The Compliance Risk Assessment of Electric Power Market based on Bayesian Comprehensive Evaluation Model

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Abstract. With the deepening of the new round of power system reform, the importance of power market compliance risk management is further highlighted. And compliance risk assessment is a key component of compliance risk management. Based on the compliance risk points of each participant in the power market, this paper constructs the compliance risk evaluation indication system of the power market. We determine the weight of each indicator by integrating the analytic hierarchy process, the improved entropy weight method and Bayesian comprehensive evaluation model. And then the compliance risk evaluation value of the power market is obtained, which provides effective support for the compliance risk management of the power market.

1. Introduction
Under the current economic situation and the reform of electric power system, the electric power market is gradually moving towards a new pattern. With the emergence of new business formats, the transaction mode of the power market is becoming increasingly complicated. And the electricity market is faced with various risks brought by the new situation, which makes the construction and management of the electricity market faced with more and more challenges. Compliance management of the power market refers to a series of activities to improve the compliance management mechanism, risk prevention and response of compliance management through establishing the compliance management system, which is to achieve the compliance goal. The power market compliance management system is an important part of the construction of a central enterprise under rule of law, and an internal requirement for the realization of the strategic goal of "Three Types and Two Networks, World-class" of the State Grid Corporation. And it is also an important guarantee for preventing and resolving major risks. The construction of compliance management system is to comply with the reform direction, meet the construction requirements, and serve the electric power supervision business, which is of great significance to the sustainable and healthy development of the electric power market. A scientific and effective power market compliance management system can meet the needs of the situation, and continuously regulate the management of power market transactions based on the actual operation and management of the trading center. In addition, it can carry out the pre-event, in-event and post-event compliance control of transactions, which ensures that the operation of electricity trading business is in compliance with the law. Therefore, the scientific and effective power market compliance management system ensures the orderly control and standardized operation of the power market and prevents market
risks to the maximum extent, which meets the supervision and regulation requirements of regulatory authorities, market entities and the public.

2. Literature review

Currently, the research on the risk assessment and management of the power market mostly focuses on the risks faced by a certain kind of participants and the risks in the operation of the power system, while the research on the compliance risk assessment of the power market is quite scarce. The researches on risk assessment and prevention of compliance management mostly is mostly concentrated in banks and securities enterprises, while the research on power industry is less. Woo C.K. (2004) established an optimization model of power purchase to minimize the purchase cost and risk, showing that the cost and risk of power purchase can be reduced by predicting the power demand and buying forward shares at forward prices [1]. Yang (2009) made a preliminary thinking and exploration on how to improve the compliance system and management process of commercial Banks and build an effective compliance risk management mechanism [2]. Zhao (2009) studied the compliance risk management of a bank’s Shanghai branch, and made an objective evaluation of the bank’s compliance risk management plan in terms of compliance philosophy, system, risk identification and evaluation, and inspection [3]. Huang and Yan (2010) classified and analyzed the application of risk management in power trading from three parts: risk avoidance, portfolio optimization and risk measurement [4]. Deng (2010) emphasized that only by integrating compliance risk management into the institutional scope of corporate governance can the ultimate effect be achieved [5]. Fan et al (2012) sorted out the relevant laws, regulations and management systems of China's current multi-channel power payment transaction, and comprehensively identified the risk points [6]. Yu (2016) constructed the risk assessment index system to quantify the risk of direct power purchase by large consumers [7]. Zhang (2016) constructed an index system and used the matter-element extension model to evaluate the operation risk level of electricity selling enterprises [8]. Lin (2017) classified the risks into operation risks, risks brought by power grid planning, speculative risks of power grid enterprises, reliability risks of power grid and social risks. And then she put forward corresponding solutions to the risk management of power generation enterprises in the power market [9]. Zheng (2018) proposed that a complete closed-loop compliance management system should include three aspects: working mechanism, organization mechanism and guarantee mechanism [10]. Yang (2018) designed a comprehensive evaluation index system of trading behaviors combining basic indexes and early-warning indexes, a comprehensive evaluation method for trading irregularities, and comprehensive evaluation and hierarchical control measures for illegal behaviors of different market entities [11]. Wang et al (2018) constructed a multi-order credit risk effect model and analyzed propagation mechanism of multi-order credit risk in regional power market [12]. Liu (2020) analyzed and compared the differences and common points between risk, internal control and compliance management and proposed the construction path of the integration of the three systems [13].

3. Method

3.1. The violation risk indicators selection of participants

3.1.1. Power generation companies.

The violation risk indicators of power generation enterprises are as follows:

(1) **Basic information.** The change frequency of registration information refers to the change frequency of fundamental information such as the industry, nature of the enterprise, and place of ownership of the enterprise, as well as significant information such as ownership structure and shareholder list on the trading platform.

(2) **The matching degree of business capability and business scope.** Check the credit rating in the credit rating report issued by the third-party rating agency when the enterprise enters the market, and check whether the business ability of the enterprise matches with its business scope and business area.
(3) Market power. The market power of power generation enterprises mainly refers to their ability to breach the contract in the quotation, which is usually judged by their market share. Assuming that there are \( n \) power generation enterprises and \( m \) power purchasing enterprises in the market, the indicators to judge market power are as follows:

1) **Market concentration.** Market concentration refers to the market share held by the power generation enterprises with the largest market share in the electric power market, which is often measured by the market static index (HHI).

\[
HHI = \sum_{i=1}^{n} S_i^2
\]

Where \( S_i \) represents the market share of power generation enterprise \( i \). The higher the HHI value, the higher the market concentration degree and the greater the degree of market monopoly. The HHI index in a perfectly competitive market tends to 0.

2) **Top-m index.** The top-m index is the sum of the market shares of \( m \) power generation enterprises with the largest market share. The calculation formula is as follows:

\[
I_m = \sum_{i=1}^{m} \beta_i, m \leq F
\]

Where \( I_m \) is the total market share of the \( m \) companies, and \( \beta_i \) is the market share of power generation enterprise \( i \). In the industrial field, \( m = 4 \) is generally adopted.

3) **Pivotal supplier index.** Specifically, pivotal supplier index detects whether the total capacity of other power plants can meet the load demand after deducting the capacity of the target power plant. If the load demand can be satisfied, then \( PSI = 0 \); if not, \( PSI \) equals to 1, proving that the power plant is a pivotal supplier with the ability to manipulate market prices.

4) **Residual supply index.** The residual supply index (PSI) is a continuous form of the PSI index used to measure the abundance of surplus generating capacity of power plants other than the target power plant. The calculation formula is as follows:

\[
I_{RSI} = \sum_{j=1}^{n} q_j - q_i
\]

Where \( n \) is the number of power generation enterprises in the market, \( q_j \) is the capacity of the \( j \)th power generation enterprise, \( q_i \) is the capacity of the \( i \)th power generation enterprise, and \( D \) is the load demand of total market. If \( I_{RSI} < 1 \), the market will not be able to meet the demand without the \( i \)th power generation enterprise, which indicates that the \( i \)th enterprise has market power. The smaller the \( I_{RSI} \), the stronger the ability to control market prices.

5) **Lerner index.** Lerner index (LI) measures the degree of market monopoly by the degree of deviation between the actual market price and the ideal competitive price. The greater the deviation, the higher the degree of market monopoly. In a perfectly competitive power market, Lerner index is equal to 0. When the Lerner index is much larger than 0, it indicates that the market power exists in the market. The specific definition is shown as below, where \( P \) is the market price of the electricity market, and \( MC \) is the ideal competitive electricity price calculated based on the marginal cost of the electric generator set.

\[
LI = \frac{P - MC}{P}
\]

6) **Market supply-demand ratio.**

\[
\%SD = \frac{\sum_{i=1}^{n} S_i \times 100%}{\sum_{j=1}^{n} D_j}
\]
Where $x_{SD}$ is the market supply-demand ratio, that is, the ratio of power supply to power demand, $S_i$ is the $i$th power generation company in the market, and $D_j$ is the $j$th power purchase company in the market.

7) **Market share of declared electric quantity.** It can reflect the market power of power generation enterprises to a certain extent. The greater the market share of a power generation company, the stronger its ability to manipulate market prices. The expression is shown as below, where $x_i$ is the market share of the declared electric quantity of power generation company $i$, and $S_i$ is the declared electric quantity of power generation company $i$.

$$x_i = \frac{S_i}{\sum_{i=1}^{n} S_i} \times 100\% \quad (6)$$

(4) **Quotation strategy.** The indicators that reflect the quotation strategy include relative quotation ratio, quotation security, quotation consistency, retention ratio, etc.

1) **Relative quotation ratio.** The relative quotation ratio reflects the difference between a certain quotation and the average quotation of power generation enterprises, which is close to 100% normally. If the difference is large, it indicates abnormal declaration.

$$p_i = \frac{P_i}{(\sum_{i=1}^{n} P_i)/n} \times 100\% \quad (7)$$

Where $p_i$ represents the relative quotation ratio of power generation enterprise $i$.

2) **Quotation security level.** Quotation security level measures the degree of deviation between the quotation and the historical clearing price. Power generation enterprises usually quote close to the historical clearing price. If the quotation deviates much from the historical clearing price, it may be an illegal operation.

$$S_i = \frac{P_m - E_m}{E_m} \times 100\% \quad (8)$$

Where $S_i$ is the quoted security level of power generation enterprise $i$, $P_m$ is the weighted average of declared price of power generation enterprise $i$, which is obtained by weighted average of multiple quotations with each segment of the declared electric quantity as the weight. And $E_m$ is the expected market marginal price, which can be calculated based on the marginal price of historical transactions.

3) **Quotation consistency.** The probability of the same or similar quotations of different power generation companies is relatively low. Therefore, if consistent quotations occur, it is likely to be the result of collusion.

$$c_i = \frac{P}{\sum_{i=1}^{n} P_i} \times 100\% \quad (9)$$

Where $c_i$ is the ratio of the quotation consistency of power generation company $i$. $P_i$ is the quotation whose quotation similarity is within a certain range which can be determined by market conditions.

4) **Retention ratio.**

$$K_i = \frac{F_m - F_{i}}{F_m} \times 100\% \quad (10)$$

Where $K_i$ is the retention ratio of power generation enterprise $i$, and $F_m$ is the maximum power generation capacity of power generation enterprise $i$.

5) **Excess returns.** The excess returns of power generation enterprises can be reflected by high price winning ratio, low price winning ratio and quotation success level.

1) **High price winning ratio.**

$$H_i = \frac{S_{hi}}{S_i} \times 100\% \quad (11)$$
Where $H_i$ is the high price winning ratio of power generation enterprise $i$, and $S_i$ is the total amount of bid-winning electricity of power generation enterprise $i$. $S_m$ is the amount of bid-winning electricity, the quotation price of which is higher than the highest historical clearing price.

2) **Low price winning ratio.** In order to increase the bid-winning ratio, some power generation enterprises would offer lower prices to increase the bid-winning rate.

$$L_i = \frac{S_m}{S_i} \times 100\%$$

Where $L_i$ is the low price winning ratio of power generation enterprise $i$ in the above formula. $S_m$ is the amount of bid-winning electricity, the quotation price of which is lower than the lowest historical clearing price. And $S_i$ is the total amount of bid-winning electricity of power generation enterprise $i$.

3) **Quotation success level.** It measures whether the quotation strategy has been successfully completed. In the expression below, $D_i$ is the quotation success level of power generation enterprise $i$. $S_i$ is the turnover ratio of the declared electric quantity of power generation enterprise $i$. And $S_a$ is the turnover ratio of market average declared electric quantity.

$$D_i = \frac{S_m}{S_a} \times 100\%$$

3.1.2. **Power sales companies.**

Assuming that there are $m$ electricity sales companies in the market, the violation risk indicators of the enterprises are as follows:

(1) **Market power**

1) **Market share of declared electric quantity.** The market share of declared electric quantity of power sales enterprise $i$ can be expressed as follows:

$$y_i = \frac{D_i}{\sum_{i=1}^{m} D_i} \times 100\%$$

Where $y_i$ is the market share of the declared electric quantity of power sales company $i$, and $D_i$ is the declared electric quantity of power generation company $i$. The greater the market share of a power sales company, the stronger its ability to manipulate the market prices.

2) **Quotation strategy.** The indicators which reflect the quotation strategy include relative quotation ratio, quotation security, quotation consistency, retention ratio, etc.

1) **Relative quotation ratio.**

$$p_w = \frac{P_m}{\left(\sum_{i=1}^{m} P_i\right)/m} \times 100\%$$

Where $p_i$ represents the relative quotation ratio of power generation enterprise $i$.

2) **Quotation security level.**

$$S_m = \frac{P_m - E_m}{E_m} \times 100\%$$

Where $S_m$ is the quoted security level of power sales enterprise $i$, $P_m$ is the weighted average of declared price of power sales enterprise $i$, which is obtained by weighted average of multiple quotations with each segment of the declared electric quantity as the weight. And $E_m$ is the expected market marginal price, which can be calculated based on the marginal price of historical transactions.

3) **Quotation consistency**

$$c_m = \frac{P_m}{\sum_{i=1}^{m} P_i} \times 100\%$$
Where $c_i$ is the ratio of the quotation consistency of power generation company $i$. $P_i$ is the quotation whose quotation similarity is within a certain range, and the specific range can be determined according to market conditions.

4) **Retention ratio.**

$$y_i = \frac{S_{mi} - S_i}{S_{mi}} \times 100\%$$ (18)

Where $y_i$ is the retention ratio of power sales enterprise $i$, $S_{mi}$ is the maximum power generation capacity of power sales enterprise $i$, and $S_i$ is the actual purchased electric quantity.

(5) **Excess returns.** The excess returns of power sales enterprises can be reflected by high price winning ratio, low price winning ratio and quotation success level.

1) **High price winning ratio**

$$H_i = \frac{B_{Hi}}{B_i} \times 100\%$$ (19)

Where $H_i$ is the high price winning ratio of power sales enterprise $i$, and $B_i$ is the total amount of bid-winning electricity of power sales enterprise $i$. $B_{Hi}$ is the amount of bid-winning electricity, the quotation price of which is higher than the highest historical clearing price.

2) **Low price winning ratio**

$$L_i = \frac{S_{li}}{S_i} \times 100\%$$ (20)

Where $L_i$ is the low price winning ratio of power sales enterprise $i$ in the above formula. $S_{li}$ is the amount of bid-winning electricity, the quotation price of which is lower than the lowest historical clearing price. And $S_i$ is the total amount of bid-winning electricity of power sales enterprise $i$.

3) **Quotation success level**

$$D_i = \frac{D_{si}}{D_a} \times 100\%$$ (21)

$D_i$ is the quotation success level of power sales enterprise $i$. $D_{si}$ is the turnover ratio of the declared electric quantity of power sales enterprise $i$. And $D_a$ is the turnover ratio of market average declared electric quantity.

3.1.3. **Power grid enterprises.**

The role of power grid enterprises in power transactions market is as follows: to ensure the safe and stable operation of power transmission and distribution facilities; to provide fair transmission and distribution services and grid access services for market entities; to obey the unified dispatching of the power dispatching agency, to construct, operate, maintain and manage the supporting technical support system of the power grid; to provide various power supply services such as installation, measurement, meter reading and maintenance to market entities; to collect electricity charges for transmission and distribution, and to collect and pay electricity fees, government funds and surcharges, etc.; to forecast and determine the power demand of priority users, and to implement contracts such as priority power generation contracts between plants and networks; to provide electricity sales services at government prices to priority power users and other power users who do not participate in market transactions; to sign and perform the corresponding power supply contract and power purchase and sale contract; to disclose and provide information as required.

3.1.4. **Power consumers.**

The role of power consumers in power transactions market is as follows: to participate in power market transactions, to sign and perform power purchase and sale contracts, transmission and distribution service contracts, and to provide information about direct transaction power demand, typical load curve and other production matters; to have access to fair power transmission services, power distribution
services and grid access services, and to pay for electricity purchase, electricity transmission and
distribution, government funds and some accessorial services; to disclose and provide information as
required and to obtain relevant information such as the information of market transactions and
transmission and distribution services; to obey the unified dispatching of the power dispatching agency,
and to arrange electricity consumption according to the requirements of the dispatching agency under
the special operation conditions of electric system (such as accidents, serious shortage of supply, etc.);
to comply with the regulations of power demand side management of the government power
management department, orderly carrying out power management and cooperating with the peak
avoidance.

3.1.5. Power trading agency.
The role of power trading agency in power transactions market is as follows: to organize all kinds of
transactions and be responsible for the construction, operation and maintenance of the trading platform;
to draft implementation rules for corresponding power transactions; to prepare the transaction plan; to
be responsible for the registration management of market entities; to provide power transaction
settlement basis, which including but not limited to full electric charges, auxiliary service fee and
transmission service fee, etc., and to provide related services; to monitor and analyze market
performance; to build, operate and maintain the technical support system for electricity market
transactions; to cooperate with the National Energy Bureau and management departments of local
government power to analyze and evaluate the market operation rules, and to put forward suggestions
for revision.

3.1.6. Power dispatching agency.
The role of power dispatching agency in power transactions market is as follows: to be responsible for
safety check; to implement the power dispatch according to the dispatch procedure, and to be responsible
for the real-time balance of the system to ensure the safety of the power grid; to provide security
constraints and basic data to power trading agency and to cooperate with the agency to perform market
operation functions; to reasonably arranges the power grid operation mode to ensure the execution of
the power transaction results (If the deviation between actual execution and transaction results is caused
by the power dispatching agency itself, the power grid enterprise where the power dispatching agency
is located should be responsible for the corresponding economic responsibility); to disclosure and
provide relevant information on grid operation as required.

3.1.7. Independent auxiliary service provider.
The role of independent auxiliary service provider in power transactions market is as follows: to
participate in ancillary service transactions as required, sign and perform ancillary service contracts; to
obtain fair transmission services and grid access services; to obey the unified dispatching of power
dispatching organization, and to provide auxiliary service according to dispatching instruction and
contract; to disclose and provide information as required, and to obtain relevant information such as
information about market transactions and ancillary services; to perform other rights and obligations
prescribed by laws and regulations.

3.2. Calculation of total risk

3.2.1. Analytic Hierarchy Process.
AHP is a kind of evaluation method that combines qualitative and quantitative analysis. Its basic steps
include construction of judgement matrix and matrix consistency test. The construction of judgment
matrix is based on the comparison of the relative importance degree, which is shown in Table 1.

| Scale | Notion                  |
|-------|-------------------------|
| 1     | Pairwise comparison: Two factors are equally important |
3 Pairwise comparison: One factor is slightly more important than the other
5 Pairwise comparison: One factor is obviously more important than the other
7 Pairwise comparison: One factor is strongly more important than the other
9 Pairwise comparison: One factor is extremely more important than the other
2, 4, 6, 8 The median of the above two adjacent judgments
Reciprocal The judgment compared factor i to j is $a_{ij}$, the judgment compared factor j to i is $a_{ji}$.

However, due to the complexity of multi-stage judgment, some values may be inconsistent. Thus it is necessary to check the consistency of the judgment matrix.

\[ CI = \frac{\lambda_{\text{max}} - n}{n-1} \]  \hspace{1cm} (22)

\[ CR = \frac{CI}{RI} \]  \hspace{1cm} (23)

Where $n$ is the rank of the judgment matrix, $\lambda_{\text{max}}$ is the maximum eigenvalue, and $RI$ is the average random consistency index. If $CI$ equals to 0, the matrix is completely consistent. The greater value of $CI$ means worse consistency. And when $CR < 0.1$, the matrix passes the consistency test. If it fails to pass the consistency test, the judgment matrix shall be reconstructed until it passes the consistency test. The eigenvector corresponding to the largest eigenvalue of the judgment matrix that has passed the consistency test is the ranking of the importance of the indicator relative to the upper-level indicator.

Table 2. Average random consistency index.

| n  | 3   | 4   | 5   | 6   | 7   | 8   | 9   | 10  |
|----|-----|-----|-----|-----|-----|-----|-----|-----|
| RI | 0.58| 0.89| 1.12| 1.26| 1.36| 1.41| 1.46| 1.49|

3.2.2. Improved entropy weight method.

The smaller the information entropy of the evaluation index, the more information the index provides and the greater the weight value is supposed to be. The steps of entropy weight method to determine the weight of the index system are as follows:

1) Data standardization

Due to the inconsistency in the units of evaluation indexes, the original data of each index needs to be dimensionless. The specific operations are as follows:

\[ \bar{x}_{ij}^k = \frac{x_{ij}^k - x_{ij}^k}{x_{\text{max}}^k - x_{\text{min}}^k} \]  \hspace{1cm} (24)

Where $x_{ij}^k$ is the jth index of the participant i in the electricity market k, and $x_{\text{max}}^k$ and $x_{\text{min}}^k$ are the maximum and minimum values of the jth item in some power markets respectively.

2) Calculation of information entropy

\[ H_i = -\beta \sum_{j=1}^{n} f_j \ln(f_j) \]  \hspace{1cm} (25)

\[ f_j = \frac{x_{ij}^k}{\sum_{j=1}^{n} x_{ij}^k}, \beta = \frac{1}{\ln(n)} \]  \hspace{1cm} (26)

This article makes the following assumptions that $f_j = 0$ may appear in the process of calculating $H_i$, then $\ln(f_j)$ has no mathematical meaning. Therefore, if $x_{ij}^k = 0$, we have $f_j = 0$, and $f_j \ln(f_j) = 0$.

3) Calculation of entropy weight

The traditional entropy weight method uses normalized way to calculate the entropy weight $w_i$, as is shown in the following formula:

\[ w_i = \frac{1 - H_i}{\sum_{i=1}^{n} (1 - H_i)} \]  \hspace{1cm} (27)

Relevant researches have shown that when the entropy value is in a certain range, the slight difference may cause the entropy weight to change exponentially, which is inconsistent with the information
conveyed by the entropy value. To avoid this problem, the improved entropy weight method was used to calculate the objective weight value of the $i$th index:

$$w'_i = \frac{\sum_{j=1}^{n} H_j + 1 - 2H_i}{\sum_{j=1}^{n} (\sum_{i=1}^{n} H_j + 1 - 2H_j)}$$  

(28)

3.2.3. Bayesian comprehensive evaluation method.

The main step of Bayesian evaluation model is as follow:

$$P(x_i | y_i) = \frac{P(x_i)P(y_i | x_i)}{\sum_{x_i} P(x_i)P(y_i | x_i)}$$  

(29)

Where $y_i$ is the main evaluation type of the power market participant $i$. In the comprehensive evaluation of power market risk, the prior probability distribution information of the evaluation object is usually lacking. Without loss of generality, we assume that $P(y_i)$ is uniformly distributed. In general, the likelihood function $P(y_i | x_i)$ is calculated using the normal distribution method and the geometric distance value method. This section selects the geometric distance value method and uses the derivative of the actual value of the evaluation factor and the absolute value of the standard deviation for calculation.

$$P(y_i | x_i) = \frac{1}{L_y} \sum_{i=1}^{n} \frac{1}{L_y}$$  

(30)

Where $L_y = |y_i - \bar{x}_y|$. Then we can obtain the comprehensive risk assessment value as:

$$P_j = \sum_{j=1}^{n} w'_i \cdot P(x_i | y_i)$$  

(31)

In summary, the final risk weight is determined on the basis of the entropy method, taking into account the principle of maximum likelihood, which reduces the uncertainty of subjective risk evaluation and improves the stability of system evaluation.

4. Empirical study

4.1. Standard for evaluation

According to the setting of analytic hierarchy process, the full mark of each index is 10 points. For some indicators that cannot be quantified, as long as they do not meet the requirements of the power industry, one point will be awarded. While for indicators with missing information, zero points will be awarded. The determination of the risk level is based on a comprehensive assessment by experts in the power industry. And the risk level is divided into different types, namely basically no risk, great risk, and highest risk. Therefore, we define that a score of 7 or more is basically risk-free, a score of 3-7 is relatively high risky, and a score of 3 or less is the highest risk. Without loss of generality, this section adopts random number simulation for example analysis. First of all, the evaluation value of 100 entities on the target evaluation department is randomly generated, and the evaluation value is randomly distributed between 0 and 10. Secondly, according to the setting of the hierarchical analysis method, the judgment matrix is constructed and the consistency test is verified. Then the improved entropy weight method is used for objective assignment. Finally, under the Bayesian rule, the subjective judgment matrix after consistency test is combined with entropy weight to form the comprehensive evaluation Bayesian standard.

4.2. Power generation companies

The violation risk indicators of power generation companies include five first-level indicators, among which market power, quotation strategy and excess return are relatively important decision-making bases for violation. According to the principle of importance ranking, the index system of risk assessment is established as shown in Table 3. It can be seen from Table 3 that the weight assignment
of entropy weight method is relatively average, and it does not well highlight the relative importance of the evaluation index. After combining the subjective evaluation, the “quotient success level” and the “quotient security level” are given greater weight. Therefore, the Bayesian comprehensive evaluation is more reasonable.

Table 3. Indicator weighting for power generation companies’ violation risks

| First-level indicators                        | Secondary indicators       | Entropy weight | Bayesian comprehensive evaluation |
|-----------------------------------------------|----------------------------|----------------|----------------------------------|
| Basic information                             | The matching degree of      | 0.0622         | 0.0061                           |
|                                               | business capability and    |                |                                  |
|                                               | business scope             |                |                                  |
| Market power                                  | Market concentration       | 0.0584         | 0.0268                           |
|                                               | Top-m index                | 0.0634         | 0.0198                           |
|                                               | Pivotal supplier index     | 0.0650         | 0.0337                           |
|                                               | Residual supply index      | 0.0536         | 0.0427                           |
|                                               | Lerner index               | 0.0680         | 0.0435                           |
|                                               | Market supply-demand ratio | 0.0558         | 0.0732                           |
|                                               | Market share of declared   | 0.0692         | 0.0667                           |
|                                               | electric quantity          |                |                                  |
|                                               | Relative quotient ratio    | 0.0602         | 0.0977                           |
| Quotation strategy                            | Quotation security level    | 0.0610         | 0.0547                           |
|                                               | Quotation consistency      | 0.0653         | 0.1161                           |
|                                               | Retention ratio            | 0.0598         | 0.0898                           |
|                                               | High price winning ratio   | 0.0721         | 0.0919                           |
|                                               | Low price winning ratio    | 0.0605         | 0.0927                           |
|                                               | Quotation success level     | 0.0598         | 0.1323                           |

4.3. Power sales companies

The violation risk indicators of power sales companies include three first-level indicators. The index system of risk assessment is established as shown in Table 4. It can be seen from Table 4 that after combining the subjective evaluation, the “low price winning ratio” is given greater weight. Therefore, the Bayesian comprehensive evaluation is more reasonable.

Table 4. Indicator weighting for power sales companies’ violation risks

| First-level indicators | Secondary indicators                      | Entropy weight | Bayesian comprehensive evaluation |
|------------------------|-------------------------------------------|----------------|----------------------------------|
| Market power           | Market share of declared electric quantity| 0.1322         | 0.0316                           |
|                        | Relative quotation ratio                  | 0.1245         | 0.0562                           |
|                        | Quotation security level                  | 0.1187         | 0.0765                           |
|                        | Quotation consistency                     | 0.1291         | 0.1207                           |
|                        | Retention ratio                           | 0.1311         | 0.1556                           |
|                        | High price winning ratio                  | 0.1251         | 0.1700                           |
|                        | Low price winning ratio                   | 0.1371         | 0.2383                           |
|                        | Quotation success level                    | 0.1021         | 0.1510                           |

4.4. Power grid enterprises

The violation risk indicators of power grid enterprises include five first-level indicators. The index system of risk assessment is established as shown in Table 5. It can be seen from Table 5 that after combining the subjective evaluation, the “compliance risk of power transaction” is given greater weight. Therefore, the Bayesian comprehensive evaluation is more reasonable.

Table 5. Indicator weighting for power grid enterprises’ violation risks

| First-level indicators                          | Entropy weight | Bayesian comprehensive evaluation |
|------------------------------------------------|----------------|----------------------------------|
| Compliance risk of power construction          | 0.2164         | 0.0740                           |
| Compliance risk of grid marketing              | 0.1649         | 0.0860                           |
Compliance risks of power grid operation and maintenance 0.1831 0.1590
Compliance risk of power dispatching 0.2101 0.2792
Compliance risk of power transaction 0.2255 0.4019

4.5. Power consumers
The violation risk indicators of power consumers include four first-level indicators. The index system of risk assessment is established as shown in Table 6. It can be seen from Table 6 that after combining the subjective evaluation, the “complying with power management” is given greater weight. Therefore, the Bayesian comprehensive evaluation is more reasonable.

Table 6. Indicator weighting for power consumers’ violation risks

| First-level indicators | Entropy weight | Bayesian comprehensive evaluation |
|------------------------|----------------|----------------------------------|
| Providing information on electricity demand | 0.2310 | 0.0809 |
| Paying the electricity market transaction fees as required | 0.2811 | 0.2396 |
| Obeying the unified dispatching of power dispatching organization | 0.2031 | 0.1877 |
| Complying with power management | 0.2848 | 0.4918 |

4.6. Power trading agency
The violation risk indicators of power trading agency include four first-level indicators. The index system of risk assessment is established as shown in Table 7. It can be seen from Table 7 that after combining the subjective evaluation, the “being responsible for the construction, operation and maintenance of the transaction platform” is given greater weight. Therefore, the Bayesian comprehensive evaluation is more reasonable.

Table 7. Indicator weighting for power trading agencies’ violation risks

| First-level indicators | Entropy weight | Bayesian comprehensive evaluation |
|------------------------|----------------|----------------------------------|
| Complying with power management | 0.2925 | 0.1351 |
| Offering power transaction settlement basis and related services | 0.2091 | 0.1380 |
| Monitoring and analyzing market performance | 0.2149 | 0.2188 |
| Being responsible for the construction, operation and maintenance of the transaction platform | 0.2836 | 0.5081 |

4.7. Power dispatching agency
The violation risk indicators of power dispatching agency include four first-level indicators. The index system of risk assessment is established as shown in Table 8. It can be seen from Table 8 that after combining the subjective evaluation, the “rationally arranging the operation mode of power grid” and “being responsible for the safety check” are given greater weight. Therefore, the Bayesian comprehensive evaluation is more reasonable.

Table 8. Indicator weighting for power dispatching agencies’ violation risks

| First-level indicators | Entropy weight | Bayesian comprehensive evaluation |
|------------------------|----------------|----------------------------------|
| Disclosing and providing information related to the operation of power grid as required | 0.2667 | 0.1202 |
| Providing security constraints and underlying data | 0.2615 | 0.2301 |
| Rationally arranging the operation mode of power grid | 0.2516 | 0.3209 |
| Being responsible for the safety check | 0.2202 | 0.3278 |

4.8. Independent auxiliary service provider
The violation risk indicators of power trading agency include six first-level indicators. The index system of risk assessment is established as shown in Table 9. It can be seen from Table 9 that after combining the subjective evaluation, the “signing and performing ancillary service contracts” is given greater weight. Therefore, the Bayesian comprehensive evaluation is more reasonable.
Table 9. Indicator weighting for independent auxiliary service providers’ violation risks

| First-level indicators                                                   | Entropy weight | Bayesian comprehensive evaluation |
|--------------------------------------------------------------------------|----------------|----------------------------------|
| Other rights and obligations prescribed by laws and regulations          | 0.1704         | 0.0494                           |
| Obtaining fair transmission services and grid access services            | 0.1636         | 0.0911                           |
| Obeying the unified dispatching of power dispatching agency             | 0.2057         | 0.2162                           |
| Providing auxiliary services according to dispatching instructions and contractual agreements | 0.1306         | 0.1162                           |
| Disclosing and providing information as required                         | 0.1452         | 0.1795                           |
| Signing and performing ancillary service contracts                       | 0.1845         | 0.3476                           |

5. Conclusions

Based on the compliance risk points of each participant in the power market, this paper constructs an power market compliance risk evaluation index system. This paper combines the analytic hierarchy process, the improved entropy weight method and the Bayesian comprehensive evaluation model to determine the weight of each index. And finally, this paper draws the following conclusions.

Through the objective weighting method, the weights of the risk indexes of different participants in the power market are obtained. And we also find that the weights are evenly distributed. Further, due to the importance of risk index of subjective evaluation, this paper adopts Bayesian comprehensive evaluation model. For power generation companies, the “quotation success level” and the “quotation security level” are given greater weight. For power sales companies, the “low price winning ratio” is given greater weight. For power grid enterprises, the “compliance risk of power transaction” is given greater weight. For power consumers, the “complying with power management” is given greater weight. For power trading agency, the “rationally arranging the operation mode of power grid” and “being responsible for the safety check” are given greater weight. For independent auxiliary service provider, the “signing and performing ancillary service contracts” is given greater weight.

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