Residential PV Multilateral Trading Platform Based on Blockchain

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***Abstract*—With the continuous advancement of the energy supply side reform, the State Grid proposed a "ubiquitous power Internet of Things" development plan, and the digitalization of energy entered the fast lane.Based on the new era of users and energy needs of the Internet, in line with the development trend, this paper designs a blockchain-based household PV multilateral trading platform, and describes the process of the entire program. The program uses the latest environment and tools to develop applications. Tests have shown that the system works well and achieves the desired results. Through the trading platform, users in the community can conduct real-time energy trading, utilize the power generated by photovoltaic products, promote the promotion of new energy and lay the foundation for the application of blockchain technology. (*Abstract*)**

Keywords—Blockchain,Ubiquitous power internet,photovoltaic power generation,multilateral trading platform,smart contract(*key words*)

I. INTRODUCTION

With the rapid depletion of traditional fossil fuels, the global environmental crisis has increased and sustainable development has become the theme of today. Among the new energy sources with clean and renewable characteristics, the largest quantity is solar energy[1]. Photovoltaic power generation can effectively alleviate global energy shortages and environmental pollution[2], but it has strong intermittent and volatility[3], and the power system is subject to huge impacts and challenges[4-5]. At the same time, new-generation communication technologies such as "big cloud object shifting chain" have accelerated penetration into various industries[6], and the integration of traditional power industry has become a trend[7]. The real-time power market platform is an important way and method for the realization of source-network-load interaction balance in the new generation of power systems[8], and energy sharing can also effectively improve resource utilization and economic development[9]. However, the establishment of a management mechanism with intermediate operators is costly, vulnerable, and user privacy is difficult to guarantee[10]. Therefore, this paper proposes the use of blockchain technology to establish a decentralized trust management mechanism to complete the design of the multilateral trading platform for household photovoltaic residual energy.

Foreign blockchain and traditional power integration have entered the application stage[11]: Vattenfall Energy of the Netherlands launched the Power Peers platform to meet the needs of distributed applications for power consumers; LO3Eenergy of the United States also launched the Trans Active Grid project, establishing a global The first interactive distributed PV sales platform; We Power's blockchain, launched in 2018, issued the cryptocurrency We Power to allow neighbors to trade solar surplus power. However, domestic related applications have not yet been implemented. China's distribution system distributed power penetration is increasing[12], the photovoltaic user group[13-14] has grown, and a large number of producers and accessors are bound to form direct free trade of electricity[15]. This platform is an inevitable outcome of the era and a powerful solution to solve the biggest hidden danger network security problem of the power Internet of Things[16].

II. BLOCKCHAIN

Blockchain is a shared database, which is a cryptographic principle based distributed P2P network shared trustbook technology[17], which is a new application mode of computer technology such as distributed data storage, point-to-point transmission, consensus mechanism and encryption algorithm[18]。

At first the blockchain was the underlying technology of Bitcoin[19]. The blockchain is divided into three categories: the public chain, the alliance chain and the private chain, and the three are successively decreasing in terms of openness. At present, from the perspective of Ethereum platform application, Bitcoin application belongs to blockchain 1.0, Ethereum smart contract design belongs to blockchain 2.0, and industrial applications (finance, energy, copyright management, etc.) belong to blockchain 3.0[20] . Blockchain technology can be said to be "second-generation Internet", which is reflected in four aspects: after the birth of 2009, we first pushed us from the information Internet to the value Internet; and prompted human society to move from the consumer Internet to the industrial Internet, the industrial Internet. The Internet of Things is still not mature enough, but the blockchain may promote the maturity of this technology. Third, it will move from the existing completely transparent open Internet to the "encrypted Internet" stage; finally, the Internet will move from the central Internet. Distributed Internet.

The core technologies of the blockchain are summarized as follows:

①Asymmetric encryption algorithm, that is, generating a public key and a private key at the same time, and only the corresponding public key and private key can decrypt the information.②Based on the asset database, it can share and interact data on different nodes, locations and platforms. Each node can have identical copies of data.③The use of smart contracts, while reducing costs, can also prevent unilateral breach of contract, to ensure that the entire system code operates according to regulations[21].

Therefore, it has an inherent advantage in the development of distributed energy trading and transaction subject credit management[12].

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III. BASIC FRAMEWORK OF HOUSEHOLD MULTILATERAL TRADING PLATFORM

A. Platform overall design architecture

This paper designs a blockchain-based household PV multilateral trading platform. The platform structure is divided into five levels: data layer, network layer, incent ive layer, consensus layer and smart contract.

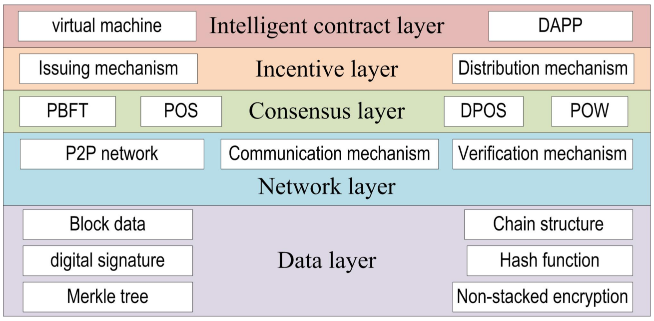

Fig.1. Blockchain platform basic framework

According to the characteristics of the power grid system, this paper classifies the household PV multilateral trading platform as a special public chain (the power company is a special node). When the energy storage technology is mature, it can develop into a formal public chain. Its user base includes power companies, general users, and users who install photovoltaic power plants. It uses a chain of increasing time axis as a storage structure. The chain contains highly dense blocks. The block consists of a block header and a block body. The structure is shown in Figure2:

Version 4 bytes	Prev Block Hash 32 bytes	Merkle Root 32 bytes	Time 4bytes	difficulty Target 4 bytes
numTransactionsBytes 1 byte		numTransactions 0~8 bytes		transactions

Fig.2. Block structure

The hash value of the previous block before the block header is linked, and the block body mainly includes the body information of the transactions between the nodes, thereby forming a chain structure. It exists in multiple copies on a peer-to-peer network and can only be appended to the general ledger database.

B. Design of trading model

First, each producer user, each pure consumer user, and the power company correspond to nodes in a blockchain network. Considering the speciality of electric energy as a commodity, in order to ensure the unified planning and operation of transmission and distribution, the power grid terminal is a special node to provide, transport and store electric energy for users. Each node corresponds to an account, and all user account applications are controlled by the grid but the asset information is not subject to the grid. Although there is a management center, in the transaction, the blockchain technology still guarantees the decentralization of the transaction. That is, the transactions between each user are not managed by the grid nodes, and the transactions between the nodes are equal, and there is no need to worry about other node users or grid companies tampering with their own energy assets. It still has the characteristics of a public chain.

Second, the transaction completes the transfer of assets through the blockchain smart contract, which is divided into active trading and trigger trading. The active transaction is the power purchase behavior initiated by the user; the initiation of the triggered transaction is determined by the energy meter, and when the measurement reaches the set current value, the execution of the contract content is triggered. All networks share a smart contract. As shown in FIG. 3, the red thick arrow represents physical layer transmission, that is, transmission and distribution, and the solid arrow and the dotted single arrow indicate data stream transmission, that is, user node information exchange (purchasing assets, transferring assets). The self-sufficient power consumption of PV producers is not included in the asset consumption of the blockchain account. The excess power is delivered to the grid or other users. The power station transfers the corresponding amount of assets to the user account. When the user account assets are zero, the power station no longer supplies power to the user. Users need to purchase electricity from a power company or other consumer.

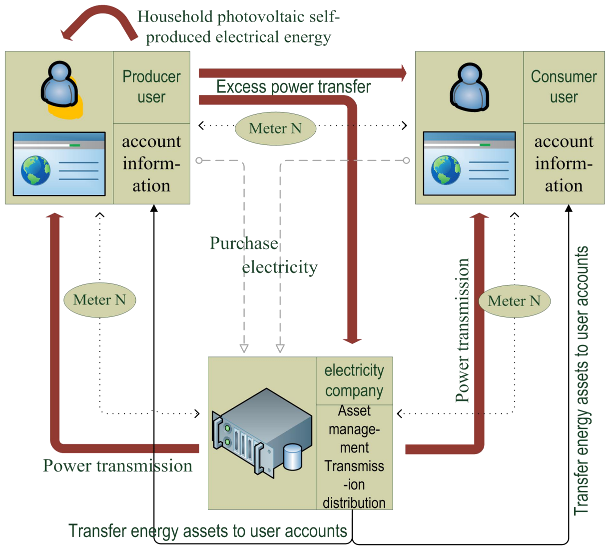

Fig.3. Trading process

The transaction is initiated by the client and certified by digital signature. The transaction is sent to the node in the blockchain system and waits for the transaction information to be verified. After the completion of the confirmation, the next block will record the relevant data. Then all nodes use the consensus algorithm to consensus on the new block. After the consensus is completed, the area is written. Blockchain, indicating that all nodes agree with the new block. The trading principle of the household PV multilateral trading platform is shown in Figure 4.

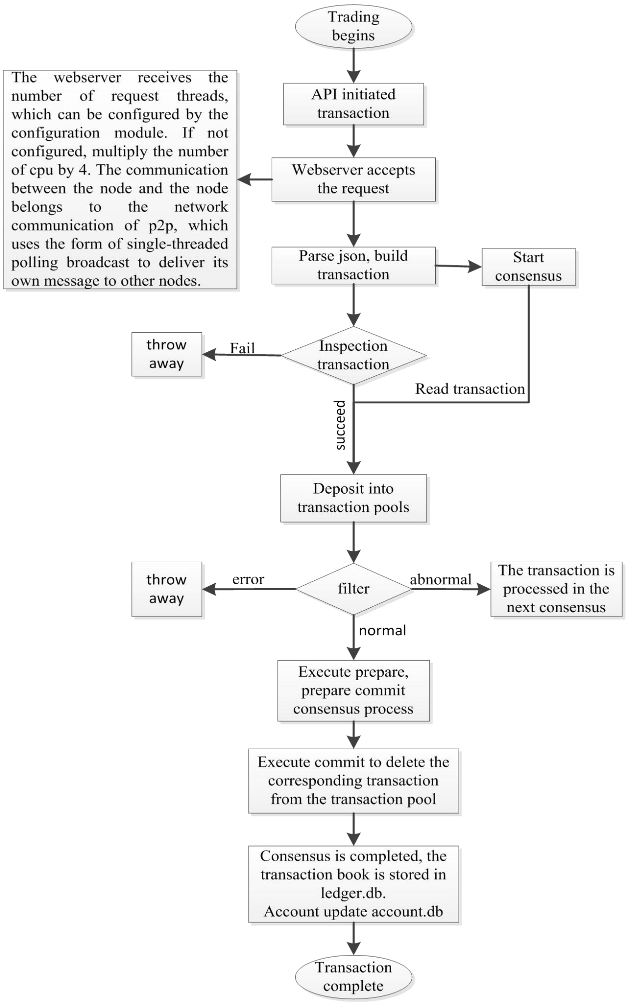

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Fig..4. Analysis of trading principles

There are two verification procedures in the process of completing the transaction. One is that before being deposited in the transaction pool, the verification step is divided into three parts: whether the nonce is legal, the operation type check parameter, and whether the transaction pool is full. Successfully verified data can be stored in the trading pool. The second is before the implementation of the consensus. Abnormal and incorrect transactions need to be filtered out. Consensus transaction number (32M) and nonce too large are abnormal cases; and nonce is too small to be an error, only normal can continue to execute. These two steps will effectively protect the security and stability of the transaction against attacks.

IV. MODULE DESIGN

The platform is built in the mainstream operating system Ubantu, and the program composition is shown in Figure 5.

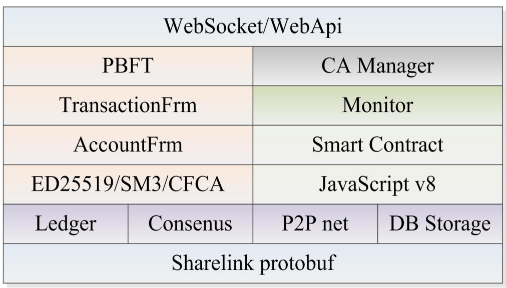

Fig.5. Platform module architecture

A. CA contract user account

In the decentralized blockchain trading platform, the accounts used by the users need to be embedded with smart contracts, ie contract users. Accounts are divided into creation account, grid account and general user account. The grid account creates a user account and the grid account is created by the creation account. The creation account is the first account of the blockchain platform. Its information is configured in the config file and can be viewed through the API interface.

The grid has the same account attributes as other users. When creating a user account, you need to specify the user account permissions, and set the user account to not have the rights to issue assets. Tx_threshold | optional, default 0, which represents the minimum privilege of the account, the transfer asset type is 1, and the threshold is set to less than this value. Creating a User Account for a Grid Account is the same as creating a Grid Account for a Genesis Account. Modify the source address and set the user account permissions created. A transaction of type 2 is an issue asset, and a threshold less than tx_threshold has no execute permission.

B. Network communication module

Because the power company and all users in the multilateral trading platform, whether or not installed photovoltaic power generation equipment, are the providers and acquirers of resources, services and content, share some of the hardware resources they own. The system uses p2p as the network structure for running dependencies, so that the co-energy can be directly accessed by other Peers. The entire network does not rely on dedicated centralized servers or dedicated workstations.

C. Data storage module

The data storage of the data layer is mainly based on the Merkle tree. It is implemented by the block mode and the chain structure, and most of them are implemented in the form of KV database. The account data is in account.db; the storage consensus data is stored in keyvalue.db; the block data is stored in ledger.db.

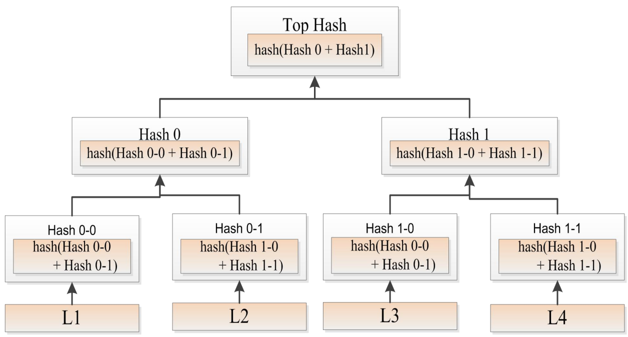

Fig.6. Data storage principle

The Merkle Hash Tree is a hash tree or a check tree. The leaf node is the hash value of each data block, and the parent node is the leaf node hash value serially obtained in the hash.

D. Smart contract

A smart contract is a piece of code that triggers a run when a user initiates a transaction or an energy meter reaches a set value. It is implemented using a javascript v8 engine whose execution relies on transferring asset operations.

Encryption and consensus have the function of maintaining network security and effectively resisting hacker attacks. Each account initiates a transaction and the transaction is successful, with the value of nonce plus one. Nonce can prevent hacking and transaction forgery. Blockchain security is based on encryption algorithms and bookkeeping consensus. A transaction requires multiple verifications and 2/3 nodes in the blockchain to take effect. The underlying data merkle tree is a 16-fork tree, and prefixes are added to different nodes, which enhances the encryption strength and ensures the network operation security of the system. The consensus has a maximum fault tolerance of 33% and a minimum of 4 nodes. The account security consensus for ensuring blockchain security is shown in Figure 6.

Fig.7. Account security consensus

E. *Log and configuration module*

The configuration file runs through the entire system. It is divided into the following six parts, and the log information of the corresponding level is output.

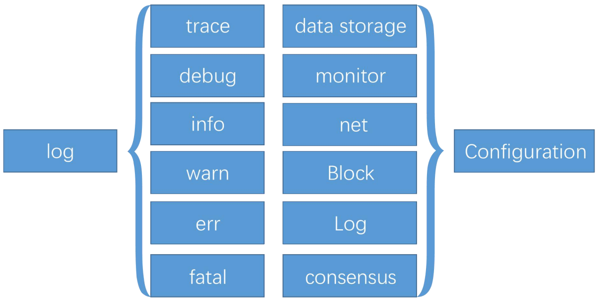

Fig8. Log and configuration module

V. LINUX-BASED TRANSACTION FLOW IMPLEMENTATION

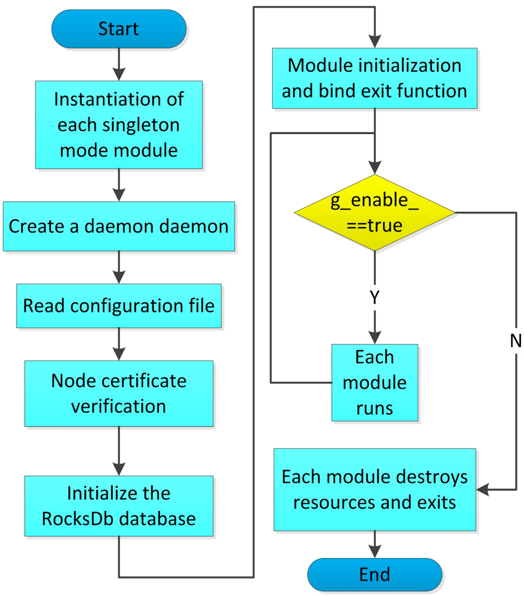

Fig.9. Share_link initialization

Energy trading is the main part and central link of the blockchain platform. The winding up of each transaction consists of three steps in the bottom layer: creating a transaction, trading a signature, and submitting a transaction. Only the submit transaction returns "success_count" : 1 to indicate that the transaction was executed successfully. The underlying code operation and signature, and the running results are shown in the appendix.

The grid user receives the power of the power plant and the household photovoltaic power source to become the total assets of the account, and the asset amount varies with the actual possession value. However, in this experiment, when the power grid is set to 10,000,000 kWh, the energy assets of each user are 0 when the power is not purchased or the power is generated, and the energy meter N is set to 100. The grid account can monitor the assets of each user in real time, but can not change the asset value of its supervised users. Only the operation of triggering the smart contract can change the asset status.

Fig.10. Grid account interface

Therefore, the initial interface is shown in Figures 18, 19 and 20. The code "a0020a52c701ebf5b7170291b89cf0624b0c6c5681e659" consisting of letters and numbers in the upper left corner of the interface is the account address of the power company. "a002795729493b1e8834c4ec269b2182eaf5d41dc0627a" and "a0029a42e5518bea59c200dab0 73bda4670b617351cb55" in Figs. 19 and 20 are the user's account address.

Fig.11. Consumer interface

Fig.12. Production consumer account interface

The account address is obtained by the address prefix (1 byte), encryption type (1 byte), digest algorithm (SHA-256), and the value obtained by removing the first 12 bits of the public key hash. Hash again to get a new hash, add Crc8 or Crc16. The checksum (1 byte) obtained by the new hash is composed of four parts. The account address is equivalent to a client node. When registering, the user is authenticated by real name, and the account name is the name of the head of the household. If there is any change, it can be changed and set.

At this time, the household photovoltaic power generation has not reached the set value of 100, and the contract execution cannot be triggered.

Fig.13. Consumer purchase interface

First, the consumer initiates a power purchase transaction, triggers a smart contract, and the account recharges 1,000 kWh of assets.

Fig.14. Asset transfer interface

Secondly, as time progresses, the PV continues to generate electricity, reaches the set value of the energy meter, and triggers the smart contract to perform the transfer of asset operations.

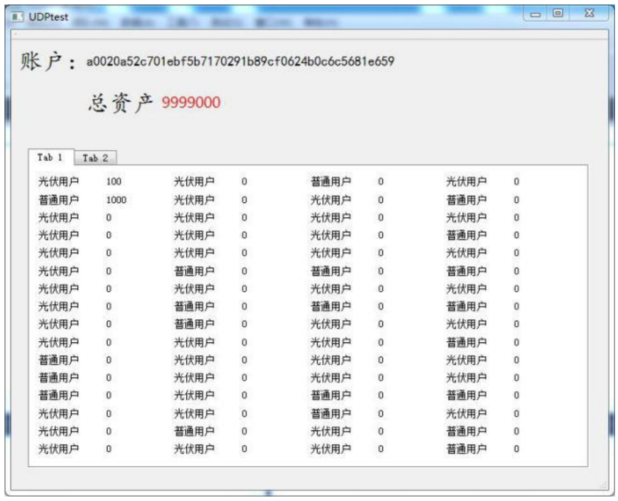

Fig.15. Power grid monitoring interface

Finally, by looking at the monitoring interface of the grid users, it can be seen that the active transaction and the trigger transaction are successful.

VI. CONCLUSIONS AND PROSPECTS

In this paper, the blockchain technology is used to build a multilateral trading platform with photovoltaic power supply installed on the user side. Although the user-friendliness of the interface needs to be improved, the code operation analysis can indicate that the trading platform is feasible and can be used for household use in the future. The PV trading platform has great reference significance and will vigorously promote the integration of new-generation communication technologies such as “Big Cloud Object Shift Chain”and the traditional power industry, and accelerate the digital transformation of energy grid enterprises.

The characteristics of blockchain technology can indeed meet the needs of future development of the PV trading platform and prevent risks. However, it must be embedded in the traditional power industry to solve the problem of household PV expansion in the future. The issue of free trade is currently facing three challenges:

First, the standards of blockchain are not uniform, and different blockchains are difficult to connect and interconnect. This split will reduce the advantages of blockchain power trading to a certain extent.

The second is the support of real laws. The legislation and supervision of digital currency and blockchain technology are not synchronized, but the development of legislation behind practice is an overall feature. At this stage, the Supreme People's Court is still in the initial stage of research on the application of new technologies such as time stamps and blockchains in the rules of evidence [23].

Third, the development of the photovoltaic industry is not yet mature, and it is necessary to follow up with supporting technologies such as energy storage.

The evolution of future blockchain technology and the further development of new energy sources will make the field of power trading a big leap in essence. The multilateral trading platform based on blockchain technology will essentially subvert the carrier form of power trading.

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