Research on Risk Assessment Model of Electricity Spot Market Considering Local Grid and Incremental Distribution Network

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Abstract. Under the background of incremental distribution reform, the local grid and the incremental distribution network will directly participate in the electricity spot market, and compete with main power supplies in the market segments of quotation, clearing, pricing, and settlement, etc. Local grid enterprises and incremental network enterprises will also directly participate in the competition of the spot market, which will exacerbate the risks of price fluctuation, information disclosure, and network congestion in the spot market. In order to help enterprises identify and evaluate market risks, develop scientific risk prevention strategies, firstly, the risk impact mechanism of local grids and incremental distribution networks on the electricity spot market was analyzed; then, indicators were selected from five dimensions, such as competing risk and price risk, and a risk assessment model of the electricity spot market with consideration of local grids and incremental distribution networks was established; finally, strategic suggestions for preventing market risks were put forward, which provide a reference for rationally controlling the market risk of the spot market and promoting the safe and stable operation of the market.

Keywords: spot market; risk assessment; local grid, incremental distribution network

1 Introduction

At present, Chinese electricity market reform has entered a critical period, and the electricity spot market, as an important supplement to the medium and long-term electricity market, has gradually begun to build and develop. At this stage, China develops the electricity spot market on a pilot basis, and several provinces have conducted trial runs of electricity spot market settlement (2023, Zhao Yue). With the incremental distribution reform, the number and size of incremental distribution companies have grown significantly, the local grid, the incremental distribution network and the two major grid companies jointly support the transportation and transmission of electricity. With the development of the electricity spot market, local grid companies and incremental distribution companies will directly participate in the market, competing with other types of power generation companies and electricity retailers in the electricity spot market segments, such as quotation, clearing, pricing, and settlement (2023, Yin Hang). Local power grids and incremental distribution networks, as an integral part of Chinese power grid enterprises, will bring greater risks in terms of price fluctuation and power dispatch to the electricity spot market. Therefore, how to identify and assess these risks and develop

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reasonable risk prevention and control strategies is of great significance to improve the benefits of power grid enterprises and ensure the security and stability of the electricity spot market (2023, Wang Kai).

2 Literature review

At present, scholars have researched on the assessment and prevention of electricity spot market risk. Research on the identification of risks in the electricity spot market mainly focuses on the market force control and credit risk, price risk, forecast error risk and so on[1–4]. Liu, Y et al. investigated the stability of the spot market, and estimated the relationship between prices and demand[5]. Wang, H et al. proposed a method for electricity sales companies to make optimal decisions on renewable energy source (RES) power and conventional energy source (CES) power mixed with power trading in the spot market to improve the efficiency of electricity market trading[6]. Fu Jingyu et al. pointed out that the identification and mitigation of market force risk is a necessary part of the electricity spot market system, and designed a market force risk control system for it[7,8]. Bao et al. studied the mechanism analysis and construction path of the risk aversion mechanism in the electricity spot market, and pointed out that credit risk management contributes to price stability[9]. For research on market risk aversion, it mainly focuses on avoidance methods and market mechanism design[10,11]. Mosquera-Lopez, S and Nursimulu, A found that in the case of the spot market, the determinants of prices are renewable infeed and electricity demand[12]. Yucekaya, presented a sensitivity analysis for spot price volatility on the profit[13]. Liu Xingyu et al. considered the risk aversion of wind power through CVaR, and pointed out that the portfolio can be determined by economic model based on risk and expected return[14].

By sorting out the above literature, it can be seen that: the existing literature has mainly developed risk aversion mechanisms based on the consideration of the main factors affecting the electricity spot market risk, and has not considered the impact of the participation of local grids and incremental distribution networks on the spot market, and there is a lack of research on the identification, assessment and prevention of the spot market risk by considering the participation of local grids and incremental distribution networks. Based on this, this paper first analyzed the impact of local grids and incremental distribution networks on the electricity spot market, and then, constructed the risk assessment indicator system, and determined the indicator weights through the Analytical Hierarchy Process(AHP) - entropy weight method, and constructed a risk assessment model, which provides a methodological basis for identifying the market risks and developing the prevention strategies.

3 Mechanism analysis of the impact of local grids and incremental distribution networks on spot market risk

1. Market competing risk

Due to the natural monopoly characteristics of electric goods, in the spot market, each power generators has a certain amount of market force. Such as the market force possessed by the market participants' own high proportion of installed capacity or required capacity, these enterprises may utilize their competitive advantages to abuse the market force and obtain illegal profits, thus undermine market equity and create competitive risks for the market. When power sources of local grids and incremental distribution networks directly participate in the spot market, the competing risk in the market will be further magnified because there is often a system cross section between the main grid, local grids, and incremental distribution networks, and more constraints on the operation of the spot market due to the management differences in the operation and scheduling of the two grids.

2. Market security risk

The internal supply of local grids and incremental distribution networks directly involved in the spot market, will significantly influence the current cross-grid power dispatch between the main grid and local grids, incremental distribution networks, and it is more difficult to access grid optimum load and transfer load in case of accident, it also brings about an adverse impact on the overall coordinated operation of the grid, and the electricity spot market makes the power grid dispatching work more centralized, it is very easy to cause the distortion of the grid voltage, current waveforms. At the same time, it will bring harmonic interference to the power grid, resulting in the risk of power quality.

3. Market price risk

Due to the uncertainty of the electricity spot market price, local grids and incremental distribution networks may implement economic withholding when participating in spot market transactions, raise the market clearing price to make its remaining capacity can be sold at a high price. This behavior increases the price fluctuation risk of the spot market, resulting in market prices do not truly reflect the actual supply and demand situation. At the same time, most of the local grids, incremental distribution networks and the power generation enterprises under them are basically owned by the same enterprise group with common interests, and it is very easy for them to secretly work together to form an oligopoly, and to take advantage of the enlarged market force to obtain profits, which results in the risk of collusion.

4. Market trading risk

Local grids and incremental distribution networks need to purchase electricity on behalf of industrial and commercial users who are not in the market, and after entering the spot market, it is more difficult to accurately forecast the electricity consumption to be purchased by industrial and commercial users, and the current mechanism of the domestic spot market basically takes into account the recovery of the excess returns of the spot, and does not take into account the compensation for the excess losses of the participants in the market due to individual differences, which may lead to a higher cost of power purchase for local grids and incremental distribution networks. At the same time, the time gap in the collection and payment of user-side fees will adversely affect the cash flow of local grids and incremental distribution networks, and increase the operating pressure on local grids and incremental distribution networks.

5. Market management risk

When local grids and incremental distribution networks participate in spot market transactions, there are risks of insufficient information disclosure, untimely information disclosure and other information disclosure quality risks, policy change risks, and risks of data fabrication for the purpose of obtaining higher returns, which harm the market price discovery function and reduce the market credibility.

4 Construction of spot market risk assessment model considering local grids and incremental distribution networks

4.1 Selection of risk assessment indicators

On the basis of the previous risk mechanism analysis, a set of assessment indicator system that can comprehensively reflect the risk of local grids and incremental distribution networks participating in the electricity spot market is shown in Table 1.The meanings and calculation standard of each indicator are shown in Table 2.

Table 1. Risk assessment indicator system for participation of local grids and other entities in the electricity spot market

Target layer A	Criterion layer B	Indicator layer C	Meaning	Scoring standard
Risk assessment of participation of local grids and other entities in the electricity spot market A	Market competing risk B_1	Generation-side market concentration ratio C_1	It reflects the level of market force of generation-side market participants and the level of monopoly in the generation market.	It is divided into 5 grades: very high, high, average, low, and very low, and the corresponding indicators scores are 100, 75, 50, and 0 points.
		Sales-side market concentration ratio C_2	It reflects the level of market force of sales-side market participants and the level of monopoly in the electricity sale market.	It is divided into 5 grades, the specific rules are the same as those of number 1.
		Market force behavior test rate C_3	It reflects the extent to which market participants influence the outcome of market transactions and disrupt market operations through the exercise of market force.	It is divided into 5 grades, the specific rules are the same as those of number 1.
	Market security risk B_2	Lerner index C_4	It dynamically measures the degree of market price deviation from marginal cost and reflects the stability of market operation.	The Lerner index ranges from 0 to 1. The higher its value, the stronger the monopoly force in the market; the weaker the monopoly force and the higher the degree of competition.
		Credit risk level C_5	Credit occupancy level is used to assess the credit risk level in the electricity market.	It is divided into 5 grades, the specific rules are the same as those of number 1.
		Market participation rate of power users C_6	It reflects the participation rate of electricity consumers in the market.	Indicator score = (number of users participating in market transactions / number of access users)
		Market contract	It reflects the overall scale of the electricity market liberalization.	Indicator score = (market contract electricity / total traded electricity)

		electricity rate C_7		
		Acceptance degree of new energy C_8	It reflects the acceptance degree of new energy sources by the grid.	Indicator score = (power generation from new energy sources / power generation of the power grid)
	Market price risk B_3	Price fluctuation rate C_9	It reflects the market risk of electricity goods.	It is divided into 5 grades, the specific rules are the same as those of number 1.
		Price concordance index C_{10}	It assesses the possibility of unusual behavior in the market.	It is divided into 5 grades, the specific rules are the same as those of number 1.
		Price cap clearing node proportion C_{11}	It is used to determine whether market entities make the market clearing price deviate from the normal level.	It is divided into 5 grades, the specific rules are the same as those of number 1.
	Market trading risk B_4	Trade execution deviation rate C_{12}	It reflects the level of deviation between market declarations and actual settlements by market participants.	Indicator Score = | actual settlement electricity - market clearing electricity | / market clearing electricity
		Rate of timely settlement of electricity charges C_{13}	It reflects the efficiency of the settlement of electricity charges after market transactions.	Indicator score = (timely settlement of electricity charges / billable electricity charges)
	Market management risk B_5	Effective response rate of public opinion C_{14}	It reflects the level of response to public opinion in the market.	Indicator score = (number of effective responses to public opinion / total number of public opinion occurrences)
		Growth rate of market complaints C_{15}	It reflects the degree of satisfaction of market entities with the market.	It is divided into 5 grades, the specific rules are the same as those of number 1.
		Composite index of information disclosure quality C_{16}	It reflects the degree of openness and transparency of the market.	It is divided into 5 grades, the specific rules are the same as those of number 1.

4.2 Determination of risk assessment indicator weights

This section uses AHP-entropy weight method to calculate the weight of each indicator, and combines subjective and objective methods to ensure the scientific weight of the indicator.

4.2.1 Analytical Hierarchy Process(AHP) method.

AHP method uses mathematical methods to quantify the process of analysis, judgment and decision-making, which ensures the objectivity and standardization of the program. The steps for determining the weights of indicators by AHP method are as follows:

1. Construct pairwise judgment matrices

On the basis of modeling the hierarchical structure and clarifying the affiliation between the elements of each level, construct a pairwise judgment matrix A:

$$A = \left(a_{ij}\right)_{n\times n} = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix}. \quad (1)$$

In the matrix A, a_{ij} is the result of the comparison of the importance of the element i and the element j with respect to the upper elements, and $a_{ij} > 0$, $a_{ii} = 1$, $a_{ji} = 1 / a_{ij}$, $i, j = 1, 2, 3 \cdots n$.

2. Calculate a single judgment matrix weight vector

Secondly, ω, the feature vector of matrix A is obtained by the normalization calculation process.

Summing the elements of each row of the judgment matrix A, and normalize the summation of the elements of each row:

$$\overline{\varpi}_i = \sum_{j=1}^{n} a_{ij}, i = 1,2,\cdots,n \quad (2)$$

$$\varpi_i = \frac{\overline{\varpi}_i}{\sum_{i=1}^{n} \overline{\varpi}_i}, i = 1,2,\cdots,n \quad (3)$$

ϖ_i is the obtained weight vector, namely the weight coefficient of indicators .

3. Consistency test

Let λ_{max} be the largest eigenvalue of the reciprocal matrix $A = \lfloor a_{ij} \rfloor_{n\times n}$, there must be $\lambda_{max} \geq n$, and the equation is set up only if the matrix A satisfies consistency.

Assuming that $\lambda_1, \lambda_2 \cdots \lambda_n$ is the eigenvalue of the judgment matrix A, we can obtain the largest principal eigenvalue of this matrix λ_{max}:

$$\lambda_{\max} + \sum_{i=2}^{n} \lambda_i = trA = n, \text{namely } \sum_{i=2}^{n} \lambda_i = n - \lambda_{\max} \quad (4)$$

The consistency index CI for the matrix is as follows:

$$CI = \frac{\lambda_{max} - n}{(n-1)} \quad (5)$$

n is the number of factors in the factor set.

The formula for the random consistency ratio CR is as follows:

$$CR = \frac{CI}{RI} \quad (6)$$

CR is the random consistency ratio, and RI can be obtained from Table 2. When CR<=0.1, the judgment matrix has excellent consistency, and the weights of indicators are reasonable, otherwise the weights are unreasonable.

Table 2. the RI values of order 3-11 reciprocal matrix with a sample size 1000

matrix order	1	2	3	4	5	6	7	8	9	10	11
RI	0	0	0.51	0.89	1.12	1.25	1.35	1.42	1.46	1.49	1.52

4.2.2 Entropy weight method

In the multi-objective decision-making problem, for a certain indicator value of each alternative, the indicator with a large deviation can better reflect the differences of each program, the complementary value of entropy can be used as the objective weight of the indicator after normalization. The steps for determining the weights of indicators by the entropy weight method are as follows:

There are n enterprises to be evaluated, m assessment indicators, xij represents the value of the jth assessment indicator of the ith enterprise, the original matrix is:

$$X = (x_{ij})_{n\times m} \tag{7}$$

(1) The data from the original matrix X is dimensionless treated to get the matrix Y=y$ijn\times m$. The dimensionless treatment method is as follows:

set upmax1≤i≤$mxij$=aj, min1≤i≤$mxij$=bj, then for the benefit-based indicators:

$$y_{ij} = \frac{x_{ij}}{a_j} \tag{8}$$

For cost-based indicators:

$$y_{ij} = \frac{b_j}{x_{ij}} \tag{9}$$

(2) Calculate the proportion of the ith enterprise under the jth indicator:

$$p_{ij} = \frac{y_{ij}}{\sum_{i=1}^{n} y_{ij}} \tag{10}$$

(3) Calculate the entropy value of t the jth indicator:

$$e_j = -\frac{1}{\ln n}\sum_{i=1}^{n} p_{ij} \ln p_{ij} \tag{11}$$

(4) Calculate the coefficient of variation of the jth indicator:

$$g_j = 1 - e_j \tag{12}$$

Among the formula, $0 \le g_j \le 1$.

(5) Calculate the weight of the jth indicator:

$$\begin{pmatrix} \omega_j = \frac{g_j}{m - E_e} \\ E_e = \sum_{j=1}^{m} e_j \\ 0 \le \omega_j \le 1 \\ \sum \omega_j = 1 \end{pmatrix} \tag{13}$$

4.2.3 Determination of comprehensive weight

Integration of the subjective and objective weights of the indicators enables the assessment model to reflect both the subjective judgment of the experts and the objective weights reflected in the data information. The determination of the composite coefficient contains human subjective tendency by the weighted linear method and mixed addition and multiplication method, so this paper adopts the multiplicative synthesis method based on the principle of minimum information entropy.

The comprehensive weight can be obtained by Lagrange multiplier method:

$$w_j = (w_k w_{oj})^{0.5} / \sum_{j=1}^{n} (w_k w_{oj})^{0.5} \tag{14}$$

4.3 Risk assessment modeling

(1) Standardization of indicators

Considering the wide range and poor comparability of the data collected by the indicators in Table 1, they need to be standardized, namely the attribute set needs to be normalized, in order to facilitate the subsequent assessment. The positive indicators in the risk assessment indicator system for the participation of local grids and other entities in the electricity spot market are C_{10}, C_{13}, C_{14}, and C_{16}; the rest are inverse indicators.

In order to avoid the proportional differences when indicators are dimensionless treated, this paper adopts the extreme value processing method for the consistent processing of indicator types, unified data form of each indicator, so that:

$$X_{ij} = (M_j - X_{ij}) / (M_j - m_j) \text{ (positive indicator)} \tag{15}$$

$$X_{ij} = (X_{ij} - m_j) / (M_j - m_j) \text{ (inverse indicator)} \tag{16}$$

M_j is the maximum value of the jth indicator among enterprises to be assessed, and m_j is the minimum value of the jth indicator among enterprises to be assessed.

(2) Determination of risk assessment value

Using the indicator weights derived from the comprehensive weighting method, the risk assessment value of the participation of local grids and incremental distribution networks in the electricity spot market is calculated T. The ith T is calculated as.

$$T_i = \sum_{j=1}^{n} X_{ij} w_j \tag{17}$$

In summary, by analyzing the risk factors of local grids and incremental distribution networks participating in spot transactions, this paper determined the weights of each factor and established an assessment model for scoring, and quantified the various types of risks. This can help entities to be aware of the risk factors in the process of spot trading timely, and adjust the risk management strategy according to the level of risk.

5 Conclusion

In this paper, we design the risk assessment system for local grids and incremental distribution networks to participate in the spot market, the system is designed from the three dimensions of risk assessment indicator selection, indicator weight determination and assessment model construction. At the same time, this paper puts forward the following suggestions for spot market risk prevention according to the above research:

1. Optimize the quantity quotation method of power generators. For power generators with the ability of implementing market force in local grids and incremental distribution networks, when they report their offer curves, limit the steepness of their offer curves and the generation capacity for which they can report their prices, and limit power generators with a large proportion of generation capacity from taking advantage of their market position in order to seek unfair profits.

2. Improve the inter-network settlement mechanism between provincial power grids and local power grids and incremental distribution networks. It is necessary to establish a set of scientific and effective settlement mechanism between provincial power grids and other power grids to promote the fair and efficient flow of capital in the market, so as to promote the smooth and healthy development of the electricity spot market.

3. Improve the mechanism of information disclosure and assessment of market entities. On the one hand, cultivate awareness of local grids and incremental distribution networks' responsibility for information disclosure; on the other hand, strengthen the construction of the platform and the capacity of various market entities to report and disclose information, improve the accuracy, timeliness and completeness of information reporting, reduce problems such as late reporting, missing reporting, and misreporting. At the same time, set up reward and punishment mechanism.

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