Energy Data Security and Multi-Source Coordination Mechanism Based on Blockchain

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***Abstract*—Energy is the material basis for human society to survive and has a very important strategic position in the national economy. With the advancement of Internet technology and the extensive use of clean energy, the energy industry has demonstrated a new development trend. Based on blockchain technology, this paper analyzes energy data security and multi-source synergy mechanism, processes and classifies a large amount of energy data in energy system, and builds a blockchain-based energy data supervision and transaction model. A summary tree of energy data is proposed; a consensus mechanism based on multi-source collaboration is proposed to ensure efficient negotiation; and finally, blockchain is verified in the energy scenario. This provides reference for the application of blockchain technology in the energy industry.**

Keywords—data security, summary directory tree, multi-source collaboration

I. INTRODUCTION

Energy is the foundation for human survival and development, the lifeblood of the national economy, and the fundamental of the country. Therefore, the energy issue has always been the focus of attention for all countries in the world. The technological transformation and innovation in the energy field runs through the history of human society. The fourth energy revolution promoted the upgrading of energy types and the rapid development of energy technologies, and gradually formed a diversified energy coexistence, intelligent system control, distributed plant autonomous energy structure, and also produced massive energy data.

At present, with the deep integration of informationization and industrialization, changes in the energy development model of Internet + and smart energy, energy Internet, and integrated energy services and energy systems have become a key infrastructure for the high integration of energy flow and information flow [1]. The business data flow of the internal production management of the energy system realizes the "intelligent control of energy flow based on information flow".

The state and energy industry authorities have strict management regulations on the collection, storage, transmission, application and destruction of energy data, however, with the rapid development of contemporary energy leading to huge increase in energy data, energy data security has become great challenge. The full lifecycle management and application model of energy data faces the following challenges: In the process of data aggregation, as long as the network and equipment flowing through it are possible to backup data, the risk of data theft is increased to a certain extent, and the difficulty of data security review and positioning is increased. It is difficult for the energy industry supervision department to implement daily effective supervision of energy safety production. The most uninterrupted technique to regulate the energy industry is to follow the energy big data idea, collect all the energy plant stations, energy dispatch centers and other operational data, and then carry out centralized big data analysis. However, due to the inconsistent data classification format of each plant and the large amount of data, the supervision cost of the energy industry supervision department through the self-built big data center is too high with low efficacy.

As a shared distributed database and decentralized peer-to-peer (P2P) network, blockchain has the characteristics of distributed decision-making, collaborative autonomy, tamper-proof high security and open transparency [2]. Each node in the chain can also participate in the transaction, sharing and storage of data, effectively preventing data from being tampered. At the same time, the blockchain naturally conforms to the energy Internet concept in terms of operation mode, topology, security protection, etc. It can complement the energy big data well and complement each other, effectively solving the problem of energy information security.

Simultaneously, the growing energy demand is leading to worldwide energy crisis and environmental degradation. Thus, in order to meet the growing demands of the society for energy and for the pursuit of healthy life, human beings began to change their minds and pursue sustainable development [3]. Therefore, the comprehensive utilization of clean energy such as wind, solar and hydro has become a trend for the future development of the energy industry. For the energy demand put forward by the user side, the problem of multi-source synergy is urgently needed to be solved. The multi-source solution is to meet the energy needs of the user side and also considering the actual scenario of the power plants at the source end. In response to the above problems, the traditional centralized decision-making model can no

978-1-7281-4930-1/19/$31.00 ©2019 IEEE

longer meet its requirements, and cannot fully consider the interests of various energy power plants in the hybrid power supply. The decentralized distribution decision technique in the blockchain corresponds to the multi-energy collaborative scheduling problem [4].

Blockchain technology has great potential in the energy field. As the world's largest energy consumer, China can speed up the application of blockchain technology in China's energy sector by summarizing the application of blockchain technology in the international energy sector, making blockchain technology a catalyst for energy transformation and model evolution. At present, many power companies in China are actively researching and investing in blockchain pilot projects, striving to establish a safer and more efficient energy environment.

II. SECURITY MECHANISM FOR ENERGY DATA REGULATION AND TRADING

A. Processing and classification of energy data

The energy system is the foundation and economic pillar of the national economy, covering the power, oil, natural gas, coal mining and other industries, and the energy data bridges the energy primary system and the energy secondary system. At present, the information level and data system maturity of the power industry in the energy system are the highest, with typical representative significance. Therefore, this paper analyzes the types and characteristics of power data from the power plant station of the power industry, and studies the security of supervision and transaction of life cycle management such as energy data collection, storage, transmission, application and destruction based on blockchain technology. The mechanism seeks to provide reference for the management of other energy data.

In the energy system, a large amount of data is generated at all times. In order to trace the data in the energy system and ensure the authenticity and security of the original data, a hash function is used to calculate the daily data generated by the power plants in each energy group. Then, through a pair of hashes into a hash tree, and finally generate a periodic data hash value, the specific process is as follows: Define the operation Hash1 $\oplus$ Hash2 to hash the two hash values to get a new hash value. The hash value generated by the data of the power plant P_j on the TTH day in a period of T is $Hash_t^j$. Where, j is the power plant number, $j \in \{1,2,...,n\}$, where t is the number of days, $t \in \{1,2,...,T\}$. The data hash value $Hash_j$ of P_j in a period T is obtained by hashing the daily hash value of the power plant in pairs, as shown in equation (1).

$$Hash^j = Hash_1^j \oplus Hash_2^j \oplus ... \oplus Hash_T^j \qquad (1)$$

Energy industry regulators, energy groups, and data buyers have large differences in demand for power data. In order to realize the safety management and value requirements of power data, the data hash values of each power plant analyzed and processed by the data center are classified into the following four types of data：

- Valuable data D1 for trading and its hash value Hash (D1)
- Regulatory data required by the energy industry regulator D2
- Energy group's own management data D3
- Data traceability and tamper-proof trusted total hash value HashG.

Among them, $Hash_G$ satisfies formula (2):

$$Hash_G = Hash^1 \oplus Hash^2 \oplus \cdots \oplus Hash^n \qquad (2)$$

The above four types of data are exchanged with the outside world or local/cloud storage based on different data ports according to their respective functional requirements. Specifically implement the following functions:

- The data D_1 and its hash value Hash (D_1) are stored in the local or cloud database, and the hash value Hash (D_1) is added with descriptive information (DI) and then packaged into a summary block and uploaded to a third-party platform. The data D_1 can be used for data transaction, and the content in the summary block can be used for data retrieval;
- Data D_2 and $Hash_G$ values are uploaded to the energy industry regulatory authorities to support the energy industry's regulatory functions for energy production and operational data;
- The data D_3 and $Hash_G$ values are stored in the local or cloud database to support the internal management functions of the energy group.

B. Energy Data Supervision and Transaction Model Based on Blockchain

As an important basic strategic resource, energy data has a large number, a large number of data types, and geographically dispersed features [5]. In the normal mode, the supervision and transaction of energy data can collect the result data of the data center analysis and processing of each energy group through the construction of a third-party platform, unify the summary and comparative analysis, and realize the data transaction through the cloud trading platform. However, in the data management mode of the third-party platform, the method is easy to leak and be tampered with during data transmission, and the third-party platform threatens to back up and leak energy data.

Therefore, in order to solve the above problems, based on the analysis of the integration of energy data and blockchain technology, based on the technical complementarity of the two, based on the blockchain technology, the energy chain supervision and transaction model based on blockchain is designed. As shown in Figure 1. The model builds the business chain, regulatory chain and the trading chain based on the blockchain technology. The business chain belongs to the private chain, and regulatory chain and the trading chain belong to the league chain.

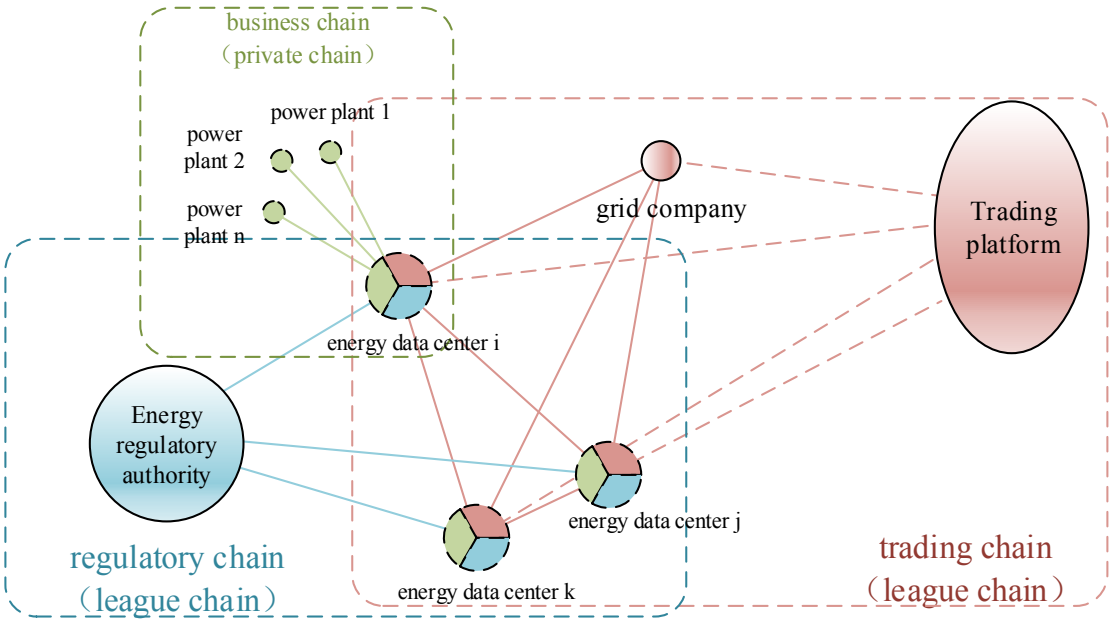

Fig. 1 Energy Data Supervision and Transaction Model Based on Blockchain

Among them, business chain and regulatory chain have constructed a supervision mechanism by using block chain tamperproof technology, which is used to realize the authenticity and efficient supervision of the energy production and operation data of each energy group and each power plant. At the same time, the regulatory authorities of the energy industry effectively supervise the energy production and operation data of the whole energy group and each plant and station to ensure the authenticity of the data. The trading chain mainly uses the characteristics of blockchain decentralization and traceability technology to record data transactions between data centers of various energy groups and grid companies [6]. A blockchain-based smart contract mechanism builds a peer-to-peer transaction trust mechanism that requires no third-party intervention.

In this model, the third-party platform for energy data sharing transactions is a weakly centralized platform. It does not require users to upload data to the platform in a unified manner, avoiding the possibility of data leakage during network transmission, platform storage and transaction process, and greatly improving the security of data. The platform can meet the requirements of the authenticity of each user identity in the energy data transaction chain and the traceability of each transaction, and also realizes the centralized data retrieval function for data transaction users based on the abstract directory tree mechanism. The summary directory stores only the data summary and user basic information, the data volume is small, the query speed is fast, and the user can efficiently query.

C. *Summary directory tree construction method*

Energy trading third-party platform for weak centralized data platform, the platform upload data center of each energy group to the third party trading platform the Hash value of the Hash (D_1) and data description information DI form the blocks, and the blocks according to the regulation of entry in a directory tree, the tree structure implementation is based on the directory tree mechanism for data exchange users provide centralized data retrieval function, guarantees for peer-to-peer sharing of data transaction. Since data D_1 is not uploaded to the third-party trading platform completely, the possibility of leakage of data D_1 in network transmission, platform storage and trading process is avoided. The specific generation process of summary directory tree in the third-party trading platform is shown as follows:

- Data collection and analysis: The periodic data hash value $Hash_j$ of each power plant is analyzed and processed by each energy group data center to obtain the required data D_1 and its hash value Hash (D_1).
- Generate summary block: The energy group data center extracts the hash value Hash (D_1) of the valuable data used for the transaction, and adds the body description information DI (It mainly includes the energy type of data, mathematical type, generation time and address information and other attribute values) to form the summary block.
- Forming a summary tree: The DI in the summary block describes the energy type, generation time, and data type of the data. These attribute values are the key to the summary directory tree structure. The tree structure design uses the energy type as the first-level node, and then the data type of each specific energy industry is the secondary node, such as the power generation data of the thermal power plant, and then the regional, group and subordinate units are respectively regarded as the third, fourth and fifth nodes. After the platform obtains the summary block, the platform can input the corresponding node of the summary directory tree according to the tree structure according to the description information and the address information in the summary block.

III. CONSENSUS MECHANISM BASED ON MULTI-SOURCE COLLABORATION

In the blockchain, the negotiation between nodes is completed in the form of information flow. Therefore, while ensuring information security, it is important to study the negotiation between nodes in the blockchain. The ultimate goal of the construction and development of the energy Internet and the reform of the power system is to improve the efficiency of the use of clean energy on the premise of

meeting the needs of the entire society safely and economically [7]. However, due to the instability, unpredictability and intermittent nature of clean energy such as wind, solar and hydro, power volatility and load uncertainty exist in the power system.

Therefore, on the premise that China encourages large-scale access of clean energy to the power grid, the focus of the study is to discuss how to take into account the interests of different types of power plants, the overall cleanliness of the source side and the electricity stability of the user side, and to give greater flexibility and openness to the energy market under the decentralized dispatching part. Therefore, it is urgent to establish independent, intelligent and partially decentralized collaborative optimization mechanism among various energy sources.

As a shared distributed database technology, blockchain has the consensus mechanism, distributed decision-making, collaborative autonomy, high security and open transparency of tampering, etc., which can well support the large-scale access of clean energy. Each energy node constructs autonomous, mutual trust and security collaborative optimization mechanism under the decentralization of the dispatching part according to its own power generation, cost control and benefit, grid power balance and other constraints. The use of blockchain technology guarantees the efficiency of the negotiation mechanism in the system.

Power plants, grid companies, and various end users at the source end can be considered as a type of node in the blockchain. For the demand put forward by the end user at the load end, multiple power plants at the source end negotiate and determine the transmission and distribution scheme considering the transmission and distribution of the grid company, as shown in Figure 2. In order to solve the problem of decentralization in multi-source systems, a consensus mechanism based on multi-source collaboration is proposed to ensure the efficient operation of the system.

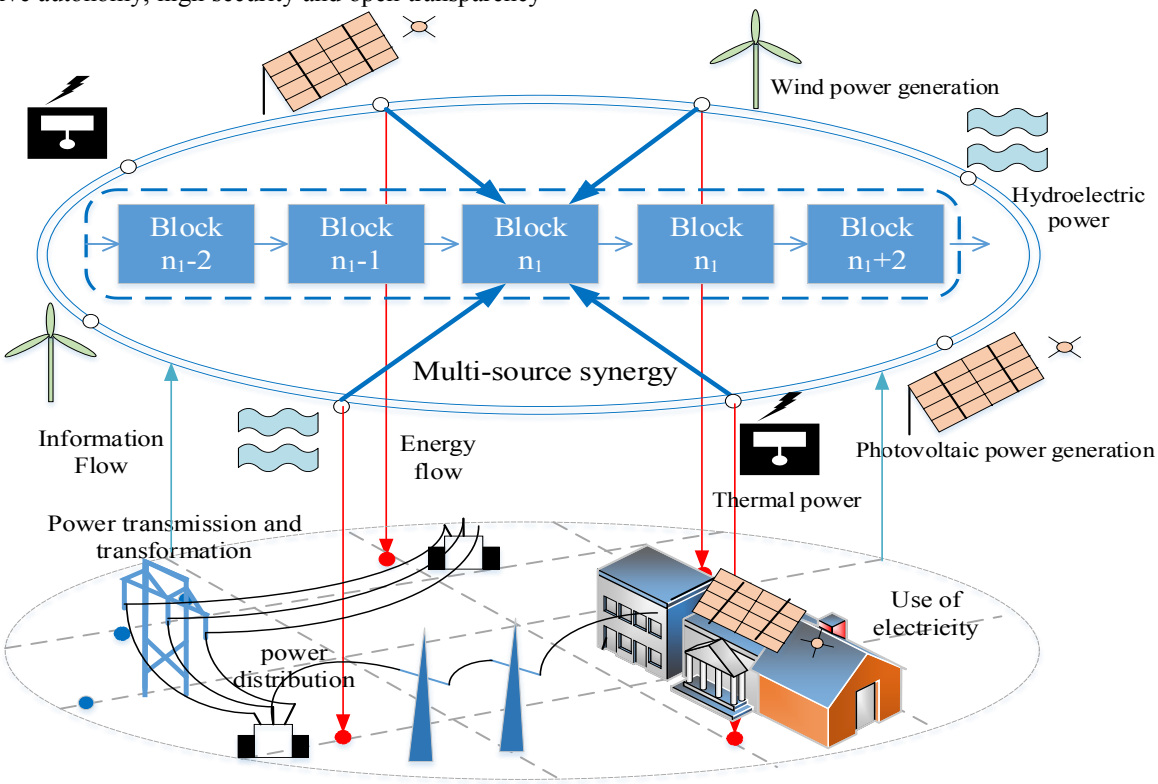

Fig. 2 Multi-source collaborative model based on blockchain

The consensus needs to consider the energy transaction amount W of the n source nodes (n>2) in a time period T, the cleanness degree R of the energy, the coefficient S of the social importance degree, and the selling price M of the electric energy. Further, the voting weight value V of each node is determined. The voting weight of any node cannot exceed 50%. A mathematical description of these considerations is given in accordance with the above requirements to calculate the voting weight value V for each node. The mathematical description is as follows:

$$\begin{cases} V_k = f(W,R,S,M),(V_k \le 50\%) \\ \sum_{k=1}^{n} V_k = 1 \end{cases} \tag{3}$$

After the node at the source end receives the demand data, each source node needs to reach a consensus on the power supply allocation for a certain period of time T, and broadcast the scheme to the entire network after negotiation. Each node at the source end performs statistics on W, R, S, M, and the like in the time period T according to the consensus mechanism. The node weight value V participating in the voting is calculated in accordance with equation (3), and the scheme is voted. When the vote rate exceeds 50%, the program passes; when the vote rate does not exceed 50%, the plan is re-planned and uploaded until the final plan is determined.

IV. SUMMARY

This paper studies the energy chain security and multi-source coordination mechanism based on blockchain. By analyzing the characteristics of blockchain and the existing problems and needs in the energy industry, a large amount of energy data in the energy system is processed and

classified. The energy chain supervision and transaction model based on blockchain is constructed. The energy data summary tree with centralized data retrieval function is designed, and a consensus mechanism suitable for multi-source coordination mechanism is proposed. Simultaneously, with the continuous popularization of the blockchain concept, blockchain technology will develop rapidly for long term. Based on this, we will further study the application of blockchain in the energy industry, make the generated energy data safer, coordinate and utilize existing energy sources more and more efficiently, and continuously expand the application range of research. This provides a reference for the future exploration of the information technology in the energy industry.

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