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Research on Microgrid Power Direct Transaction Behavior Based on Blockchain

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Abstract:Because data mining has a good processing capacity for data, the clustering analysis of the historical data which is direct transactions of microgrid power provides a reliable technical support. In order to solve the problem of the imbalance between the power demand of users and the power supply of the grid in the direct transaction of microgrid power, an algorithm based on spectral clustering combined with empirical rules is proposed in this paper. The historical data (such as electricity energy, quotation submission time, and transaction price) between users and power suppliers who complete transaction settlement through the blockchain is used for clustering analysis by this method. By analyzing the clustering results, a reliable adjustment scheme to control the balance of supply and demand in microgrid power market is obtained. Through simulation experiments, the feasibility of the direct power trading model based on blockchain and the effectiveness of the algorithm based on spectral clustering combined with empirical rules are verified, so as to obtain the variation law of electricity demand and electricity price in different time periods.

1. Introduction

With the promotion of power marketization reform, microgrid is allowed to participate in power market transactions as the main seller [1]. However, because the output of the microgrid cannot meet the user's load demand in time, transient power gap, power interruption, and the imbalance between supply and demand are caused.

A microgrid power trading model based on blockchain and dual auction mechanism is proposed in [1]. The main research content and progress of blockchain technology from the perspective of P2P protocol, consensus algorithm and intelligent contract are described in [2]. A new trading framework for the existing problems in the current energy market is proposed in [3]. The framework is based on blockchain technology in distributed power market, which includes pricing method and power trading system architecture.

At present, for the behavior analysis of data, the clustering method is mostly used. An algorithm for identifying frequent behaviors based on time granularity is proposed in [4]. A new dynamic clustering method for electricity consumption behavior is proposed in [5]. This method uses the CFSFDP to obtain the typical dynamics of consumption behavior. The four spectral clustering algorithms of k-means, fuzzy c-means, self-organizing mapping and weighted kernel principal component analysis is compared through experiments in [6]. It is concluded that the application of spectral clustering algorithm is better.

Aiming at the problem of imbalance between supply and demand in the microgrid, a research scheme on the behavior of direct trading for the microgrid electricity based on blockchain is proposed.This scheme uses the algorithm of spectral clustering combined with empirical rules to conduct behavior analysis on historical transaction data.By comparing the literature [4] [5] [6] [7], it can be concluded that the spectral clustering combined with empirical rule is simpler and faster than the traditional spectral clustering algorithm.

2. Related Technologies

2.1. Blockchain Technology

The data structure of the blockchain is mainly divided into two parts, namely the block header and the block body[8]. From a data perspective, blockchain is a distributed database that is almost impossible to change. The "distributed" here is not only reflected in the distributed storage of data, but also in the distributed records of data [9]. As a distributed database and decentralized P2P peer-to-peer network, blockchain has the characteristics of smart contract, distributed decision, collaborative autonomy, tamper-proof high security and transparency [10]. In the microgrid, power purchasers and DGs complete transaction matching through the principle of continuous double auctions.

2.2. Cluster analysis

Cluster analysis technology is an unsupervised learning technology, which is divided into clustering algorithms based on partition, density, and hierarchy according to the different clustering ideas. Among the clustering algorithms based on partitioning, the k-means algorithm is faster and easier to implement than other clustering algorithms [11]. The first step in spectral clustering is to construct a symmetric similarity matrix from a dataset sample. Then get the eigenvalues of the Laplace matrix. Finally, traditional clustering methods such as k-means are used to cluster the eigenvalue components [12]. The algorithm can be basically divided into three main steps: (a) Data preparation; (b) Solve the matrix; (c) Use k-means or other classic clustering algorithms to cluster feature vectors in the feature vector space.

3. Design

3.1. Microgrid Electricity Direct Transaction Model Based On Blockchain

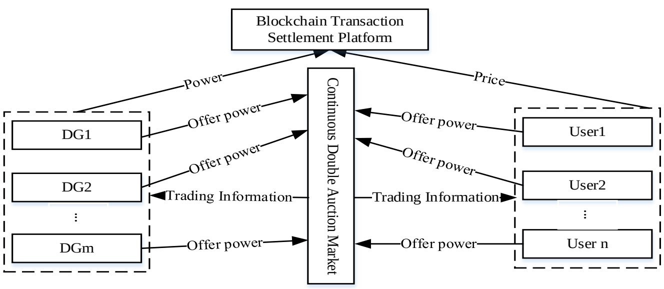


Figure 1: Microgrid electricity direct transaction architecture.

There are multiple DG and users in the microgrid. The two parties of the transaction match electricity and price through the continuous double auction market, and settle the transaction through the blockchain. The transaction architecture is shown in Figure 1. In each trading cycle, DG and users submit quotations and electricity to the continuous double auction market respectively, and the market automatically matches according to the quotations of both parties. The unmatched DG and the user adjust the quote according to a certain quote strategy through the agent system. The matching DG transfers the digital power certification to the user through the blockchain, and the user transfers the power purchase fee to the DG through the blockchain. After each node in the entire network confirms, the transaction between the buyer and the seller is successful.

The blockchain transaction process can be roughly divided into the following 5 steps:

Figure 2: Blockchain transaction flow chart.

It can be seen from figure 2 that the transaction application is an application to send a transaction to the blockchain. Network-wide broadcasting is an announcement to the entire network. Transaction verification is the verification of each block to ensure the security of the transaction. The approval is a full staff review to complete the transaction verification. The final transaction is completed, that is, accounting is completed.

In the whole network broadcast stage, when the transactions are matched in accordance with the principle of continuous double auction. When the match is unsuccessful, an adaptive aggressive strategy is used to adjust the quote. The specific process is as follows:

- Competitive equilibrium price estimation;
- Aggressive model;
- Adaptive learning process;
- Quotation Strategy;
- Balance mechanism.

Blockchain technology and continuous double auctions are used to complete microgrid power transactions in this paper. Then use the historical data of the transaction to conduct behavior analysis in the next section to improve the imbalance between supply and demand in the microgrid power market.

3.2. Design And Implementation Of Spectral Clustering Algorithm

Analyze the transaction behavior of the two parties in the transaction, that is, the change in the amount of electricity energy, transaction price, and time of the transaction between the DG and the user. Then use the spectral clustering algorithm to cluster historical transaction data. The clustering process and algorithm are as follows:

- Preprocessing of raw data. In the formula, Z^* is the index value after standardized processing; Z_{min} is the minimum value of the index data; Z_{max} is the maximum value of the index data.

$$Z^* = (Z - Z_{min})/(Z_{max} - Z_{min}) \quad (1)$$

- Constructing a similarity matrix. Where w_{ij} is the element in matrix W, S_i is the i-th row vector of matrix S, S_j is the j-th row vector of matrix S, W is an n*n matrix, and n is the number of records in 24 time periods.

$$w_{ij}=\begin{cases}0 & i=j\\ \sqrt{\left(S_i-S_j\right)\left(S_i-S_j\right)^T} & i\neq j\end{cases} \tag{2}$$

- Degree matrix.

$$D=\begin{cases}\sum_{i=1,j=1}^{n} w_{ij} & i=j\\ 0 & i\neq j\end{cases} \tag{3}$$

- Laplace matrix $L=D-W$. The normalized Laplace matrix is $L_n=D^{-1/2}LD^{-1/2}$.
- Determine the number of clusters k. On the basis of the empirical rule $k\leq\sqrt{n}$, the value of k with the largest difference in relative eigenvalues is taken as the number of clusters. Among them, the eigenvalues and eigenvectors are λ and x, and the difference in the relative eigenvalue is $\Delta\lambda_k$.

$$Lx=\lambda x,\quad \Delta\lambda_k=\left(\lambda_{k+1}-\lambda_k\right)/\lambda_k \quad k\geq 2 \tag{4}$$

- Clustering with k-means algorithm. The feature vector x corresponding to the first k eigenvalues of L is selected to form a new data feature space $X=[x_1,x_2,\ldots,x_k]$ of k×n.

4. Example Analysis

This paper selects a set of DG data and actual load data as an example.This data involves 6 DG (including 2 wind power and 4 PV), represented by PV1, PV2, PV3, PV4, WP1 and WP2, and 5 users represented by LD1, LD2, LD3, LD4 and LD5.

4.1. Algorithm Analysis Of Direct Transaction Of Microgrid Electricity Based On Blockchain

According to the trading strategy mentioned in Section 3.1, the following experiments were performed using MATLAB simulation analysis to verify the feasibility of the trading model.

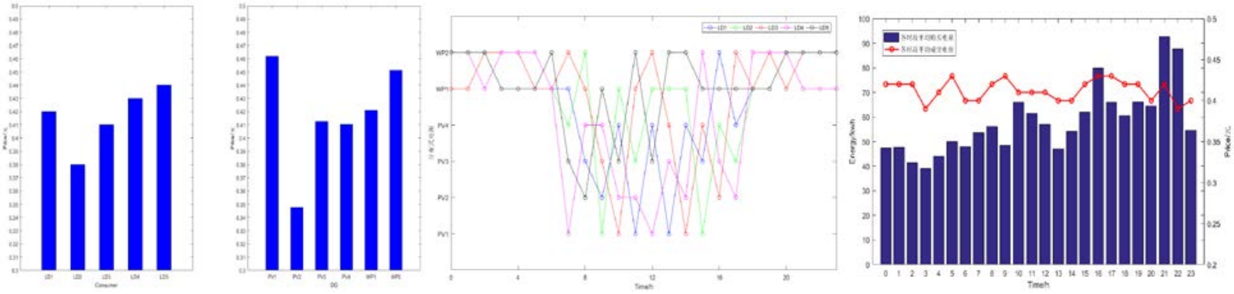


Figure 3: Quotes from both parties in the transaction at 8 am and 24-hour trading situation and average trading power and electricity prices in the microgrid electricity trading market.

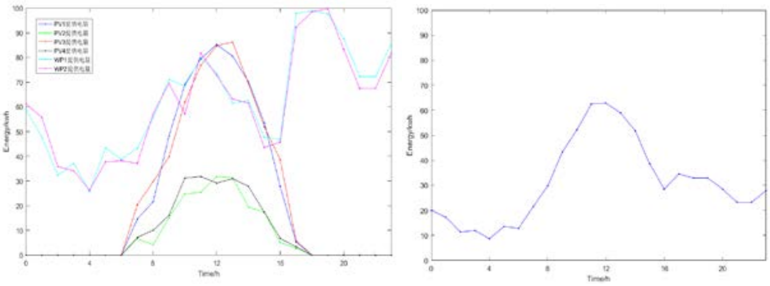
It can be seen from the figure that during this period, the user's optimal buying price is 0.44 yuan, and the optimal selling price of DG is close to 0.35 yuan. According to the principle of continuous double auction, this round of transactions is (LD5, PV2), (LD4, PV4), (LD1, PV3). At this time, the optimal bid price of 0.41 yuan for the user is less than the optimal sell price of 0.42 yuan for the DG, and then the adaptive aggressive strategy is used to complete the next two rounds of transactions (LD3, WP1), (LD2, WP2). What’s more, there are still some periods when the price of electricity and the corresponding demand for electricity are unreasonable. The next section will propose a reasonable adjustment plan for electricity prices and demand of electricity for this situation.

4.2. Cluster Analysis Of Transaction History Data

Table 1: 24 hours for electricity purchasers.

Time	LD1 (kWh)	LD2 (kWh)	LD3 (kWh)	LD4 (kWh)	LD5 (kWh)	Time	LD1 (kWh)	LD2 (kWh)	LD3 (kWh)	LD4 (kWh)	LD5 (kWh)
0	94.30	60.20	37.80	21.83	22.50	12	169.81	38.38	43.94	16.50	16.50
1	90.70	51.70	37.30	33.25	25.20	13	133.30	39.45	35.23	12.75	14.50
2	85.80	47.70	35.60	19.50	18.00	14	171.97	39.18	33.99	11.00	14.40
3	83.80	39.90	41.70	15.42	14.40	15	216.81	38.80	25.53	14.33	14.20
4	85.20	39.80	41.50	39.50	14.40	16	292.56	30.54	27.58	25.67	22.90
5	88.90	40.80	46.60	51.58	21.90	17	220.38	30.36	41.54	19.00	18.50
6	83.60	29.60	41.10	61.92	23.80	18	186.42	38.18	45.20	18.58	14.80
7	120.80	31.01	44.90	49.42	21.90	19	198.20	45.70	55.10	15.75	16.60
8	136.83	13.67	41.50	73.67	14.40	20	199.20	46.70	46.10	15.33	15.20
9	157.13	18.51	37.10	14.08	14.50	21	287.58	95.30	40.00	16.92	24.00
10	211.96	29.65	39.40	16.17	32.80	22	249.80	98.80	42.70	20.50	27.00
11	195.26	31.77	41.60	13.42	25.50	23	143.20	52.90	36.40	24.17	16.50

In order to verify the validity of the clustering results, the following experiments will be performed on the transaction history data in the previous section. Construct the Laplace matrix of Table 1, and the number of clusters k is solved. Finally, the last 3 clusters are obtained by the k-means algorithm. The experimental results are as follows.



ID	Clustering Results
1	0,1,2,3,4,18,19,20,21,22,23
2	4,5,6,7,8,9,10,11,12
3	13,14,15,16,17

Figure 4: The four groups of PV and two sets of wind power DG provide power and the DG provides power on average and clustering results

Figure 4 shows the clustering results of historical transaction data (refer to Table 1) between users and DG. Based on the analysis of the clustering results, the following schemes for adjusting electricity energy and electricity quotes are proposed in this paper. In the first period of time, the demand for electricity decreased slowly. Therefore, DG can reduce the power generation and reduce the price of electricity. So as not to cause oversupply of electricity. In the second type of 9 time periods, power demand increased significantly. Therefore, DG should increase the power generation and appropriately increase the electricity price. So as not to cause supply shortage. In the third category of 5 time periods, power demand has dropped significantly from peak periods. Therefore, DG should immediately reduce power generation. So as not to produce excessive power and cause waste. The relationship between supply and demand can be balanced by the above adjustment plan. At the same time, it can also stimulate users' purchasing behavior and increase electricity sales revenue.

5. Conclusions

Aiming at the problem of imbalance between user power demand and grid energy supply in direct trading of microgrid power, the behavioral analysis of historical data for the microgrid power trading based on blockchain is performed. According to the clustering results, the reasons for the imbalance between supply and demand in the microgrid power trading market are analyzed in different time periods, and corresponding adjustment schemes are proposed.The above experiments verify the effectiveness of the algorithm based on spectral clustering combined with empirical rules.

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