional value-at-risk considers all kinds of situations in which the loss is greater than the value-at-risk. The conditional value at risk calculated by profit is opposite to that calculated by loss, that is, the greater the conditional value at risk, the smaller the risk. The calculation method is as follows.

\[ R_v = \{ x \mid \int_{-\infty}^{x} f (r) \, dr = \alpha \} \]  

(1)

\[ R_{CV} = \frac{1}{1 - \alpha} \int_{-\infty}^{x} rf (r) \, dr \]  

(2)

Where,
\[ R_v \] — Risk Mechanism (VaR)
\[ x \] — Quantile of Probability Density Function
\[ r \] — Revenue
\[ f (r) \] — Probability Density Function of Revenue
\[ \alpha \] — Confidence Coefficient
\[ R_{CV} \] — Conditional value-at-risk (CVaR)

Due to the different number of agent users and electricity of different market players, the income level of electricity purchase and sale is also different. In order to compare the purchase and sale risks of different market players, it is necessary to normalize the conditional risk value, that is, the conditional risk value divided by the expected return.

\[ R'_{CV} = \frac{R_{CV}}{E(R)} = \frac{R_{CV}}{\int_{-\infty}^{x} rf (r) \, dr} \]  

(3)

Where,
\[ R'_{CV} \] — Normalized Conditional Value-at-risk
\[ E(R) \] — Expected Revenue

4. Risk Warning
Risk early warning can be carried out in the following ways:

(1) Maximum Load
According to the maximum normal load value of the industry, the maximum power load is agreed according to the current contract agreement and the actual situation of users. When the user appears or exceeds the maximum load, the user shall be informed in time to restrict the power consumption.

(2) Cumulative Power Consumption at Time Point
By balancing the ideal value with the accumulated power consumption at the normal time point in history, the base value of the accumulated power consumption at each time point for a specific user is obtained. When there is a big deviation between the electricity consumption of the user at this point and the base value, the user shall be informed in time to restrict the electricity consumption.

(3) Time Point Warning
Carry out calculation and analysis on the above indexes at the planned time point, and form the
routine inspection values, which can be used as an important basis for analyzing the law of user electricity consumption and formulating the next phase contract.

(4) Extreme Data Warning
When a certain index of the user is abnormal, the early-warning mechanism is triggered to calculate the deviation of contract execution for the user immediately, which is an effective means to ensure the safe and stable operation of the system and the execution of the contract.

5. Contract Execution Deviation Control Strategy
According to the above analysis, in order to realize the effective avoidance of risks in the spot power market, the following Suggestions are put forward.

(1) Optimize Contract Decomposition Method, Lock in the Income Level
The core of day-ahead market risk aversion is to reduce the deviation between the contract decomposition curve and the day-ahead bid winning load curve. Generally, service providers are the passive recipients of the market price in the spot electricity market. Therefore, the main measures to avoid the day-ahead market risk are to optimize the contract decomposition mode, refine the contract decomposition curve, and basically lock in the medium and long-term income level of the service provider with a reasonable contract for difference.

For the main selling electricity, the principle of contract decomposition is to use the contract to lock in earnings in advance and reduce the market risk. In the period when the clearance price is small and the fluctuation is small, the contract decomposition quantity is small and the electricity is mainly purchased through the spot market. In the period of high clearance price and high fluctuation, the contract decomposition power is large. Contract decomposition mainly includes the decomposition and combination of generating sets according to the standard decomposition curve provided by the power trading center, as well as the two ways of generating sets, selling companies and users to negotiate the decomposition independently.

1) If the generator set standard decomposition curve provided by the power trading center is used for decomposition and combination, the power seller shall take into account the type of generator set signed the contract, typical output curve, clearing price and other factors at the node. Taking the maximum total market return and the minimum risk of spot market as the objective function, the optimal contract decomposition curve combination is obtained by using the optimization model.

2) If the generator set and the selling company, the customer independently negotiate decomposition plan. Then both parties need to negotiate bilaterally to form a contract decomposition mode acceptable to both parties.

(2) Improve Load Prediction Accuracy, Smooth Energy Storage Load Fluctuation
The core of real-time market risk aversion is to reduce the deviation between real-time load curve and day-ahead winning load curve. Therefore, the main measures for real-time market risk avoidance are as follows: first, to improve the accuracy of service providers' short-term and ultra-short-term load prediction of agent users; second, to collect real-time power consumption information of agent users based on smart electricity meters, Internet of things and other technologies, and to use energy storage technology to smooth load fluctuation and reduce load deviation.

6. Conclusion
According to the power market settlement method, the main risk factors are different in the day-ahead and real-time markets. For day-ahead market, day-ahead clearance price is the main risk factor. A normal distribution probability density function model associated with day-ahead market load space can be used to approximate the day-ahead clearance price. For the real-time market, real-time load and real-time clearing price are the main risk factors. The normal distribution probability density function model associated with the real-time market load space can be used to approximate the real-time clearing price.

Generally, compared with day-ahead market, the load space of real-time market is smaller and the corresponding risk is smaller. Therefore, compared with the accuracy of load lifting prediction and energy storage smoothing load fluctuation, optimizing contract decomposition and reasonably
determining contract for difference have more advantages in terms of technology and economy, which will be the main measures to avoid risks in the spot power market.

Acknowledgements
This research was financially supported by research and development of the key technology of electric energy trading for spot market and green energy trading, Number: 52467M180053.

References
[1] Tian Lin, Gan Beiyu, Sun Qian, Ji Tianyao, Sheng Jiansheng, Xu Lixin, Xie Yuting, Jing Zhaoxia, Tan Jie, Hu Xiuzhen, Luo Jinqing. Credit risk management of guangdong electric power spot market [J]. China southern power grid technology,2019,13(06):50-56.
[2] Gao Rui, Guo Hongxia, Yang Ping, Guo Minhua, Ren Zhijun. Real-time market deviation electric quantity control strategy of power selling companies based on user side adjustable resources [J]. Power construction,2019,40(06):114-122.
[3] Jia Chen. Analysis and decision of power purchase behavior of power selling companies under the power market environment [D]. Taiyuan university of technology,2019.
[4] Gao Yi. Study on electricity purchase and sale strategies of e-commerce sellers considering the quota system of renewable energy [D]. Huazhong university of science and technology,2019.
[5] Ma Hui, Chen Hugo, Chen Ye, Liu Wentao, Lin Shaohua, Zhang Xuan, Bai Yang, Luo Gang, Lai Xiaowen, Wang Yang. Mechanism design of spot market of electric power in southern China (starting from guangdong province) [J]. China southern power grid technology,2018,12(12):42-48.
[6] Lu Bo. A study on the operation strategy of power selling companies considering risk and demand response [D]. Southeast university,2018.