Research on PD-IoT Cloud Master Station Architecture Based on Blockchain Technology

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Abstract. Blockchain technology is a new type of distributed database technology solution, which has unique advantages in terms of decentralization, security and transparency. These characteristics of the blockchain can solve some typical technical problems in the construction of the current power distribution IoT cloud master station. In this context, the architecture design and implementation of the power distribution IoT cloud master station based on blockchain is first discussed; then, the blockchain is integrated from three aspects: security performance, state estimation algorithm, and deep search engine. The new framework of the technology is analyzed. Finally, the application of the blockchain technology in the cloud master station of the distribution network is summarized.

1. Introduction

Since the State Grid proposed the ubiquitous electric power Internet of Things, the technological innovation in the field of distribution network automation has been deeply integrated with the ubiquitous Internet of Things, resulting in a new business form of power distribution IoT with a cloud master station as its core platform. In the construction of the power distribution IoT cloud master station, new models of security performance and data analysis under the new business situation urgently require technical change. Blockchain technology is highly efficient and stable in terms of decentralization and algorithm on-chain, which meets the current technical requirements for the construction of the Internet of things in power distribution, and can play an important role in deeply mining the value of data.

The application of blockchain in the power field is mainly to integrate distributed databases into the power business system. In [1], based on the network topology of the blockchain and the power spot market system, a new mechanism for the power spot trading market was proposed. In [2], it make full use of the blockchain's security verification algorithm to form a blockchain-based method of power transaction and congestion management; In [3], it found the technical value of the blockchain in the field of power auxiliary services, and clarified the auxiliary service system development from centralized management to distributed intelligent management.

The above papers have directly applied blockchain technology to the electricity market and electricity transactions, and have not been involved in the field of grid operation. This article mainly analyzes the construction of the blockchain and discusses the application of the blockchain technology on the distribution network operation, especially the cloud master station fusion architecture. It integrates the blocks from three aspects: security performance, state estimation algorithm, and deep
search engine. The advantages of the new framework technology of the chain technology are analyzed, and the application of the blockchain technology in the cloud master station of the distribution network is summarized.

2. Blockchain architecture design of cloud master station of power distribution IoT

The State Grid Power Distribution IoT Cloud Master Station uses a three-tier (IAAS, PASS, SAAS) cloud architecture. On this basis, the fusion transformation of each layer of the blockchain is implemented to realize the blocks in the field of power distribution IoT Chain technology application. Taking into account the key position of the power distribution Internet of Things and good hardware scalability, the cloud can be designed according to the positioning of the full node when the architecture blockchain is transformed.

Figure 1. Blockchain fusion architecture of the IoT cloud master station

Infrastructure as a service layer: Based on existing computing, storage, and network resource pools that have been constructed using virtualization, distributed storage, and other technologies, the blockchain operating system is deployed in the computing resource pool, blockchain database, and buffer cache. The storage resource pool, blockchain local load balancing, and P2P communication are in the network resource pool, which mainly provides hardware hardware services for the operating system and database for the blockchain.
Figure 2. Blockchain process of functional transactions

Platform as a service layer: The cloud platform master station and the blockchain are configured logically. The cloud platform master station platform layer is mainly for public resource management and data services. The blockchain platform layer implements basic block execution, transaction processing, and on-chain code function. Taking the fault location analysis of the power distribution area as an example, the implementation of the positioning function is defined as a new transaction, forming the on-chain code of the functional transaction, and completing the blockchain processing of the fault analysis at the platform layer.

Software as a service layer: It builds applications with functional transactions as the carrier at this layer. It should be noted that the scalability of the blockchain's functional implementation needs to be improved at this stage. Therefore, it is only recommended to run important applications on the on-chain code, and maintains the redundant function design with the cloud master station.

3. The technical contribution of the blockchain to the cloud master station of the power distribution IoT

3.1. Blockchain decentralization guarantees the security and reliability of the core data of the master station

The power distribution IoT cloud master station using blockchain integration has the technical advantage of being difficult to be tampered with and difficult to be forged in the storage, analysis, and use of power business data. It can make the most of the plant-side upload measurement, while ensuring that the historical data of the distribution network is reliable.

Blockchain is a peer-to-peer network. There is no centralized hardware and management agency. There is neither a central server nor a central router. As long as the power data enters the blockchain, even the insiders of the power system, it is difficult to artificially deliberately manipulate the data. Due to the convergence of the blockchain, the status of each node in a part of the network (ie, the
peer-to-peer network of the blockchain) can be used only as a client and server at the same time, which greatly increases the difficulty of data tampering. The modification of the core power business data in the blockchain not only consumes a lot of time and energy, but also generates a time stamp in the block. For example, when we tamper with the history of a circuit breaker's opening and closing in a certain distribution line, all the system nodes involved in the blockchain in the distribution network networking cloud master station are updated and maintained (this operation theoretically takes a long time). On the other hand, once the record of the circuit breaker is tampered, it will be traded broadcast to other nodes in the system, the node will generate a block timestamp related to this, proving the existence of tampering behavior.

The function implementation of the distribution network business data in the blockchain will not directly save the clear text transaction records, but only the function implementation process will form a certain length hash value through the SHA256 algorithm, and these string will be recorded in the block. Because the hash function is unidirectional and random, it is almost impossible to snoop on the implementation of a specific function of the distribution network without authorization. The probability of forgery and deletion of data is almost zero.

3.2. A new algorithm for state estimation of distribution networks based on smart contracts

The distribution network measurement data is encapsulated into the smart contract of the blockchain after value reduction. It is used in the on-chain code to estimate the state of the distribution network, and an accurate state estimation mechanism for the distribution Internet of Things based on smart contracts is established.

The calculation process of the distribution network state estimation based on smart contracts is as follows: In the first step, the smart contract predefines the distribution network network model and node state quantity rules, it establishes state estimation equation constraints and inequality constraint trigger conditions; in the second step, the entire network nodes (including simplified knife switches, segmented switches, etc.) sign smart contract definitions, and the distribution network structure diagram, topology map, and pseudo-measurement are unified valued by the blockchain; in the third step, we define the signing and valued data attached to the blockchain in the form of on-chain code, which will be recorded in the distributed ledger of each node after being verified by smart contract propagation. In the fourth step, without special system configuration and other interfaces call, it runs directly and automatically, and when the power grid state estimation and optimization is needed, the corresponding contract algorithm is activated and executed according to the trigger conditions and the principle of fastest convergence.

The new algorithm of distribution network state estimation based on smart contracts is more reasonable in clustering and classification of measurement data. It can filter and preprocess the original measurement data uploaded by the sensing equipment. Combined with the unknown power grid operation mode, a reasonable deduction experiment is performed to generate the initial feature quantity matrix required by the state estimation program. The on-chain code fuses the single-period, single-electricity feature state estimation feature matrix constructed by multiple different electrical feature quantities into a multi-time series, multi-electricity feature state estimation feature matrix. To a certain extent, the state estimation of the smart contracted distribution network has substantially improved the autonomous decision-making compared with the traditional method.

3.3. A deep search engine for the distribution IoT master station with the help of the block Merkle tree

In the situation of power distribution Internet of Things, the establishment of a cloud platform on the main station side supports the upload and storage of large-scale data. At the same time, the irregular data accumulation will seriously affect the functional analysis, especially the retrospection of historical sections. In blockchain networks, deep search engines can be built with the help of Merkle tree attributes.

The Merkle tree organizes the completed distribution network function operations according to the structure of a binary tree, which will form a regular power business block with good scalability. In the IoT of power distribution, the realization of the function is equivalent to the completion of the
transaction, then the cross-section tracing and function drill are the search of the algorithm. Finding the Merkle root from the bottom traceability can verify whether a certain function is implemented reasonably, and obtain analysis of the time dimension of the radio station. The time complexity of this deep retrieval process is only $\mathcal{O}N$, and the resource occupation is very small.

4. Conclusion

This paper proposes the framework design of the cloud master station of the power distribution Internet of Things based on blockchain technology. It elaborates the transformation method of applying the blockchain on the three-tier structure of the cloud master station, and demonstrates that the blockchain technology operation mechanism in the cloud master station. At the same time, technical analysis and discussion were conducted from the aspects of security, state estimation algorithms, and deep search engines, etc., which provided ideas for the application of blockchain technology in the power distribution IoT in the future.

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