Research on Blockchain-Based Distributed Power Trading Technology

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Abstract. With the continuous promotion of the energy revolution strategy, the supply side and demand side of energy is changing dramatically, especially the large-scale access to distributed power sources such as wind turbines and photovoltaics, which brings a great impact on the operation and transaction of distribution network. Considering the characteristics of blockchain technology such as high data security, mutual trust in transactions, and programmable smart contracts, the article first constructs a blockchain-based distributed power trading system architecture from six layers: data layer, network layer, consensus layer, incentive layer, contract layer, and application layer; Secondly, proposes a distributed power peer-to-peer trading mechanism and simulates power trading in a distribution grid trading scenario with a large number of distributed power accesses. Finally, the test proves that the above mechanism can play a role in improving economic efficiency and transaction security.

Keywords: Distributed Energy Trading · Blockchain · Decentralized Architecture

1 Introduction

Since distributed power generation is characterized by randomness and volatility and is susceptible to environmental influences, it is prone to the problem of imbalance on the supply and demand side of energy. Blockchain technology, with its characteristics of decentralization and data immutability, can break the trust barrier and increase the participation of distributed power supply. The power generated by distributed power sources is transmitted to integrated energy service providers and power purchase users through distribution networks, while integrated energy service providers can also sell the stored power to users who cannot participate in peer-to-peer (P2P) transactions, realizing extensive interaction between distributed power sources and users at all levels and improving the level of distributed power consumption.

Blockchain can meet many needs of distributed applications, and thus can be used as the underlying technology to support a variety of distributed energy trading systems.

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Analyzing blockchain algorithms based on blockchain technology architecture and clarifying the future application methods and positioning of blockchain in distributed power trading will help the future application of blockchain technology in the field of power trading [1]. By introducing smart contracts into the pricing model, guiding energy trading mechanisms, and monitoring and recording all energy transactions, it can effectively facilitate energy sharing among customers within the microgrid, and an overall increase in the energy efficiency of the distribution network [2]. A real-time P2P energy trading approach helps maximize benefits and is feasible using blockchain technology to enable this energy trading approach [3].

2 Blockchain-Based Distributed Power Trading System Architecture

Establish the framework of distributed power trading system based on the mainstream architecture of blockchain technology. This paper elaborates on the mainstream architecture of blockchain technology. The architecture usually includes six layers: data layer, network layer, consensus layer, incentive layer, contract layer, and application layer [4], as shown in Fig. 1.

(1) Data Layer
The data layer is located at the lowest level of the entire architecture, responsible for storing the transaction data received over a while into the data block being created, then encapsulating the transaction data stored in the block through a specific hash function and Merkle tree data structure, and generating a new block with a timestamp that conforms to the algorithmic agreement with the assistance of the upper layer protocol, and then linking it to the main chain through the corresponding consensus

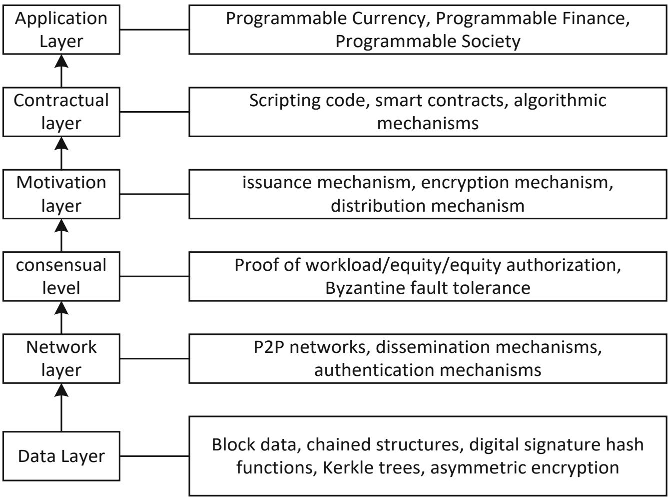

Fig. 1. Blockchain technology architecture

mechanism on the main chain through the corresponding consensus mechanism. To ensure the reliability and stability of data in the blockchain-distributed ledger.

(2) Network layer

The blockchain network layer adopts the P2P (peer-to-peer network) networking method of completely decentralized data storage without any authoritative node control or hierarchical model constraints.P2P networks in blockchain systems have unique application advantages in terms of networking structure and communication mechanism: in terms of networking, each node is both a resource provider and a resource user, and each node has equal status in the network, which is exactly what block In terms of communication mechanism.

(3) Consensual level

The consensus layer quickly reaches consensus on the validity of transactions and data in a decentralized storage data system involving highly decentralized nodes with the help of relevant consensus mechanisms to ensure the consistency and validity of bookkeeping of all nodes in the whole system.

(4) Motivation layer

The incentive layer mainly stimulates each node in the network to participate in the generation (mining) and verification of new blocks in the blockchain by providing an incentive mechanism to ensure the safe, efficient and stable operation of the decentralized storage data blockchain system. The incentive layer and the consensus layer operate with the same mechanism.

(5) Contractual layer

Smart contracts are protocols deployed on the blockchain that use computer programs to implement the content and execution process of daily contract terms. There is a set of Turing-complete programming languages built into Ether, and users can write complex smart contracts on the Ether platform according to their needs to realize various applications of decentralized stored data. With the application of smart contracts, blockchain technology is no longer limited to Bitcoin applications but has become a pervasive underlying technology framework.

(6) Application Layer

Blockchain technology is most maturely applied in public chains, it also supports various kinds of the decentralized application (DApp) with the powerful functions of smart contracts in response to the current situation of "everything is Web". The federated chain reflects the diversity and richness of blockchain application value, enhances the breadth and depth of blockchain applications, and can enable blockchain technology to take root to the maximum extent.

3 Distributed Power Peer-To-Peer Trading Mechanism

Since distributed power has the characteristics of randomness and volatility, traditional centralized trading requires huge costs to establish trust among different users, and there is also the problem of security of trading data because the trading data is held by centralized institutions. In the process of power trading on the grid, smart contracts help to achieve de-trusting and automation [5]. Therefore, this paper designs a distributed power security trading model based on smart contracts, which optimizes the transaction

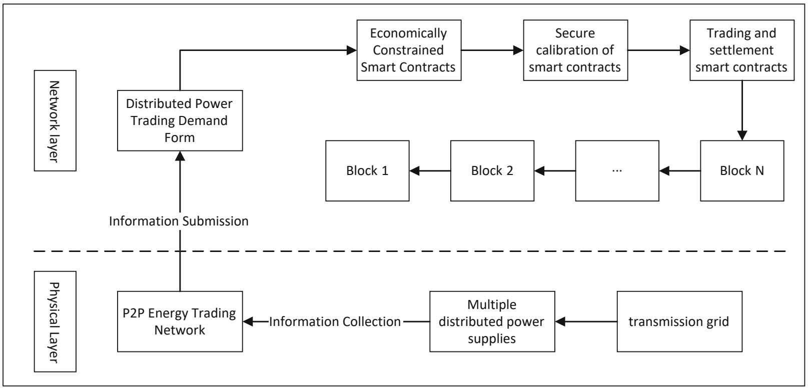

Fig. 2. Distributed Power Trading Process

settlement mechanism. The whole process is divided into two parts (see Fig. 2). Firstly, users post the transaction information to the blockchain trading system through the P2P energy trading network, then the system verifies the economy and grid load security through the load verification smart contract and the economy constraint smart contract, and finally, users who determine the transaction intention complete the power transaction through the transaction settlement smart contract. The model realizes the whole process of tracking power transaction data and ensures the security of data. The transaction process is automated and executed based on smart contracts, reducing transaction costs.

3.1 Optimization Strategies for P2P Energy Trading Networks

This paper constructs a P2P energy trading network based on the Bloom filter, connecting each block node, allowing users to submit their energy demand or remaining power information in real-time, and building an information flow network between users to achieve effective interoperability of information between producers and consumers, to apply the demand of low memory and low energy consumption of multi-energy network end nodes.

$$m = -\frac{n \ln p}{(\ln 2)^2} \tag{1}$$

$$k = \frac{m}{n} \ln 2 \tag{2}$$

where: m is the Bloom filter length; n is the number of inserted elements; p is the false alarm rate; k is the number of hash functions.

Based on the data structure of distributed power transaction data, this model selects suitable parameters, designs a data type-aware mechanism, constructs a Bloom filter to filter invalid information, improves data query and insertion efficiency of P2P energy information network, reduces disk IO and network requests, lowers data transmission pressure, and realizes adaptive recognition of transaction data by energy blockchain network nodes.

3.2 Smart Contract Based Distributed Power Trading Mechanism

This paper designs a distributed power trading mechanism based on smart contracts, which utilizes the automated execution of smart contracts and automatically records data into the blockchain through smart contracts under the Merkle tree data structure to realize the de-trusting of transactions and enhance the security of data.

The model smart contract is divided into 3 parts, which realize the smart contract templating and componentization, making it easy to use even for users who do not have programming ability. The flow of smart contract-based transactions is shown in Fig. 3. First, the load calibration smart contract collects distribution network information. After the information is collected, it is first calibrated in the security calibration smart contract. Then, based on the pre-set algorithm, the economic constraint smart contract constrains the users of production and consumption according to the load status of transmission and distribution network and local energy consumption at that time, and only those users who meet the economic constraint can participate in the transaction and determine the transaction price. Finally, the cost settlement smart contract automatically records the transaction data into the Merkle tree data structure, completing the market settlement and value transfer between producers and consumers, and thus completing the electricity transaction. The whole operation process is verifiable, and traceable, and adjusts energy supply and demand from the demand side.

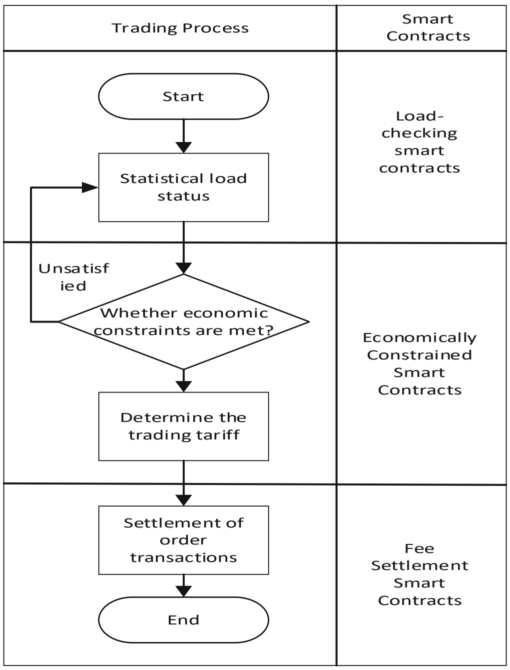

Fig. 3. Smart contract-based trading process

4 Example Analysis

The algorithm simulates a power trading simulation test in a micro-distribution network trading scenario with a large number of distributed power sources connected. First, each distributed power supply node publishes the transaction request information containing power and time quotes for that period before the transaction moment arrives. Secondly, through the optimized P2P energy trading network, the transaction request information of distributed power sources is published to the blockchain system for power trading, security checks are performed, the market is settled using smart contracts, and the settlement result information is shown in Table 1.

Further analysis of the transaction data, assuming that Case 1 is an energy transaction based on a traditional centralized exchange, and Case 2 is an energy transaction using a blockchain-based method in this paper, the transaction data of producers and consumers in the system are modeled and analyzed, and the results are shown in Table 2 for simulation tests under the two cases. The experimental results prove that the adoption of blockchain-based transaction method reduces the cost of electricity purchase by users, improves the revenue of electricity sales users, and enhances the overall revenue of producers and consumers.

Table 1. Market Settlement Information

Both sides of the transaction	Amount of electricity /(kW·h)	Electricity price/10^{-6}eth·(kW·h)$^{-1}$
Main Network -650	12.69	873.45
Main Network -680	6.33	615.34

Table 2. Simulation results for two scenarios

Indicators	Situation 1	Situation 2
Average revenue of electricity sales customers /10–6eth	5 780.65	7 162.59
The average cost of electricity purchasers /10–6eth	3 895.56	2 986.43
Average total relative earnings of producers and consumers /10–6eth	1 885.09	4 176.15
Comparison of Distributed Electricity Consumption	63.26%	86.37%
Transaction Data Security	Centralized storage method, vulnerable to attacks	Distributed storage method with high security

5 Conclusions

This paper proposes a distributed power trading technology based on blockchain. Firstly, the mainstream architecture of blockchain technology is analyzed and described in detail; secondly, a P2P energy trading network is constructed to transfer information flow among users and realize effective interoperability of information of producers and consumers, to apply the demand of low memory and low energy consumption of terminal nodes of the multi-energy network; finally, by deploying smart contracts, a distributed power trading model applicable to the participation of multiple parties such as distributed power supply, integrated energy service providers and users is proposed. Finally, by deploying smart contracts, we propose a distributed power trading model that applies to multiple parties such as distributed power sources, integrated energy service providers, and users to ensure accurate and efficient execution of distributed power trading. The simulation results show that the model can improve the economic efficiency of power and the participation of distributed power supply, and ensure safe and efficient power trading.

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