Blockchain Technology Hyperledger Framework in the Internet of Energy

Dongpo Zhang¹, Zhenyuan Zhang¹, Luan Chen¹, Shu Li¹, Qi Huang¹, Yihong Liu²

¹School of Energy Science and Engineering, University of Electronic Science and Technology of China, Chengdu, China
²China Academy of Space Technology, Beijing, China
e-mail: 751583778@qq.com

Abstract. Internet of Energy, a combination of power grid and Internet, contains many energy forms. Different form of energy is distributed in Internet of energy, which means that it is closely related to distributed technology. Different forms of energy needs to interconvert, so it is necessary to make power trading in this distributed system, the current power trading model is not adaptive to distributed power trading, so a new distributed trading model is important to Internet of energy. Blockchain technology with distribution and decentralization features is widely used in electronic currency transactions, Hyperledger-Fabric is the one of typical framework of blockchain, which could provide a platform for distributed ledger, it has distributed blocks and ledgers to make decentralized trading by using blockchain technology for Internet of energy.

1. Introduction

Energy is the foundation of social operation, the reform of Energy is driving social development [1]. Internet of energy (IOE) is a significant energy reform combining energy with Internet in the information age, which is a new energy system that deeply integrates the energy system and the Internet, where openness is the key idea and deep integration of the Internet ideas and technologies is the key feature [2]. IOE can increase the development of new energy because it is totally based on varieties of energy integration. In addition, it adapts to new energy access and improves energy efficiency [3]. IOE is different to traditional power grid in user part, the traditional power grid users in the IOE are not simple consumers, and they can also be producers when new energy and power storages are widely used [4], so IOE can provide intelligent demand response to the user side. But these above features greatly increase the complexity of the IOE, it is a distributed system with various energy forms, different form of energy need to interconvert, it also means users need make distributed trading to constitute the energy network [3], a central model can not meet the diverse needs of the IOE, Moreover, it faces challenges because existing trading model lack the method of distributed power trading, it urgently requires a operation model [4].

The blockchain is a decentralized distributed accounting technique, which is gradually becoming popular with the boom of Bitcoin, which is a special currency that relies on encryption algorithms [6]. In essence, blockchain can be understood as an open general ledger based on a computer program, it records all transactions which is occurred on blockchain system [7]. Each node in the system can update its recorded data to the network. Each of participants can copy a complete data from
blockchain container, which constitutes a decentralized distributed data to achieve the distributed trading and interaction [8].

This emerging technology can fundamentally change the trading network links, it can solve bottleneck and reduce costs and risks compared with the traditional center system. As a new-type decentralized trading technology, the blockchain is widely used in the financial field [9], and its decentralized transaction model is consistent with the IOE, the decentralized trust mechanism provided by the blockchain satisfies no third-party transaction in the IOE model, the information in the IOE will be shared for each users, this way of trading could reduce transaction costs and improves power trading efficiency and precision. The information in blockchain can not be tampered, it can ensure the accuracy of power measurement and reduce the power metering mistake[10]. However, Power trading is more complicated than financial transactions, the customers in financial field only make financial transactions by information interaction, but power trading in IOE includes information interaction, energy form conversion, power dispatching. Although blockchain technology is compatible to the distributed trading, a framework of blockchain which is compatible to the power trading is needed.

This paper discusses a blockchain framework in power trading for the Internet of Energy, analyzes the advantages of decentralized trading, moreover, this paper explains the process of hyperledger which is used to power trading for the Internet of Energy.

2. Centralized and Decentralized Power Trading

2.1. Centralized Power Trading Model

The traditional power trading model be shown in Fig. 1, power trading system as the center of the transaction, it has a high authority in the transaction structure, each unit must trust the power trading system and all transactions need to pass the center of the certification, user is a node of the center in this framework. There are some disadvantages in centralized power trading model, firstly, every user must trust this center, and this system will crash if the power trading system gets error. In addition, users are isolated in this centralized model, the transaction line must pass the power trading system if one user want make power trading which could cause wasting of time and resource.

Figure 1. Example of a centralized power trading model.

2.2. Decentralized Power Trading Model

The decentralized power trading model of the structure is shown in Fig. 2, it shows that a blockchain system with decentralized construction. Users are important part of the blockchain system rather than node of center, all trading are maintained by each user to ensure the blockchain system has the characteristics of no repudiation and decentralization. Therefore, the benefits of every user can be protected. And in this model, Transaction line can connect user to user, it is a peer to peer model to be compatible with the power trading in the internet of energy.
3. Hyperledger-Fabric and Power Trading.

3.1. Blockchain Framework in Power Trading.
Centralized power trading requires accreditation of central authority, but in blockchain system, there is not a central authority. Every node of this blockchain system will preserve all of trading information. The information will write in block, once the written process is done, the block information will be the unique record and cannot be rewrite anymore. The block will synchronize with blockchain container to ensure the transactions are reliable. Power dispatch system will execute dispatching after trading success and sync success. The blockchain framework in Power Trading is shown in Fig. 3.

![Figure 3. Blockchain framework in power trading.](image-url)
When power trading request is called, the blockchain transaction API will receive this request and process it, if the request is available, transaction information will be sent to Transaction System. Transaction System will receive the request and execute the request, at the same time, it will write transaction information in Block. When one block is writing, the writing information will sync other block of blockchain container, when the process of sync is complete, power dispatch system will receive the status and execute the power trading request.

3.2. Hyperledger Framework in the Internet of Energy.

Hyperledger-Fabric is a collaborative project under the management of the Linux Foundation. The Hyperledger project is an IBM open source blockchain project with a good community and ecosystem. Unlike some traditional blockchain technology such as Ethereum, the Hyperledger-Fabric does not set any tokens in itself. The most famous token in blockchain is the Bitcoin which is the first generation of blockchain applications. The feature of Bitcoin is using the Proof of Work (POW) mechanism to ensure that the entire blockchain system balance and stability. The users through the computer terminal compute equations to get the token of the special reward. The special solution of this system is limited; it means that the total amount of tokens is certain. The difficulty of the equation will increase with the reduction of the remaining token. Generating a token on each meter requires other users to agree. Unlike most currencies, Bitcoin does not rely on a specific currency institution, which is generated by a large number of calculations based on a particular algorithm. The bit currency economy uses a distributed database of many nodes in the entire P2P network to confirm and record all transactions, and the use of cryptographic design to ensure that all aspects of currency circulation security.

![Figure 4. Transaction model of bitcoin.](image)

Fig. 4 is a transaction model of Bitcoin; the user calculates the equations and gets some tokens. These tokens can be traded by encryption methods, the generation and transaction of each token requires the members of the system to consensus agreement. Each user has an account to store tokens. There is not exist one user has more computing power than all other users. Therefore, the system is maintained by everyone in the system. The stability of the encryption algorithm ensures the reliability of the transaction and the user's consensus on all transactions ensures that the transaction record can not be changed. But energy can not be well stored such as electricity, and the energy generation is not dependent on the solution equation. However, the blockchain can meet the precise measurement of energy Internet and transaction traceability and other characteristics, so the energy of the blockchain application does not require setting tokens. So a distributed ledger technology based on the blockchain enables the energy Internet to be combined well. Hyperledger is a distributed ledger system which is a framework
of blockchain technology; it uses Kafka as its consensus mechanism to create a transparent and non-tampering distributed ledger. The core module of the Hyperledger-fabric runs in the Docker container. Docker is an open platform for developers to build and run distributed applications, it also is an open source application that allows developers to package their applications to a portable container. Docker is published to any popular Linux machine, it can also achieve virtualization. The container is completely using the sandbox mechanism, and there is no contact between them.

This paper designs a Hyperledger-based power trading architecture, NodeSDK unit, a tool to operate Hyperledger, is used to interact with the terminal and other units, Dispatch unit for the implementation of physical transactions, chain-code is used to interaction with Blocks and Ledgers, CouchDB, a distributed database, is used to a database query for Blocks value.

![Diagram of power trading model with hyperledger.](image)

The process of energy transaction with Hyperledger is shown in Fig. 5, when one of the users in the blockchain system want to make a trading, this user can log in through the blockchain system terminal, manually select or through the Chaincode automatically select appropriate transaction. When the transaction has submitted, the transaction information will be sent to NodeSDK unit. And then NodeSDK will analyse transaction data submitting to the chain-code and initiate the transaction, after the peers and orderer complete the process of calculation, kafka consensus, and broadcast, chain-code will write block and ledger. The information in Blocks is mapped to CouchDB in the form of key and value for user query. When the block write is complete, the NodeSDK unit will call the Dispatch unit, it will carry out electrical control to complete the dispatching, to achieve power trading. At the same time, the transaction information will be recorded by all ledgers. In this blockchain system, each user can trade between users, so there is not an authoritative, centralized trading platform. The trust mechanism is maintained by every user within the system, blockchain as a network of information between users of the network, constitute a network of mutual trust and communication. Chain-code can make the transaction automation and intelligence. Thus, it can make the IOE intellectualized through use the smart chain-code. Public ledgers can provide a non-repudiation and non-tampering of the trust mechanism to ensure that the benefits of users within the Blockchain system.

### 3.3. Hyperledger-Fabric Transaction Process

In the transactions of energy, the IOE is a distributed system, it require a consensus trading model. Hypeledger provides a decentralized trading framework, in this framework, all transactions logs will be recorded. Every peer will join transactions. It can make the transactions secure and stable.

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**Figure 5.** Power trading model with hyperledger.
Figure 6. Trading process of Hyperledger framework.

Transaction process of Hyperledger framework is shown in Fig. 6, the core module of the Hyperledger-fabric runs in the Docker container, there are some Docker images of Hyperledger including fabric certificate components Fabric-CA, Client is used to be a access gateway for users, chain-code is smart contract for trading, Peers are endorsement node, and Orderer is consensus node, Blocks is a block container of Hyperledger system, CouchDB is distributed databases of Hyperledger. When the system run, all peers will join the channel and deploy the chain-code to the Docker and initialize the chain-code. At this time, Docker images is up. And the Genesis block will be generated, genesis block is the first block of this system. In the subsequent transaction, the client initiates the transaction and sends the transaction request to each Peer. Peers receive the request and then perform the transaction separately through the chain-code, then peers return the result to the client, and submit the result to the Orderer, the Orderer processes the consensus and writes the result to Blocks. When the block is written successfully, Blocks will return the results to Orderer, and then, Order broadcast the results to each peer to complete the endorsement. After each peer verifies the transaction, Hyperledger will complete this transaction.

Hyperledger information is stored in CouchDB, the form of information is ‘key and value‘, it provides users query API. When the transaction is carried out several times, once a new peer is added, the channel will be reestablished by the peers and the new peer will be deployed. The new image will generate new blocks, and the previous container will be saved to ensure the continuation of the transaction and the integrity of the previous transaction records.

Orderer mainly provides two Grpc interfaces: Broadcast and Deliver, two interfaces are used to client communication. The client sends a message to the Orderer via the broadcast, and the Orderer retrieves the client's message via Broadcast and Orderer will save this message. The client obtains data from the Order through the deliver interface.
Broadcast Process is shown in Fig. 7. Peer initiates communication via GRPC, after the connection to Orderer is successful; it can send a message to Orderer. When Orderer receives the message sent by the Peer via the receive interface (Recv msg), Orderer will push the message to Kafka. When Kafka finish the consensus, it will pull the success message to Orderer, and Orderer will use chain-code to create or write blocks. In this framework, distributed transaction will be well processed. Distributed transaction is an important factor of distributed system. Therefore, it will suit the architecture of the Internet of Energy well.

4. Conclusion
Distributed power trading is an important part of Internet of Energy, and blockchain is a good method to solve the problem in the power trading. Hyperledger is a blockchain technology framework. Hyperledger use no-tokens model compared with Bitcoin so that it is more compatible for power trading, furthermore, Hyperledger has provided a decentralized and trustworthy trading model that uses consensus tools to make certification. This paper has introduced blockchain technology and Hyperledger, designs a framework in the Internet of Energy by using Hyperledger. This trade model is accordant with the concept of energy interconnection and information interconnection. Therefore, it is a feasible method for the development of power trading in the Internet of Energy.

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