Credit Risk Evaluation and Analysis of Power Generation Enterprises under the Spot Trading

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Abstract: China's economic development has entered into a stage of "new normal", with the market-oriented reform of electricity is deepening, the market risks faced by power generation enterprises are becoming increasingly severe. To reduce the loss caused by market risks and promote the efficiency of market operation, this paper established and evaluated the credit evaluation system for power generation enterprises. Specifically, based on spot power trading market, this paper firstly established a credit risk evaluation index system by assessing the credit risk of market trading members from four main aspects; then, the credit risk of typical enterprises has been analysed by fuzzy synthetic evaluation method. The result showed that power generation enterprises should focus on improving their financial ability such as profit and debt repayment in the operation process, attention should also be paid to integrity due to improving the performance rate of spot trading in the transaction process.

1. Introduction

With the deepening of the marketization process of China's power system reform [1], the number of power market participants is gradually increasing, and the credit risk of relevant transactions are also gradually rising [2]. Government and market management agencies have promulgated a series of documents and management measures on credit management. However, the credit management mechanism of China's power market is relatively extensive. On the one hand, the credit evaluation mechanism of market participants' financial operation and credit ability is still not perfect. On the other hand, the supervision and countermeasures of power market risks should be strengthened.

At present, to further found the electricity market system which is combined with the electricity spot trade, the forward trade and long-term trade [3], China has gradually carried out a series of spot electricity market construction. The establishment of spot electricity market is not only conducive to releasing reform dividends and improving clean energy consumption capacity, but also advantageous to give play to the decisive role of the market and realize optimal allocation of resources in space and time [4]. Power spot market pilot operation will make the power system reform with power market construction as the core rise to a new stage.

Spot electricity market mainly includes day-ahead market, intraday market and real-time market. In the process of trading, since market stakeholders cover power generation, transmission and distribution enterprises and end users, the existence of uncertain factors and the two-way interaction of supply and demand make the spot trading process with certain variability and complexity. At the same time, the spot electricity trading market is still in the pilot stage, which is characterized by imperfect trading rules and insufficient understanding of market competition by individual market participants, so the market...
operation is prone to chaos. In order to avoid the threat of risk factors in the process of market operation, reduce the loss caused by market risks and improve the efficiency of market operation [5], it is of great practical significance to conduct credit risk assessment for trading members on the basis of the establishment of credit risk system in the electricity market.

2. Construction of credit risk evaluation index system for power generation enterprises

2.1. Power generation enterprise credit risk evaluation index system

In this section, the power generation enterprise credit risk evaluation index system is shown in table 1.

| Criteria layer | Primary element layer | Secondary element layer             | Note   |
|----------------|-----------------------|-------------------------------------|--------|
| External environment | Policies and regulations | Energy conservation and environmental protection policy | Qualitative |
| Industry environment | Industry supply and demand situation | Energy-related industrial policies | Qualitative |
| Production and operation risk | Cost of per kWh. | Energy-related industrial policies | Qualitative |
| Operation risk | Market occupancy rate | Industry supply and demand situation | Qualitative |
| Profitability | Social influence | Cost of per kWh. | Qualitative |
| Financial credit risk | Equipment failure rate | Social influence | Qualitative |
| Debt-paying ability | Power supply coal consumption ratio | Equipment failure rate | Qualitative |
| Development ability | Operating Profit Ratio | Power supply coal consumption ratio | Quantitative |
| Transaction credit risk | Profits to Cost Ratio | Operating Profit Ratio | Quantitative |
| Transaction | Return on equity | Profits to Cost Ratio | Quantitative |

2.2. Weigh of power generation enterprise credit risk index

In the secondary factor layer, each specific index is divided into five sections based on the percentage system. This paper makes an in-depth analysis of the existing power industry credit scoring standards, and the index value of each interval is set according to Credit evaluation of the electric power industry by Dagong global credit rating group [6]. The credit standard division needs dynamic adjustment with the development of the macroeconomic environment. The credit scoring standards for power generation enterprises are shown as table 2.

| Secondary elements layer | >80 | 79-60 | 59-40 | 39-20 | ≤ 20 |
|--------------------------|-----|------|------|------|------|
| Energy conservation and environmental protection policy | Extreme advantage | Comparative advantage | Neutral | Comparative disadvantage | Extreme disadvantage |
| Energy-related industrial policies | Extreme advantage | Comparative advantage | Neutral | Comparative disadvantage | Extreme disadvantage |
| Industry supply and demand situation | Demand much greater than supply | Demand much greater than supply | Demand equal to supply | Demand little than supply | Demand less than supply |
2.3. Power generation enterprise credit evaluation

The power market credit grade is obtained through the comprehensive evaluation score. And the enterprises’ credit can be explained by the power market credit grade and its description. The explanation of the grade is shown as table 3.

| Credit rating | Score (full score 100) | Credit rating | Score (full score 100) |
|---------------|------------------------|---------------|------------------------|
| AAA           | ≥90                    | B             | 40~50                  |
| AA            | 80~90                  | CCC           | 30~40                  |
| A             | 70~80                  | CC            | 20~30                  |
| BBB           | 60~70                  | C             | 10~20                  |
| BB            | 50~60                  | D             | ≤10                    |

3. Credit risk evaluation model based on fuzzy comprehensive evaluation

3.1 Fuzzy comprehensive evaluation

Fuzzy comprehensive evaluation to the members of the electricity market risk assessment as the goal, based on the thought of systems analysis, according to the actual situation of electric power spot market.
trading, adopt scientific or method, the mathematical model of power generation enterprises, grid enterprises and large user of enterprise management situation and the financial situation description, analysis, evaluation and comparison [7].

3.1.1 Analytic Hierarchy Process (AHP)

This method is called 1-9 scale method. When the AHP is used to establish a judgment matrix, if all the elements of the judgment matrix can be established for the above properties, then the matrix is a consistency matrix.

According to the judgment matrix, the weight of the order of importance of the elements related to the upper level can be calculated to express its relative importance. This ranking measurement is called hierarchical single ranking. The calculation problem of hierarchical single sorting can be summarized as the calculation of the maximum Eigen root of the judgment matrix and its corresponding eigenvector problem. The specific method is as follows:

1. Calculate the product of each row element of judgment matrix \( M_i \):
   \[
   M_i = \prod_{j=1}^{n} A_{ij} \quad i = 1, 2, 3, ..., n
   \]  
2. Calculating the \( n - \text{th} \) power and \( W_i \) of \( M_i \) (square root method)
   \[
   W = \sqrt[n]{M_i}
   \]
3. Normalize the vector \( \tilde{W} = [W_1, W_2, ..., W_n]^T \)
   \[
   \omega_k = \frac{W_k}{\sum_{j=1}^{n} W_j}
   \]
4. Calculate the maximum characteristic root of the judgment matrix:
   \[
   \lambda_{\text{max}} = \sum_{i=1}^{n} (AW_i) / nW_i
   \]

Where \( (AW_i) \) is the \( i \) element of vector \( AW \).

According to matrix theory, when the judgment matrix cannot be guaranteed to have complete consistency, the characteristic root of the corresponding judgment matrix will also change, so that the consistency degree of judgment can be tested by the change of the characteristic roots of the judgment matrix. Therefore, the negative average value of the remaining characteristic roots other than the maximum characteristic root of the judgment matrix is introduced into the requirements of AHP as an indicator to measure the deviation consistency of the judgment matrix, that is:

\[
CI = \frac{\lambda_{\text{max}} - n}{n-1}
\]

In order to measure whether the judgment matrix of different orders has consistency, the average random consistency index of the judgment matrix should be introduced to obtain the consistency ratio of the scalar judgment matrix. \( CR = CI / RI \) When the order of judgment matrix is greater than 2, if the consistency ratio of judgment matrix, it can be considered that the judgment matrix has consistency [8]. \( CR < 0.10 \) Otherwise, the judgment matrix needs to be further adjusted until it passes the consistency test.

In using AHP to measure the evaluation index system of index weight in the process, due to involving multiple evaluation index, the actual measurement in the calculation process is more complex, therefore, this research in building distribution electricity price reform under the background of international credit rating evaluation system in the process, will use Matlab programming calculation evaluation index
weight and the consistency of judgement matrix corresponding test results.

3.1.2 Fuzzy comprehensive evaluation method

Fuzzy Comprehensive Evaluation Method is to transform Qualitative Evaluation into Quantitative Evaluation according to the membership theory of Fuzzy mathematics, with clear and systematic Evaluation results, which can solve Fuzzy and difficult to quantify problems. To be specific, fuzzy comprehensive evaluation is a comprehensive evaluation method based on fuzzy mathematics and the principle of fuzzy relation synthesis, which quantifies some factors with unclear boundary and not easy to be quantified and evaluates the status of things' subordinate levels from multiple factors. The basic principles are as follows: firstly, determine the set of factors (indicators) and evaluation (grade) of the evaluated object; Secondly, a questionnaire was designed to obtain the fuzzy evaluation matrix through expert scoring. Then, the fuzzy evaluation matrix and the weight vector of the factors are calculated and normalized, and the comprehensive result of fuzzy evaluation is obtained. Its characteristic is that the index is evaluated one by one, and the evaluated index has the unique evaluation value, which is not affected by the level of the evaluated object. The purpose of comprehensive evaluation is to select the winners from the index set. Therefore, the comprehensive evaluation results of all indexes need to be sorted.

Fuzzy comprehensive evaluation method is to quantify the fuzzy index reflecting the evaluated object by constructing evaluation fuzzy subset, and then use the fuzzy mathematical theory to conduct comprehensive evaluation on the synthesis operation of indexes at all levels. The steps are as follows:

(1) Determine the object set, factor set and comment set

Set \( X = (x_1, x_2, ..., x_p) \) as the alternative set of objects, representing the objects to be evaluated. \( U = \{u_1, u_2, ..., u_m\} \) is set of factors (index set), which is composed of the kinds of factors (that is, evaluation indicators) that describe the evaluated object.

Set \( V = \{v_1, v_2, ..., v_n\} \) as the central decision that characterizes the state of each factor (that is, the evaluation level) constitutes a comment set, which represents a division of the range of variation of the evaluated object.

Where, \( p \) represents the number of objects to be evaluated, which is determined by the evaluation problem itself. \( m \) represents the number of evaluation indicators, determined by the specific indicator system; \( n \) is the number of comments, generally divided into 3~5 levels.

(2) Construct a single factor fuzzy evaluation matrix

Firstly, single factor evaluation \( u_i(i = 1, 2, ..., n) \) is made on the indicator set or single factor, and membership degree of single factor \( u_i \) to the evaluation grade \( v_j(j = 1, 2, ..., n) \) is determined to be \( r_{ij} \), so as to obtain the single factor evaluation set of the \( i \) factor \( u_i \):

\[
\begin{align*}
 r_i &= (r_{i1}, r_{i2}, ..., r_{in})
\end{align*}
\]

In this way, the evaluation set of \( m \) individual factors constitutes a general fuzzy relation matrix \( R \).

That is, the fuzzy relation \( R \) from \( U \) to \( V \) is determined, namely:

\[
R = (r_{ij})_{m \times n} = \begin{pmatrix}
 r_{11} & \cdots & r_{1n} \\
 \vdots & \ddots & \vdots \\
 r_{m1} & \cdots & r_{mn}
\end{pmatrix}
\]

Where, \( r_{ij} \) refers to the degree of affiliation of the evaluation \( u_i(i = 1, 2, ..., m; j = 1, 2, ..., n) \) object to the evaluation grade \( v_j \) from the perspective of single factor \( u_i \). In other words, \( r_{ij} \) represents the distribution probability of the \( i \) factor \( u_i \) in the \( j \) evaluation \( v_j \), and it is usually normalized to make it meet \( \sum r_{ij} = 1 \), thus making the matrix \( R \) dimensionless.

Fuzzy synthesis and evaluation are carried out
By synthesizing the weight vector $A$ of the evaluation index and the fuzzy evaluation matrix $R$ the membership degree of the evaluated object to the fuzzy subset $B = (b_1, b_2, ..., b_n)$ of each grade can be obtained, that is, the result vector of the fuzzy comprehensive evaluation. A fuzzy subset on comment set $V$ is introduced to represent fuzzy evaluation or decision set. $B$ is usually obtained by fuzzy transformation $B = A \circ R$. There are many methods of synthetic operation, and the common method is ordinary matrix multiplication (i.e. weighted average method), which can make every factor contribute to the comprehensive evaluation and objectively reflect the actual situation of the evaluation object.

3.1.3 Credit evaluation of power generation enterprises.

Power market credit rating rating is the final comprehensive evaluation score and credit rating corresponding, through the rating and different description to explain the credit situation of enterprises. The specific explanation of the grade is shown in table 4.

| A credit rating | Score (full 100) | A credit rating | Score (full 100) |
|-----------------|------------------|-----------------|------------------|
| AAA             | ≥90              | B               | 40 ~ 50          |
| AA              | 80 ~ 90          | CCC             | 30 ~ 40          |
| a.              | 70 ~ 80          | CC              | 20 ~ 30          |
| BBB             | 60 ~ 70          | C               | 10 ~ 20          |
| BB              | 50 ~ 60          | D               | 10 or less       |

3.2 Weight calculation of evaluation indicators

This study investigated and consulted a number of experts, scholars, technicians or managers in fields related to financial management of the company through questionnaires, investigated the relative importance of factors (evaluation indicators) at various levels, and collected and sorted out the weight data of international rating indicators of the company.

In order to ensure the scientific nature and reliability of the research results, this study selected the power generation enterprises, power grid workers and industrial power enterprises as the research objects. In this project, 120 relevant experts, technical personnel and management personnel were investigated in the form of questionnaires. After sorting out and analyzing the survey results, the importance evaluation data were finally obtained. According to the calculation method of fuzzy comprehensive evaluation mentioned above, the comprehensive weight of credit risk of power generation enterprises is obtained, as shown in table 5.

| Rule layer | The weight | Secondary element layer | The weight | Analytic hierarchy | comprehensive |
|------------|------------|-------------------------|------------|-------------------|---------------|
| The external environment 0.1923 | Energy conservation and environmental protection policy 0.0550 | 0.0043 | 0.0023 |
| Production and management risk 0.2034 | Energy-related industrial policies 0.1178 | 0.0091 | 0.0046 |
| | Industry supply and demand KWH cost 0.2634 | 0.0204 | 0.0369 |
| | Market share 0.5638 | 0.0437 | 0.0460 |
| | Social influence 0.1222 | 0.0245 | 0.0393 |
| | Failure rate of equipment 0.2274 | 0.0457 | 0.0478 |
| | Coal consumption rate of power supply 0.4231 | 0.0850 | 0.0728 |
| Financial 0.2286 | Operating profit margin 0.4231 | 0.0850 | 0.0728 |
3.3 Credit risk assessment of power market members

In this study, three power generation enterprises were taken as examples to calculate their credit scores, and the comprehensive score of the three enterprises is respectively: Power generation enterprise 1=73.179, Power generation enterprise 2=76.063, Power generation enterprise 3=83.725.

From the above analysis, it can be seen that the comprehensive credit score of power generation enterprise 3 is the highest, which is AA, indicating that the credit of power generation enterprise 3 is very good, with good operation and development, financial status and external environment. The power generation enterprise 3 has strong performance ability and low possibility of default, so it has a certain status in the industry. The second is power generation enterprise 2 and power generation enterprise 3, which have the lowest comprehensive score and A credit rating, indicating that the company's operation and development, financial status and ability to resist the external environment are better, its performance ability is stronger, the possibility of default is lower, and it is well evaluated in the industry.

By comparing the credit evaluation scores of power generation enterprises, it can be seen that the transaction credit score, financial credit score and production and operation score of enterprise 3 are significantly greater than that of enterprise 1 and enterprise 2. By comparing the index score distribution within the enterprise, it can be seen that the transaction credit score and financial credit score account for the largest proportion. Based on the above analysis, power generation enterprises need to focus on improving their financial capabilities, such as profitability and solvency, and pay attention to integrity in the transaction process to improve their performance rate, so as to improve their credit rating. At the same time, in addition to the total credit score of power generation enterprises, regulators and market participants need to focus on the performance in previous transactions and financial conditions of the power generation enterprises, and comprehensively evaluate the credit status of power generation enterprises.

4. Conclusion

Firstly, this paper analyzed the credit risk of trading members in the spot electricity trading market in four aspects: external environment risk, production and operation risk, financial credit risk, and transaction credit risk. And then built an evaluation index system. Secondly, the index system was evaluated by fuzzy comprehensive evaluation method, and selected typical enterprises for credit risk analysis. The results show that:

Power generation enterprises need to focus on the improvement of their financial ability, such as profitability and debt-paying ability, and pay attention to integrity and improve their performance rate to improve their credit rating in the trading system. Meanwhile, besides the total credit score of power generation enterprises, regulators and market participants also need to focus on the performance in previous transactions and financial conditions of the power generation enterprises, evaluate power generation enterprises’ credit situation comprehensively.
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