INTRODUCTION

Renewable energy is being developed to solve issues such as fossil fuel shortages, environmental pollution, climate change, and energy security. With the further advancement of sustainable energy development strategies and low-carbon economic policies, renewable energy systems have been established. According to the “Renewable Energy Installed Capacity Data 2021” report, in 2020, the installed capacity of global renewable energy reached 2799 GW, revealing a 10.3% increase as compared to 2019. Specifically, the installed capacity of renewable energy increased by more than 260 GW. Currently, solar and wind energy dominate renewable energy systems, accounting for 91% of the total produced energy. However, with large-scale renewable energy access to the power grid, the...
current trading platform in China has difficulty handling large amounts of data in the process of centralized clearing, cross-regional sharing of transaction information, and optimized allocation of resources. To overcome this, we proposed building a distributed power trading platform in the paper titled “Distributed Electricity Market Trading Platform Based on Blockchain Technology”. This study makes full use of the advantages of blockchain technology and adopts a listing transaction mode to avoid the problems prevalent in current electricity transactions. However, the previous research did not consider the fact that delisting nodes encounter excessive listing information during listing transaction processes, which makes it difficult to determine the best delisting plan. Therefore, this study proposes a search engine for delisting nodes in order to provide an optimized delisting strategy.

In the previous study, the distributed electricity market trading platform based on blockchain technology was found to take full advantage of blockchain technology, including decentralization, openness, and security, to meet the needs of a large number of market players for distributed electricity transactions. This platform utilizes a listing transaction mechanism to ensure the autonomous transaction requirements of market players. It also considers the supervision method of electricity trading risks and employs the green certificate trading method to promote the consumption of renewable energy, which consequently promotes reform in China’s power market. This study assumes that the platform only supports renewable energy enterprise participation in electricity trading to meet the demand for electricity trading by power consumers. Meanwhile, traditional coal power companies participate in local auxiliary services to ensure the stable operation of the power system. This assumption is conducive to achieving large-scale renewable energy development and ensuring the consumption of renewable energy.

Blockchain technology has broad application prospects in the fields of energy and power, but it is still in its infancy. To date, various studies worldwide have focused on the application of blockchain technology and smart contracts in the energy field. Reference 7 gave an overall picture of blockchain research and clarified the direction of future research. Reference 8 gave an overview of blockchain technology and its application in the field of power and energy systems. Reference 9 analyzed the feasibility and applicability of blockchain technology in terms of energy and power. Reference 10 analyzed the security and privacy risks of energy transactions based on blockchain technology from the perspective of information security. Reference 11 studied the advantages of combining blockchain technology and distributed electricity transactions and analyzed the existing energy transaction theory and practical applications of blockchain technology. Reference 12 examined the advantages of applying blockchain technology to energy trading, proposed an electricity market trading model, and explained the problems in the application of blockchain technology in power transactions. Reference 13 proposed a distributed energy trading system architecture based on blockchain technology, but this architecture is not detached from traditional concentrated transaction modes and lacks transaction autonomy. Reference 14 studied a distributed power two-way listing trading system based on Ethereum. Although this system eliminates the traditional centralized transaction mode and satisfies the requirements of users for trustworthy, fair, and private transactions, it does not consider the problem of nodes delisting in the process of listing transactions.

While search engine technology is relatively mature, it has limited research in the fields of energy and power. Reference 15 examined how to use search engine technology to realize the real-time release of nuclear power information and rapid retrieval of nuclear power enterprise knowledge, providing guidance for nuclear power enterprise informatization work. Reference 16 proposed a power search engine architecture based on cloud computing that can provide efficient data sharing, interaction, and retrieval services for the scheduling and management of business applications. Reference 17 proposed using Google image search engine to identify specific power waveforms and diagnose power quality. However, currently, there is no research that introduces search engine technology into electric power listing transactions. The existing electricity listing transaction does not consider the issue of delisting during the delisting process, as it believes that the delisting process is the free choice of transaction nodes. This study used blockchain technology as a tool for delisting nodes in order to determine the best delisting strategy via search engine smart contracts. This novel concept provides greater initiative and enthusiasm for trading nodes and is more conducive to the in-depth promotion and application of the electricity trading platform based on blockchain technology.

In summary, based on a distributed electricity trading platform based on blockchain technology, this study considers the delisting requirements for delisting nodes, uses smart contracts to design a transaction search engine, and provides the best strategy for delisting during the delisting stage. According to the demand of delisting nodes, this study designed different smart contracts corresponding to different delisting strategies and proposed a comprehensive evaluation model of delisting nodes. The delisting node can select the listing node with high score for trading based on the comprehensive evaluation result. Moreover, the comprehensive evaluation model of the listing nodes proposed in this study is verified by analyzing various examples.
2 | BLOCKCHAIN TECHNOLOGY AND SMART CONTRACTS

Blockchain is a new application mode of computer technology and includes distributed data storage, point-to-point transmission, consensus mechanism, and encryption algorithms. It is a decentralized distributed shared ledger that achieves chain storage via a one-way connection of the first and last hash values of adjacent blocks. Each node in the block has a copy of the complete ledger, and any node can view and proofread the transaction data in real time. All data are stored in the block body, and the hash algorithm automatically generates a Merkle tree that stores the hash value of the transaction data. A blockchain structure containing a Merkle tree is shown in Figure 1. Note that if the data become tampered, the hash value of the corresponding Merkle tree root changes. The transaction information is stored by the Merkle tree, and every transaction can be traced to prevent tampering with the transaction information.

In recent years, owing to the advantages of blockchain technology, such as decentralization, openness, autonomy, immutability of information, and anonymity, it has been implemented in various industries. Introducing blockchain technology into electricity market transactions can make full use of its advantages during distributed transactions, ensuring transaction security, protecting market privacy, and reducing transaction costs.

Smart contracts are an important technical feature of blockchain technology and can solve the problem of inefficient transaction processes. A smart contract is pushed by the event, dynamic, and multirecognized running of the block chain and can automatically process an asset according to its preset conditions. The biggest advantage of smart contracts is the use of program algorithms to replace human decisions and contract executions, thereby avoiding the interference of malicious behavior on contract execution and improving the efficiency of blockchain transactions. Through the platform provided by Ethereum, developers can write any form of smart contract and publish it on the network. The operating mode of the blockchain smart contract is shown in Figure 2.

3 | SEARCH ENGINE FOR DELISTING NODES BASED ON SMART CONTRACT

A distributed electricity market trading platform based on blockchain technology has two listing trading modes for both parties of the transaction. First, electricity selling nodes are listed and electricity purchasing nodes are delisted. Electricity selling nodes submit the next cycle of transaction contracts, delisting the quantity of electricity, and listing the electricity price on the platform by releasing demand smart contracts. The electricity purchasing nodes then submit the next cycle of delisting the quantity of electricity to the platform through the contract. The second mode involves listing the electricity purchasing nodes and delisting the electricity selling nodes. Electricity purchasing nodes submit the next cycle of the transaction contract, listing the quantity of electricity and the electricity price to the platform by releasing demand smart contracts. Subsequently, the electricity selling nodes submit the next cycle of delisting the quantity of electricity to the platform through this contract.

Considering these trading modes, this study provided a search engine for delisting nodes. The search methods of platform search engines differ according to the needs of the delisting nodes, in which each method represents

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**Figure 1** Blockchain structure of Merkle tree
a search strategy. The search engine of the electricity market trading platform based on blockchain technology adds the search strategy algorithm to the smart contract for execution, which can ensure the intelligent and open selection of the delisting plan. Delisting nodes can call different smart contracts according to their needs and select the best listing node for trading. Based on the delisting requirements that may be considered by delisting nodes, this study designed the following seven delisting strategy smart contracts:

1. A smart contract for classifying renewable energy types: According to the premise set by this study, a large number of renewable energy companies participate in electricity trading, while coal power companies provide local auxiliary services. Therefore, the type of electricity selling nodes is renewable energy, which is divided into water and non-water renewable energies. To promote the consumption of non-water renewable energy and reduce national financial subsidies, this study proposed the necessity of a non-water renewable quota system, clarifying that companies are subject to assessing the responsible market subject. The quota system of non-water renewable energy considers the weight of the annual non-water renewable energy consumption responsibility of electricity selling companies and the certain percentage electricity consumers must meet. If a node does not meet the non-water energy consumption weight allocated by the superior, it must purchase a non-hydropower green certificate to complete its quota target.

According to the demand for renewable energy types, electricity purchasing nodes can obtain a collection of water or non-water renewable electricity selling nodes by calling a smart contract. Thus, electricity purchasing nodes can freely select the electricity selling node that best meets the requirements for trading according to the classification collection.

2. Smart contract for sorting credit score: This study designed a credit evaluation system for the distributed electricity market trading platform based on blockchain technology, wherein the two parties who have successfully traded evaluate each other. The platform continuously updates the credit score of the node based on the evaluation results and publishes the scores to the network. This study based the credit score on favorable rates and transaction activity. The platform uses the following equation to automatically update the credit score of the trading node:

$$x^k_n = a_1 * \sum_{i=1}^{N} \frac{\theta^k_n}{\sigma^2_k} + a_2 * \sum_{i=1}^{N} \frac{t^k_n}{\gamma^2_k},$$  \hspace{0.5cm} (1)

where \(\theta^k_n\) represents the number of positive reviews obtained by node \(k\) completing \(n\) transactions, \(\sigma^2_k\) represents the total number of transactions completed by node \(k\), \(\gamma^2_k\) represents the number of times node \(k\) participated in the transaction, \(\gamma_k\) represents the number of transactions carried out on the platform, \(\alpha_1\) and \(\alpha_2\) represent the weights of the favorable rate and transaction activity, respectively.

By calling the smart contract for credit score ranking, delisting nodes can obtain a collection of the ranked credit scores of listing nodes and select a listing node with a high credit score for trading.

3. A smart contract to sort listing electricity prices: The listing trading mode based on blockchain technology is based on buyers and sellers submitting their listing or delisting requests to the trading platform via a smart contract of publishing demand during the publishing demand stage. According to the publishing demand function, listing nodes submit the next cycle of transaction contracts, listing the quantity of electricity and the electricity price. Then, delisting nodes submit the next cycle of delisting quantity of electricity. A smart contract of publishing demand will record all transaction requests. Based on economic needs, delisting nodes can call the smart contract to sort listing electricity prices and select listing nodes with lower or higher listing electricity prices for delisting. In general, electricity purchasing nodes intentionally select a node with a lower listing price for delisting,
while electricity selling nodes intentionally select a node with a higher listing price for delisting.

4. The smart contract that determines the best path of electricity transmission and distribution: Because of the geographic difference between electricity purchasing and selling nodes, there may be multiple possible electricity transmission and distribution paths between purchasing and selling nodes under the condition of ensuring network security. This study proposed adopting the “stamp method” to determine the price of electricity transmission and distribution. According to the relevant price management regulations for electricity transmission and distribution in China, relevant departments clarify the electricity transmission and distribution price of each region via the “stamp method” and its dynamic adjustment plan and announce it to the entire network. On this basis, this study determined the best electricity transmission and distribution path between the electricity purchasing and selling nodes based on the transmission and distribution price determined via the “stamp method” and the line congestion in each region. The path congestion data of each section refer to the historical congestion data of that path section and are announced to the platform.

The Dijkstra algorithm is a traditional algorithm used to determine the shortest path. It can be used to calculate the distance of the shortest path from a node to all other nodes. The main feature of the Dijkstra algorithm is that its starting point is in the center and expands to the outer layer until it covers all the nodes. A flowchart of the Dijkstra algorithm is shown in Figure 3, wherein S represents the set of vertices of the shortest path, U represents the set of other undetermined vertices, and v represents the source point.

This study not only considers the price of electricity transmission and distribution when determining the best electricity transmission and distribution path but also considers the line congestion in each region. Therefore, a modified Dijkstra algorithm was adopted to determine the best path for electricity transmission and distribution. The difference between this method and the general method used to determine the shortest path problem is that the weight of each arc of this problem is not fixed. Although beginning from the same starting point, the selection of the best path varies owing to the dynamic congestion of each path. The weight update equation considering line congestion is as follows:

$$W'_{ij} = W_{ij} \times (1 - \lambda_{ij}),$$

(2)
where $W_{ij}$ represents the weight of each line considering the price of power transmission and distribution, $\lambda_{ij}$ represents the congestion of each line, and $W_{ij}'$ represents the updated weight of each path.

Herein, the best electricity transmission and distribution path were determined using the improved Dijkstra algorithm. Each transaction node can call the smart contract to obtain the best path as well as the corresponding transmission and distribution price with other transaction nodes while considering line congestion and economy.

5. The smart contract for sorting prediction errors: As renewable energy is affected by natural factors, its output is unstable. Therefore, errors exist between the actual output data and forecast data of each electricity sales company. This prediction error leads to inconsistency in the cashing ability of the electricity selling nodes. The prediction error of each company is determined by the company’s actual power generation data and forecast data of the previous month and is released to the platform for network-wide announcements. Electricity purchasing nodes can sort electricity selling nodes according to the magnitude of the prediction error by invoking the smart contract to sort prediction errors. On this basis, electricity purchasing nodes select the electricity selling node with a smaller prediction error for trade.

6. The smart contract for sorting the historical number of transactions: The distributed electricity market trading platform based on blockchain technology can continuously record historical transaction information. Each transaction node on the platform obtains the number of historical transactions with other nodes. When the number of historical transactions between electricity purchasing and selling nodes is greater, the trust between both parties of the transaction is higher. Delisting nodes can select listing nodes with more historical transactions for trading by calling the smart contract to sort the historical number of transactions.

7. The smart contract for comprehensive sorting of listing nodes: The smart contract can comprehensively evaluate electricity listing nodes. The delisting node selects a listing node with a high score for trading based on a comprehensive evaluation result. The smart contract is described in detail in Section 4. The smart contract adopts the improved Critic-G1 subjective and objective comprehensive weighting evaluation method based on the coefficient of variation. When electricity selling nodes are listed and electricity purchasing nodes are delisted, electricity purchasing nodes comprehensively consider the aforementioned factors, including renewable energy type, credit score, price of electricity listing nodes, prediction error, price of electricity transmission and distribution between the electricity purchasing and selling nodes, and the number of historical transactions. The smart contract comprehensively evaluates each electricity selling node via indicator preprocessing and subjective and objective comprehensive weighting. Electricity purchasing nodes can obtain a comprehensive score of all electricity selling nodes participating in the transaction by calling the smart contract and subsequently select the electricity selling node with a high score to trade. Similarly, when electricity purchasing nodes are listed and electricity selling nodes are delisted, electricity selling nodes comprehensively evaluate the electricity purchasing nodes based on the credit score of the electricity purchasing nodes, the listing electricity price, the prediction error, the price of electricity transmission and distribution between the electricity purchasing and selling nodes, and the number of historical transactions.

4 | SMART CONTRACT FOR COMPREHENSIVE LISTING NODE SORTING BASED ON THE IMPROVED CRITIC-G1 COMPREHENSIVE WEIGHTING METHOD ACCORDING TO THE COEFFICIENT OF VARIATION

In this study, the improved Critic-G1 subjective and objective comprehensive weighting evaluation method based on the coefficient of variation was used to comprehensively evaluate the listing nodes. According to the comprehensive evaluation results of the listing nodes, the delisting nodes can determine the best delisting strategy. The indicators involved in the comprehensive evaluation include renewable energy type, credit score, the price of electricity listing nodes, the prediction error, the price of electricity transmission and distribution between the electricity purchasing and selling nodes, and the number of historical transactions. The comprehensive evaluation flowchart is shown in Figure 4.

4.1 | Preprocessing of evaluation indicators

Because of the wide range and poor comparability of the indicator-related data involved in the comprehensive evaluation, it must be preprocessed to facilitate a comprehensive follow-up evaluation. On this basis, indicator types were divided into positive and reverse indicators. The larger the positive indicator, the better the performance of the evaluation object. The larger the value of the reverse indicator, the worse the performance.\(^\text{23}\) For example, in
the comprehensive evaluation model of electricity selling nodes, positive indicators include renewable energy type, the credit score of the electricity selling nodes, and the number of historical transactions between trading nodes. The remaining indicators are considered to be reverse indicators.

First, it is necessary to achieve consistency in the indicator types. The equation for transforming reverse indicators into positive indicators is as follows:

\[ x_{ij}^* = \max x_i - x_{ij}, \]  

(3)

where \( x_{ij} \) represents the data for indicator \( i \) of the electricity selling node \( j \), and \( x_i \) represents the data of indicator \( i \).

The data of indicators have different dimensions and magnitudes. In this study, indicator data are processed in a dimensionless manner to ensure that various indicators are transformed into comparable data with the same dimension and order of magnitude. The results of the dimensionless data processing for each indicator are as follows:

\[ x_{ij}^* = \frac{x_{ij} - \min x_i}{\max x_i - \min x_i}. \]  

(4)

4.2 | Calculating indicator weight

Different indicators contribute differently to the comprehensive evaluation scores of the listing nodes. Therefore, it is necessary to determine the weights of different indicators to measure the role of each indicator. Currently, there are several ways to determine the weight of an indicator. According to the source of the original data when calculating the weights, these methods can be divided into three categories: subjective, objective, and comprehensive weighting methods. The subjective weighting method determines the weight of indicators based on the guidance of experts and dynamically reflects the contribution of the indicator to the evaluation subject. This method has strong timeliness, but it is relatively subjective. The objective weighting method has the advantage of objectivity, but it cannot change the importance of the indicators with actual developments and needs. Therefore, this study adopted the comprehensive weighting method, which combines the improved Critic and G1 methods. This method can not only enhance the objectivity of indicator weighting but also determine the specificity of indicators according to the actual needs.

4.2.1 | Improved Critic method

The improved Critic method is an objective weighting method that considers the correlation between indicators without changing the indicator's own information.
The traditional Critic method requires continuous indicator data information, and the importance of conflict and contrast in the algorithm must be consistent. Therefore, Reference 25 proposed the CV-Critic method, which analyzes the degree of difference between conflict and contrast by introducing a difference coefficient to optimize the traditional Critic method.

This improved Critic method is an objective weighting method. It considers the influence of the indicator’s own information and the correlation between indicators on the weight of the indicators and proposes the concepts of the indicator discrimination coefficient, DDV (discrimination degree value), and the indicator conflict coefficient, CIV (conflict influence value). Meanwhile, the difference coefficient method was introduced to measure the degree of difference in conflict coefficients. The Critic method flowchart is shown in Figure 5. The corresponding calculation steps are as follows\(^{26}\):

1. **Discrimination coefficient DDV**

   The discrimination coefficient calculates the standard deviation of the indicator using the data information of the standardized data matrix. The coefficient vector for discrimination is \(v = [v_1, \ldots, v_l]\).

   \[
   v_j = \frac{q_j}{\sum_{j=1}^l q_j},
   \]

   where \(l\) represents the number of indicators.

2. **Conflict coefficient CIV**

   The conflict coefficient is obtained by solving the related coefficient matrix using the data information of the standardized data matrix.

   \[
   r_{ij} = \frac{\text{cov}(Z_i, Z_j)}{\sqrt{D(Z_i) \cdot D(Z_j)}},
   \quad t_{ij} = 1 - r_{ij},
   \]

   where \(r_{ij}\) represents the correlation coefficient between the indicators \(i\) and \(j\), and \(t_{ij}\) represents the size of the conflict between the indicators \(i\) and \(j\).

   This study also handles conflicting coefficients between indicators, in which the conflicting coefficient vector is \(c = [c_1, \ldots, c_l]\),

   \[
   c_j = \frac{\sum_{h=1}^l t_{hj}}{\sum_{j=1}^l \sum_{h=1}^l t_{hj}}.
   \]

3. Calculate the undetermined coefficient \(pv\)

   The components in the conflicting vector \(c\) are reordered from small to large to obtain an ordered vector \(p\). Then, the difference coefficient \(g\) and undetermined parameter \(pv\) of each component in vector \(p\) are calculated.

   \[
   \begin{align*}
   g &= \frac{2}{l} \sum_{j=1}^l j \cdot p_j - \left(1 + \frac{1}{l}\right) \\
   pv &= \frac{l}{l-1} \cdot g
   \end{align*}
   \]

4. Calculate the objective weight of the indicator

   The vector of the discrimination coefficient and the vector of the conflict coefficient are weighted by the undetermined parameters, and the final indicator weights are as follows:

   \[
   w^C_j = pv \cdot c_j + (1 - pv) \cdot v_j.
   \]

**4.2.2 | G1 method**

The G1 method is the subjective weighting method\(^{27}\). This method obtains the final weight vector by integrating the scores of different experts’ views on the importance of all indicators. Compared with the commonly used AHP (analytic hierarchy process) method, it does not require a judgment matrix, which means it does not require a consistency test. In addition, this method reduces the amount of calculation, has order preservation, and is convenient for the expansion of subsequent indicators.\(^{28}\) The G1 method flowchart is shown in Figure 6, and the corresponding calculation steps are as follows\(^{27}\):

1. \(l\) experts determine the importance of the indicators concerned with electricity purchasing nodes. Using the \(t\)-th expert as an example, the expert ranks the importance of indicators in the following manner. First, the expert \(t\) selects the most important indicator and marks it as \(x_{t1}^*\). Then, the expert selects, of the remaining indicators, the most important indicator and marks it as \(x_{t2}^*\). Following this procedure, the expert sorts the indicators to \(x_{tn}^*\). Therefore, the order relationship determined by the expert is as follows:

   \[
   x_{t1}^* > x_{t2}^* > \cdots > x_{tn}^*.
   \]
2. L experts determine the importance ratio of adjacent indicators in the order relationship they constructed. Using the t-th expert as an example, the expert gives the ratio $k_{ti}$ of importance between the indicators $x^{(s)}_{i-1}$ and $x^{(s)}_i$. The assignment of $k_{ti}$ is summarized in Table 1.

3. After the experts have completed the assignment judgment, some experts (L1, L2, ..., Lh; 1 ≤ Ls < L (s = 1, 2, ..., h)) may develop the same order relationship. For Ls experts, the importance values between the indicators $x^{(s)}_{j-1}$ and $x^{(s)}_j$ given in this study are $k^{(s)}_{ji}$ (k = 1, 2, ..., Ls; s = 1, 2, ..., h). The calculation method for the subjective weights is as follows:

$$\lambda^{(s)}_n = \left(1 + \sum_{i=2}^{n} \prod_{j=i}^{n} k^{(s)}_{ji}\right)^{-1}, \quad (11)$$

$$\lambda^{(s)}_{i-1} = k^{(s)}_{i} \lambda^{(s)}_i \quad i = n, n-1, \ldots, 2. \quad (12)$$

The formula for calculating the weighted average value $k^{(s)}_i$ of Ls experts to determine the importance ratio of the indicators is as follows:

$$k^{(s)}_i = \frac{1}{Ls} \sum_{i=1}^{Ls} k^{(s)}_{it} i = 2, 3, \ldots, n. \quad (13)$$

The order relationships determined by the experts are sorted according to the original numbers of the corresponding indicators from small to large, producing the vector $(\lambda^{(s)}_1, \lambda^{(s)}_2, \ldots, \lambda^{(s)}_n)$, s = 1, 2, ..., h. By synthesizing the subjective weighting information of the experts with the same order relationship, the final subjective weighting results of the indicators can be obtained as follows:

$$w_i^G = \sum_{s=1}^{h} \frac{Ls}{L} \lambda^{(s)}_i \quad i = 1, 2, \ldots, n. \quad (14)$$
4.2.3 | Comprehensive weighting method based on the coefficient of variation

The indicator weights determined by the improved Critic method and G1 method are \( w^C \) and \( w^G \), respectively. The comprehensive weight \( w_j \) can be obtained by combining the subjective and objective weights. The equation for calculating the comprehensive weight is as follows:\(^{27}\):

\[
w_j = a^*_1 w^C_j + a^*_2 w^G_j \quad j = 1, 2, \ldots, n, \tag{15}
\]

where \( a^*_1 \) and \( a^*_2 \) are constants (\( a^*_1 > 0, a^*_2 > 0, a^*_1 + a^*_2 = 1 \)). By introducing the variation coefficient into a comprehensive integrated model of subjective and objective information, the subjective and objective weighted summation of the variation coefficient of the indicator is maximized to solve \( a^*_1 \) and \( a^*_2 \).

The variation coefficient is defined as the quotient of the standard deviation and the average value of a set of data. It reflects the degree of dispersion of a set of data.\(^{26}\) The equation constructed using the variation coefficient is as follows:

\[
C = \sum_{j=1}^{n} c_j w_j = \sum_{j=1}^{n} c_j (a^*_1 w^E_j + a^*_2 w^G_j), \tag{16}
\]

where \( C \) represents the weighted sum of the variation coefficient, which reflects the overall difference between the evaluation objects. If \( C \) is larger, the degree of distinction between the subjective and objective comprehensive evaluations is greater. On this basis, the optimized model is as follows:

\[
\max C = \sum_{j=1}^{n} c_j (a^*_1 w^E_j + a^*_2 w^G_j), \tag{17}
\]

\[
a^*_1 + a^*_2 = 1 \quad a_1 > 0, \quad a_2 > 0. \tag{18}
\]

In this study, the Lagrange extreme value principle was used to solve the optimization equations (Equations 17 and 18). The Lagrange function is expressed as follows:

\[
C = \sum_{j=1}^{n} c_j (a^*_1 w^E_j + a^*_2 w^G_j) - \lambda (a^*_1 + a^*_2 - 1). \tag{19}
\]

For \( \frac{\partial C}{\partial a_1} = 0, \frac{\partial C}{\partial a_2} = 0, \frac{\partial C}{\partial \lambda} = 0 \), the calculation formulas for \( a_1 \) and \( a_2 \) are:

\[
a_1 = \frac{\sum_{j=1}^{n} c_j w^E_j}{\sqrt{\left( \sum_{j=1}^{n} c_j w^E_j \right)^2 + \left( \sum_{j=1}^{n} c_j w^G_j \right)^2}}, \tag{20}
\]

\[
a_2 = \sqrt{\frac{\sum_{j=1}^{n} c_j w^G_j}{\left( \sum_{j=1}^{n} c_j w^E_j \right)^2 + \left( \sum_{j=1}^{n} c_j w^G_j \right)^2}}. \tag{21}
\]

Finally, \( a_1 \) and \( a_2 \) must be normalized. The resultant values of \( a_1^* \) and \( a_2^* \) are:

\[
a_1^* = \frac{a_1}{a_1 + a_2}, \tag{22}
\]

\[
a_2^* = \frac{a_2}{a_1 + a_2}. \tag{23}
\]

4.3 | Comprehensive evaluation of listing nodes

In this study, the improved Critic-G1 subjective and objective comprehensive weighting method based on the coefficient of variation was used to obtain the weights of various indicators. Using the weight of each indicator, the comprehensive score of each listing node can be calculated separately. The calculation equation for the comprehensive score \( S_i \) of listing node \( i \) is as follows:

\[
S_i = \sum_{j=1}^{n} X_{ij} w_j. \tag{24}
\]

This comprehensive score can be used as the basis for the delisting node to select the best trading node. When the comprehensive score of a listing node is higher, the delisting node will give priority to this listing node for trading.

5 | EXAMPLE ANALYSIS

If there are several electricity selling nodes distributed in places B, C, D, E, and F and place B has one electricity purchasing node, the delisting electricity quantity submitted by this electricity purchasing node during the release requirements phase is 90 MWH. The geographic relationships of the five places are shown in Figure 7. In this section, how to use the comprehensive evaluation method proposed in Section 4 to achieve the best electricity purchasing strategy for the electricity purchasing node is discussed.

The known conditions are as follows: the electricity transmission and distribution prices of various regions determined by the relevant departments, as listed in Table 2, and the historical congestion between each line, as listed in Table 3.

Owing to the existence of non-water renewable energy quota indicators, non-water renewable energy is better
than water resources in this comprehensive evaluation model. Moreover, the prices of different types of renewable energy green certificates vary. The price of a green certificate is determined by the benchmark electricity price. Therefore, the value of the renewable energy type indicator is determined by the on-grid benchmark electricity price of each type of renewable energy. The value of the renewable energy type corresponding to the maximum on-grid benchmark price is assigned as 1, and the values of the remaining types of renewable energy are determined by the ratio of the on-grid benchmark electricity price to the highest on-grid benchmark electricity price.

5.1 Example 1 (10 electricity selling nodes)

In this example, it is assumed that there are ten electricity selling nodes distributed in different locations. The relevant information for each electricity selling node is summarized in Table 4.

1. The delisting node calls the comprehensive evaluation smart contract. The specific steps are as follows:

Step 1: The improved Dijkstra algorithm can be used to obtain the best path between the electricity purchasing node and each electricity selling node. When only considering the path distance, the matrix of the path weights is as follows:

\[
W = \begin{pmatrix}
0 & 0.315 & \infty & \infty & 0.296 \\
0.315 & 0 & 0.336 & 0.296 & 0.309 \\
\infty & 0.336 & 0 & 0.304 & \infty \\
\infty & 0.296 & 0.304 & 0 & 0.277 \\
0.296 & 0.309 & \infty & 0.277 & 0
\end{pmatrix}
\]

Considering the path distance, the path weight can then be recalculated while considering the historical congestion of the line. The new weight matrix is expressed as follows:

\[
W' = \begin{pmatrix}
0 & 0.284 & \infty & \infty & 0.207 \\
0.284 & 0 & 0.292 & 0.13 & 0.287 \\
\infty & 0.292 & 0 & 0.255 & \infty \\
\infty & 0.13 & 0.255 & 0 & 0.208 \\
0.207 & 0.287 & \infty & 0.208 & 0
\end{pmatrix}
\]

Through the simulation analysis of the improved Dijkstra algorithm considering line congestion, the best path from place B to any other place and the corresponding transmission and distribution prices can be obtained. The results of the simulation are summarized in Table 5.

Step 2: The second step involves data preprocessing for specific indicator information. Herein, a comprehensive evaluation indicator system was established for electricity selling nodes. The indicators established by this system include the credit score, price of electricity listing nodes, price of electricity transmission and distribution between the electricity purchasing and selling nodes, the type of

![Figure 7](image-url)  
**FIGURE 7** Geographic relationship of each region

| Table 2 Regional transmission and distribution price |
|-----------------------------------------------|
| Region | Transmission and distribution price (RMB/KWH) |
| B     | 0.151 |
| C     | 0.164 |
| D     | 0.145 |
| E     | 0.172 |
| F     | 0.132 |

| Table 3 Historical congestion between each line |
|-----------------------------------------------|
| Line | Historical congestion |
| BC   | 10% |
| BD   | 30% |
| CD   | 7% |
| CF   | 56% |
| CE   | 13% |
| DF   | 25% |
| EF   | 16% |
According to Equations (3) and (4), the data of these indicators are preprocessed. The standardized evaluation matrix $X'$ is as follows:

$$
X' = \begin{pmatrix}
0.851 & 0.069 & 1 & 1 & 0.021 & 0.75 \\
0.745 & 0.414 & 1 & 0.85 & 0.681 & 0 \\
0.638 & 0.931 & 0.672 & 0.58 & 0.936 & 0.25 \\
0.745 & 0.517 & 0.672 & 0.85 & 0.617 & 0.5 \\
0.319 & 0 & 0 & 1 & 0.106 & 0.25 \\
1 & 1 & 0 & 0.58 & 1 & 1 \\
0.638 & 0.172 & 0.08 & 1 & 0 & 0.25 \\
0 & 0.414 & 0.08 & 0.85 & 0.574 & 0 \\
0.851 & 0.138 & 0.71 & 1 & 0.149 & 0.25 \\
0.745 & 0.966 & 0.71 & 0.58 & 0.894 & 0.5
\end{pmatrix}
$$

Step 3: The improved critic method is used to determine the objective weight of each indicator. According to Equations (5)–(9), the weight vector used to calculate the objective weight of each indicator is $w^C = (0.15, 0.185, 0.21, 0.099, 0.192, 0.164)$.

Step 4: The G1 method is used to determine the subjective weight of each indicator. Herein, nine experts subjectively sorted and assigned weights to the comprehensive evaluation indicators of the electricity selling nodes. According to the weighting principle of the G1 method, as mentioned in Section 2.3, the order relationships given by the experts are classified. After sorting, a total of 4 different ordinal relationships are obtained. The expert assignment results of the indicator importance ratio under the four ordinal relationships are listed in Table 6.

According to Equations (10)–(14), the weight vector used to calculate the subjective weight of each indicator is $w^G = (0.185, 0.289, 0.155, 0.149, 0.15, 0.072)$.

Step 5: Combine the subjective and objective weights based on the coefficient of variation to obtain the weighted combination. According to Equations (15)–(23), the weighted combination coefficients of the improved Critic and G1 methods are 0.156 and 0.484, respectively. Considering Equation (15), the final subjective

| Table 5 Simulation results |
|-----------------------------|
| **Destination** | **Best path** | **Corresponding transmission and distribution price** |
| C               | B → C         | 0.315 |
| D               | B → D         | 0.296 |
| E               | B → C → E     | 0.651 |
| F               | B → C → F     | 0.611 |
and objective comprehensive weight vector is \( w_j = (0.167, 0.235, 0.183, 0.123, 0.172, 0.12) \).

Step 6: According to Equation (24), the comprehensive evaluation of electricity selling nodes is performed, and the comprehensive evaluation results of each electricity selling node are obtained, as shown in Table 7 and Figure 8.

Overall, node F2 had the highest comprehensive score, followed by node D2. Therefore, when a certain electricity selling node in place B requires an electricity quantity of 90 MWH, the best electricity purchasing strategy for this node is to purchase all electricity from node F2. If the listing electricity quantity of node F2 is less than the electricity purchasing demand of the electricity purchasing node, the electricity purchasing node purchases the remaining electricity from node D2. Overall, this method can provide the best delisting strategy for delisting nodes, guarantee the interests of delisting nodes, and improve the enthusiasm of trading nodes on the platform.

2. The delisting node does not call the comprehensive evaluation smart contract and randomly selects the delisting object.

In this scenario, the delisting node randomly selects a listing node for trading. Here, the probability of ten electricity selling nodes being selected is equal, and the electricity purchasing node has only a 10% probability that it trades with the best selling node. This kind of random selection is not conducive to protecting the interests of delisting nodes and cannot improve transaction enthusiasm.
| Renewable electricity selling companies | Credit score | Listing electricity quantity/KWH | Listing electricity price/(RMB/KWH) | Price of electricity transmission and distribution | Renewable energy type | Prediction error | Number of historical transactions |
|----------------------------------------|--------------|----------------------------------|-------------------------------------|---------------------------------------------|-----------------------|----------------|-----------------------------|
| B1 (solar power)                       | 85           | 100 k                            | 0.58                               | 0.151                                       | 1                     | 8.60%          | 3                           |
| B2 (wind power)                        | 80           | 80 k                             | 0.48                               | 0.151                                       | 0.85                  | 5.50%          | 0                           |
| B3 (wind power)                        | 95           | 70 k                             | 0.50                               | 0.151                                       | 0.85                  | 5.20%          | 1                           |
| B4 (solar power)                       | 70           | 100 k                            | 0.52                               | 0.151                                       | 1                     | 7.80%          | 2                           |
| B5 (wind power)                        | 85           | 120 k                            | 0.44                               | 0.151                                       | 0.85                  | 5.80%          | 3                           |
| B6 (solar power)                       | 73           | 110 k                            | 0.48                               | 0.151                                       | 1                     | 8.10%          | 3                           |
| B7 (solar power)                       | 80           | 89 k                             | 0.50                               | 0.151                                       | 1                     | 8.30%          | 0                           |
| B8 (wind power)                        | 82           | 95 k                             | 0.40                               | 0.151                                       | 0.85                  | 6.20%          | 3                           |
| B9 (wind power)                        | 76           | 102 k                            | 0.42                               | 0.151                                       | 0.85                  | 6.50%          | 2                           |
| B10 (solar power)                      | 78           | 150 k                            | 0.52                               | 0.151                                       | 1                     | 8.60%          | 4                           |
| B11 (solar power)                      | 80           | 167 k                            | 0.50                               | 0.151                                       | 1                     | 8.20%          | 3                           |
| B12 (solar power)                      | 82           | 152 k                            | 0.50                               | 0.151                                       | 1                     | 8.30%          | 1                           |
| B13 (solar power)                      | 68           | 78 k                             | 0.47                               | 0.151                                       | 1                     | 8.10%          | 4                           |
| B14 (solar power)                      | 70           | 98 k                             | 0.53                               | 0.151                                       | 1                     | 8.60%          | 3                           |
| B15 (wind power)                       | 75           | 110 k                            | 0.42                               | 0.151                                       | 0.85                  | 5.80%          | 2                           |
| B16 (hydroelectric power)              | 82           | 120 k                            | 0.38                               | 0.151                                       | 0.58                  | 4.50%          | 1                           |
| B17 (wind power)                       | 85           | 105 k                            | 0.40                               | 0.151                                       | 0.85                  | 6.80%          | 1                           |
| B18 (hydroelectric power)              | 75           | 80 k                             | 0.36                               | 0.151                                       | 0.58                  | 4.60%          | 1                           |
| B19 (wind power)                       | 82           | 95 k                             | 0.47                               | 0.151                                       | 0.85                  | 5.50%          | 0                           |
| B20 (wind power)                       | 76           | 100 k                            | 0.44                               | 0.151                                       | 0.85                  | 6.50%          | 0                           |
| C1 (hydroelectric power)               | 75           | 90 k                             | 0.33                               | 0.315                                       | 0.58                  | 4.30%          | 1                           |
| C2 (wind power)                        | 80           | 80 k                             | 0.45                               | 0.315                                       | 0.85                  | 5.80%          | 2                           |
| C3 (wind power)                        | 85           | 98 k                             | 0.48                               | 0.315                                       | 0.85                  | 6.20%          | 1                           |
| C4 (wind power)                        | 87           | 100 k                            | 0.42                               | 0.315                                       | 0.85                  | 5.60%          | 0                           |
| C5 (solar power)                       | 90           | 106 k                            | 0.50                               | 0.315                                       | 1                     | 7.60%          | 0                           |
| C6 (wind power)                        | 68           | 160 k                            | 0.44                               | 0.315                                       | 0.85                  | 6.50%          | 0                           |
| C7 (hydroelectric power)               | 95           | 96 k                             | 0.40                               | 0.315                                       | 0.58                  | 4.50%          | 3                           |
| C8 (solar power)                       | 82           | 108 k                            | 0.52                               | 0.315                                       | 1                     | 8.20%          | 3                           |
| C9 (wind power)                        | 92           | 90 k                             | 0.50                               | 0.315                                       | 0.85                  | 5.60%          | 0                           |
| C10 (wind power)                       | 78           | 95 k                             | 0.42                               | 0.315                                       | 0.85                  | 5.80%          | 2                           |
| Credit score | Renovable energy type | Listing quantity (KWH) | Listing price/(RMB/KWH) | Price of electricity transmission and distribution | Number of historical transactions | Prediction error |
|--------------|-----------------------|------------------------|--------------------------|--------------------------------------------------|----------------------------------|------------------|
| C11  (solar power) | 69  k  | 0.50                     | 0.315                    | 1                                                | 1                                | 8.30%            |
| C12  (hydroelectric power) | 75  k  | 0.38                     | 0.315                    | 0.58                                             | 1                                | 3.80%            |
| C13  (wind power) | 80  k  | 0.42                     | 0.315                    | 0.85                                             | 1                                | 6.00%            |
| C14  (solar power) | 86  k  | 0.48                     | 0.315                    | 1                                                | 1                                | 8.10%            |
| C15  (solar power) | 78  k  | 0.22                     | 0.315                    | 0.58                                             | 1                                | 10.10%           |
| C16  (hydroelectric power) | 75  k  | 0.40                     | 0.315                    | 0.85                                             | 1                                | 3.80%            |
| C17  (solar power) | 76  k  | 0.85                     | 0.315                    | 0.58                                             | 1                                | 8.10%            |
| C18  (solar power) | 82  k  | 0.55                     | 0.315                    | 0.85                                             | 1                                | 6.00%            |
| C19  (solar power) | 69  k  | 1.05                     | 0.56                     | 0.651                                            | 1                                | 8.30%            |
| C20  (solar power) | 60  k  | 1.00                     | 0.60                     | 0.651                                            | 1                                | 8.20%            |
| D1   (solar power) | 60  k  | 1.00                     | 0.31                     | 0.651                                            | 1                                | 8.20%            |
| D2   (hydroelectric power) | 92  k  | 0.90                     | 0.651                    | 0.58                                             | 1                                | 8.30%            |
| D3   (solar power) | 80  k  | 0.80                     | 0.651                    | 0.58                                             | 1                                | 8.30%            |
| D4   (solar power) | 92  k  | 0.50                     | 0.56                     | 0.651                                            | 1                                | 8.30%            |
| D5   (wind power) | 80  k  | 0.55                     | 0.85                     | 0.651                                            | 1                                | 8.30%            |
| D6   (solar power) | 82  k  | 1.10                     | 0.38                     | 0.651                                            | 1                                | 8.30%            |
| D7   (hydroelectric power) | 75  k  | 0.90                     | 0.651                    | 0.58                                             | 1                                | 8.30%            |
| D8   (hydroelectric power) | 80  k  | 0.90                     | 0.651                    | 0.58                                             | 1                                | 8.30%            |
| D9   (wind power) | 82  k  | 1.10                     | 0.38                     | 0.651                                            | 1                                | 8.30%            |
| D10  (solar power) | 92  k  | 1.00                     | 0.31                     | 0.651                                            | 1                                | 8.30%            |
| D11  (solar power) | 80  k  | 1.05                     | 0.40                     | 0.651                                            | 1                                | 8.30%            |
| D12  (wind power) | 75  k  | 1.00                     | 0.31                     | 0.651                                            | 1                                | 8.30%            |
| D13  (wind power) | 80  k  | 1.05                     | 0.40                     | 0.651                                            | 1                                | 8.30%            |
| D14  (hydroelectric power) | 75  k  | 1.00                     | 0.31                     | 0.651                                            | 1                                | 8.30%            |
| D15  (wind power) | 80  k  | 1.05                     | 0.40                     | 0.651                                            | 1                                | 8.30%            |
| D16  (wind power) | 75  k  | 1.00                     | 0.31                     | 0.651                                            | 1                                | 8.30%            |
| D17  (wind power) | 80  k  | 1.05                     | 0.40                     | 0.651                                            | 1                                | 8.30%            |

**TABLE 8** (Continued)
| Renewable electricity selling companies | Credit score | Listing electricity quantity/KWH | Listing electricity price/(RMB/KWH) | Price of electricity transmission and distribution | Renewable energy type | Prediction error | Number of historical transactions |
|---------------------------------------|--------------|----------------------------------|-------------------------------------|-----------------------------------------------|-----------------------|----------------|----------------------------------|
| E1 (solar power)                      | 75           | 120 k                            | 0.55                                | 0.611                                         | 1                     | 8.70%          | 1                  |
| E2 (wind power)                       | 45           | 130 k                            | 0.48                                | 0.611                                         | 0.85                  | 6.00%          | 0                  |
| E3 (wind power)                       | 68           | 98 k                             | 0.46                                | 0.611                                         | 0.85                  | 5.80%          | 0                  |
| E4 (hydroelectric power)              | 74           | 80 k                             | 0.42                                | 0.611                                         | 0.58                  | 5.80%          | 0                  |
| E5 (solar power)                      | 53           | 105 k                            | 0.58                                | 0.611                                         | 1                     | 8.50%          | 1                  |
| E6 (solar power)                      | 89           | 127 k                            | 0.53                                | 0.611                                         | 1                     | 8.40%          | 2                  |
| E7 (solar power)                      | 78           | 128 k                            | 0.49                                | 0.611                                         | 1                     | 7.80%          | 2                  |
| E8 (wind power)                       | 71           | 134 k                            | 0.50                                | 0.611                                         | 0.85                  | 5.60%          | 1                  |
| E9 (hydroelectric power)              | 75           | 142 k                            | 0.41                                | 0.611                                         | 0.58                  | 4.30%          | 0                  |
| E10 (hydroelectric power)             | 80           | 100 k                            | 0.34                                | 0.611                                         | 0.58                  | 4.50%          | 0                  |
| E11 (solar power)                     | 87           | 107 k                            | 0.52                                | 0.611                                         | 0.85                  | 5.80%          | 2                  |
| E12 (wind power)                      | 63           | 86 k                             | 0.52                                | 0.611                                         | 1                     | 8.60%          | 3                  |
| E13 (solar power)                     | 74           | 98 k                             | 0.55                                | 0.611                                         | 1                     | 8.10%          | 1                  |
| E14 (wind power)                      | 87           | 95 k                             | 0.44                                | 0.611                                         | 0.85                  | 6.50%          | 0                  |
| E15 (wind power)                      | 78           | 108 k                            | 0.48                                | 0.611                                         | 0.85                  | 6.20%          | 0                  |
| E16 (hydroelectric power)             | 60           | 126 k                            | 0.38                                | 0.611                                         | 0.58                  | 4.80%          | 2                  |
| E17 (hydroelectric power)             | 90           | 127 k                            | 0.35                                | 0.611                                         | 0.58                  | 4.40%          | 2                  |
| E18 (solar power)                     | 80           | 129 k                            | 0.53                                | 0.611                                         | 1                     | 8.30%          | 1                  |
| E19 (solar power)                     | 85           | 163 k                            | 0.55                                | 0.611                                         | 1                     | 8.00%          | 5                  |
| E20 (wind power)                      | 75           | 152 k                            | 0.50                                | 0.611                                         | 0.85                  | 5.90%          | 3                  |
| F1 (solar power)                      | 85           | 140 k                            | 0.56                                | 0.296                                         | 1                     | 7.8%           | 1                  |
| F2 (hydroelectric power)              | 80           | 150 k                            | 0.32                                | 0.296                                         | 0.58                  | 4.50%          | 2                  |
| F3 (solar power)                      | 87           | 107 k                            | 0.53                                | 0.296                                         | 1                     | 8.50%          | 0                  |
| F4 (solar power)                      | 85           | 118 k                            | 0.55                                | 0.296                                         | 1                     | 8.40%          | 1                  |
| F5 (hydroelectric power)              | 78           | 120 k                            | 0.35                                | 0.296                                         | 0.58                  | 4.10%          | 0                  |
| F6 (wind power)                       | 63           | 109 k                            | 0.45                                | 0.296                                         | 0.85                  | 6.80%          | 0                  |
| F7 (solar power)                      | 60           | 89 k                             | 0.52                                | 0.296                                         | 1                     | 7.60%          | 1                  |
| F8 (wind power)                       | 87           | 97 k                             | 0.44                                | 0.296                                         | 0.85                  | 6.50%          | 1                  |
| F9 (wind power)                       | 70           | 120 k                            | 0.48                                | 0.296                                         | 0.85                  | 5.50%          | 2                  |
| F10 (solar power)                     | 75           | 105 k                            | 0.50                                | 0.296                                         | 1                     | 7.50%          | 2                  |
5.2 | Example 2 (100 electricity selling nodes)

In this example, it is assumed that there are 100 electricity selling nodes distributed across different regions. The relevant information for each electricity selling node is summarized in Table 8.

1. The delisting node calls the comprehensive evaluation smart contract.

In this scenario, similar to example 1, the weight vector for calculating the objective weight of each indicator is $w^C = (0.131, 0.158, 0.249, 0.108, 0.192, 0.162)$, and the weight vector for calculating the objective weight of each indicator is $w^G = (0.185, 0.289, 0.155, 0.149, 0.15, 0.072)$. Furthermore, the final subjective and objective comprehensive weight vector is $w = (0.156, 0.218, 0.206, 0.127, 0.172, 0.121)$. Based on these vectors, the comprehensive evaluation result of each electricity selling node was obtained, as shown in Figure 9.

Overall, node B8 had the highest comprehensive score, followed by node C7. Therefore, when an electricity selling node in place B requires an electricity quantity of 90 MWH, the best electricity purchasing strategy for this node is to purchase an electricity quantity of 90 MWH from node B8. This example reveals that even if the delisting node is faced with a large number of choices, it can quickly obtain the best delisting strategy by calling the smart contract, thereby improving the transaction enthusiasm of the delisting node and enhancing the promotion and application of the platform mentioned in this study.

2. The delisting node does not call the comprehensive evaluation smart contract and randomly selects the delisting object.

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**TABLE 8** (Continued)

| Number of historical transactions | Prediction error | Renewable energy type | Listing electricity quantity/KWH | Listing electricity price/(RMB/KWH) | Price of electricity transmission and distribution | Prediction error | Number of historical transactions | Credit score | Renewable electricity selling companies | Listing electricity price/(RMB/KWH) |
|----------------------------------|-----------------|-----------------------|----------------------------------|------------------------------------|-----------------------------------------------|-----------------|--------------------------------------|----------------|-------------------------------------|----------------------------------|
| 1                                | 8.50%           | 1                     | 1.40 k                           | 0.296                              | 0.296                                        | 1.20 k          | 0                                    | 5.80%          | F11 (solar power)                    | 0.56                             |
| 0                                | 8.30%           | 2                     | 0.96 k                           | 0.296                              | 0.296                                        | 0.40 k          | 0                                    | 5.80%          | F12 (hydropower)                     | 0.56                             |
| 1                                | 8.50%           | 1                     | 1.20 k                           | 0.296                              | 0.296                                        | 0.40 k          | 0                                    | 5.80%          | F13 (wind power)                     | 0.56                             |
| 0                                | 8.30%           | 2                     | 1.20 k                           | 0.296                              | 0.296                                        | 0.40 k          | 0                                    | 5.80%          | F14 (wind power)                     | 0.56                             |
| 1                                | 8.50%           | 1                     | 1.20 k                           | 0.296                              | 0.296                                        | 0.40 k          | 0                                    | 5.80%          | F15 (wind power)                     | 0.56                             |
| 0                                | 8.30%           | 2                     | 0.96 k                           | 0.296                              | 0.296                                        | 0.40 k          | 0                                    | 5.80%          | F16 (solar power)                    | 0.56                             |
| 1                                | 8.50%           | 1                     | 0.96 k                           | 0.296                              | 0.296                                        | 0.40 k          | 0                                    | 5.80%          | F17 (solar power)                    | 0.56                             |
| 0                                | 8.30%           | 2                     | 0.96 k                           | 0.296                              | 0.296                                        | 0.40 k          | 0                                    | 5.80%          | F18 (hydropower)                     | 0.56                             |
| 1                                | 8.50%           | 1                     | 0.96 k                           | 0.296                              | 0.296                                        | 0.40 k          | 0                                    | 5.80%          | F19 (hydropower)                     | 0.56                             |
| 0                                | 8.30%           | 2                     | 0.96 k                           | 0.296                              | 0.296                                        | 0.40 k          | 0                                    | 5.80%          | F20 (wind power)                     | 0.56                             |

**FIGURE 9** Comprehensive scoring results of renewable energy sales companies
In this case, the delisting node randomly selects a listing node for trading. Here, the electricity purchasing node has only a 1% probability that it trades with the best selling node. When a delisting node faces a large number of choices, it is more difficult to select the best node if the smart contract is not called. Therefore, this comparison shows that the smart contract of comprehensive evaluation is crucial for delisting the selection of delisting nodes on the platform and verifies the effectiveness of the method designed in this study.

6 | CONCLUSIONS

With the rapid development of renewable energy, the participation of diversified market players in competition has become a new trend in the development of energy trading in China. The distributed electricity market trading platform based on blockchain technology makes full use of the advantages of blockchain technology and adopts a listing transaction mode to meet the needs of large-scale renewable energy transactions. As the electricity delisting nodes of the trading platform face a large number of choices when delisting, it is difficult to determine the best delisting plan. On this basis, this study proposes a search engine for delisting nodes, wherein the delisting node can call the corresponding smart contract according to its own needs to obtain the best delisting strategy, thereby guaranteeing the intelligence of the delisting plan selection and providing transaction convenience. Finally, this study verified the effectiveness of the comprehensive evaluation model of listing nodes using the comparative example analysis.

The method designed in this study are worthy of in-depth exploration, and some technologies are not yet mature. Possible future research directions include the following: 1. Modifying and improving indicators with the development and progress of society. As the fields of energy and electricity are constantly developing, the delisting factors affect electricity purchasing and selling nodes change accordingly, requiring the set of indicators to be improved and expanded. 2. Increasing the timeliness of data updates. The data sources of the indicators are more complicated, and the data related to the indicators are derived from platforms, credit bureaus, and transaction nodes. A data update requires cooperation between the platform and various departments. Therefore, the follow-up research is necessary to ensure the timeliness of data updates.

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