Virtual power plant trading method based on smart contract

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Abstract

As a new decentralized infrastructure and distributed computing paradigm, blockchain integrates and innovates a variety of computer technologies. Smart contract is one of the important technologies in the blockchain. It is a computer protocol designed to disseminate, verify or execute contracts in an informational way. Smart contracts allow for trusted transactions without third parties, which are traceable and irreversible. Virtual power plant (VPP) is an important branch of the energy Internet. It plays an important role in aggregating distributed power generation resources and establishing virtual power resource transactions. This paper analyzes the types and operations of existing VPP models, introduces smart contract technology into VPP, proposes a VPP transaction model based on smart contracts, and explains how to complete vpp transactions through smart contracts.

Keywords

Blockchain, Virtual power plant, Smart contract, Energy trading model.

1. Introduction

The National Development and Reform Commission and the National Energy Administration issued a notice on China's energy revolution strategy from 2016 to 2030, clarifying that green low-carbon energy is the development direction of China's energy in the next decade, and the use of new energy is mainly distributed power generation. When distributed energy is separately connected to the current traditional large-scale power grid system, the security and power supply reliability of the power grid will be seriously threatened. In order to achieve coordinated control and energy management of distributed power sources, virtual power plants (VPP) have become a necessity [1].

The term "virtual power plant" derives from the definition of virtual public facilities in 1997 by Dr. Awerbuch in his book Virtual Utility: Description, Technology and Competitiveness of Emerging Industries: Virtual Public Facilities are Independent and Market-Driven A flexible collaboration between entities that do not have to have the appropriate assets to provide consumers with the efficient power services they need [2].

At present, VPP technology has relatively mature development in developed countries in Europe and America, and there are some small-scale demonstration projects available in Europe and the United States. Since 2001, European countries have started research projects on virtual power plants with the main goal of integrating small and medium-sized distributed power generation units. The participating countries include Germany, Britain, Spain, France, and Denmark. The virtual power plant projects that have been implemented include: the pilot project of the Institute of Solar Energy Supply Technology of the University of Kassel, Germany, the virtual fuel cell power plant project of the European Union, and the FENIX project of the European Union [3].

2. Virtual power plant background and smart contract

2.1 Virtual power plant

The virtual power plant is a regional multi-energy aggregation mode that realizes distributed energy (DER) large-scale access to the power grid, which can realize flexible control of a large number of distributed power sources, thereby ensuring safe and stable operation of the power grid. From a technical perspective, virtual power plants do not change the way each distributed energy is connected to the grid. Instead, they integrate different types of distributed power, controllable loads, energy storage systems, and electric vehicles through advanced technologies such as control, metering, and communication[4]. Distributed power supply, and through the higher-level software architecture to achieve coordinated operation of multiple distributed energy, enabling it to participate in the electricity market and auxiliary service market operations, real-time energy trading, optimize resource utilization, improve power supply reliability[5] .

The concept of virtual power plant emphasizes the functions and effects of external presentation. This method can integrate distributed energy to stabilize the transmission of public network without modifying the power grid, and provide fast and corresponding auxiliary services to become distributed energy. The effective method of the market reduces the risk of imbalance in the operation of the island in the market and can obtain the benefits of economies of scale. At the same time, the visualization of distributed energy and the coordinated control optimization of virtual power plants greatly reduce the impact of distributed energy grid-connected on the public network, reduce the scheduling difficulty brought by the growth of distributed energy, and make the distribution management more inclined. Reasonable and orderly, improve the stability of the system operation[6].

2.2 VPP mathematical model

VPP consists of a set of S_{THE} schedulable power units, a set of S_{LOAD}flexible loads, a set of S_{ESS} storage devices and a set of RES units forS_{RES}. VPP seeks to optimize the operation of these energy sources within a 24-hour time frame of 1 hour. The VPP controller should ensure the technical feasibility of its RES and the stability and stability of VPP when making recommendations to the market. These limits should be met every hour for 24 hours. The optimal operation of VPP requires that the load demand be met at a minimum cost, using VPP sources and the day-to-day market by selling or purchasing energy at different power market prices at different times[7]. The maximum benefit B of VPP can be expressed as:

$$[MAX]B = \sum_{t=1}^{24}\begin{bmatrix} \pi_{market}\times P_{exchanged}\times 1 - \\ -\sum_{i\in S_{thE}}\begin{bmatrix} C_i\left(E_{THE}, i(t)\right) + C_i^{SU}(t) + \\ +C_i^{SD}(t) \end{bmatrix} + \\ +\sum_{i\in S_{Load}} C_i(E_{Load}, i(t)) \end{bmatrix}$$

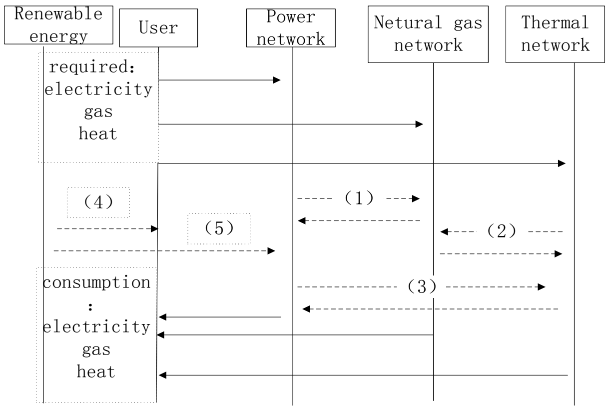

Fig. 1 Multi-energy transaction process in virtual power plant

(1) The user side first issues the energy request, such as electricity, heat, gas.

(2)The power network, natural gas network and thermal network receive demand information respectively.

(3)When the load of each network is normal, it will respond to user side demand.When the power network is in the peak period, the load is too high and the power supply is not stable:

Transactions are triggered by smart contracts, which buy gas from the natural gas network and generate electricity through a co-generation device to supplement the power grid.

When the thermal network load is too high, the contract is sent to the power grid and the thermal network energy is supplied through the electric heat pump.

In the case of load limitation of the grid, the request is sent to the natural gas network, and the heating network is replenished by the electric heating co-generation.

Users in the region, such as parks, schools, office buildings, etc. are equipped with photovoltaic power generation devices, which supply users by producing electricity during the day

Sell rich electricity to the grid at night when the park's power demand is low.

2.3 The trading process of smart contracts in virtual power plants

The construction and execution steps of the virtual power plant transaction contract based on blockchain are shown in Algorithm 1. First, two or more parties, depending on their needs, work together to create an energy deal; After that, the parties to the contract agree on the content of the contract, terms of default, liability for breach of contract and external verification data source[8]. After checking and testing the contract code as necessary, it spreads to all network nodes through P2P network and stores. Finally, smart contracts stored in the blockchain are automatically executed when the parties complete the task on agreed terms[9].

Algorithm 1 Multiple energy transaction contract

Init: bids =[], hB = 0, hB2 = 0, kwh=0, tTime=0, bTime=0, w=0

Create: INPUT: (s.deposit, kwh, tTime, bTime)

Verify s.deposit

CommitBid: INPUT: (b, hbid, deposit, nonce)

Verify b ∉ bidsVerify b.deposit ≥ deposit

bids[b] = (hbid, nonce)

RevealBid: INPUT: (b, bid, nonce)

Verify t ∈ bT ime

Verify b ∈ bids

Verify hash(b.bid, b.nonce) == b.hbid

Verify b.bid ≥ b.deposit

Vickrey(b, b.bid) → (w, hB, hB2)

Finalize: INPUT: () Verify t > tT ime, Penalty(kwh,m(s), m(w), mktP rice) → (bP enalty, sP enalty)

send(w, w.deposit - price + bPenalty)

send(s, s.deposit + price - sPenalty)

In the energy transaction process, after the participants reach bilateral and multilateral transactions through the game, the platform automatically generates the intelligent contract, writes the attributes such as trader identity, energy quota, price, transaction time, and default amount, and finally USES the private key to carry out multiple signatures to ensure that the contract cannot be tampered[10]. Smart contracts generated by transactions are not only defined by the code, but also enforced by the code. The two parties of smart contracts do not need to trust each other, nor need to trust the supervision of the intermediary. They are completely automatic and cannot intervene, reducing the additional cost of transactions. At the same time, once the smart contract is confirmed, its funds will be distributed according to the terms of the contract. The funds can only be used after the preset conditions of the contract are met. During the contract period and after the contract comes into effect, neither party can control or divert funds, which ensures the security of its transaction. In addition, the smart contracts stored in the blockchain are guaranteed by the whole network node that they cannot be tampered with at will, and the contract content can only be changed after obtaining the consent of all the contract signing parties. The entry of intelligent contract makes the transaction have the advantages of distributed trust autonomy, fairness and justice, lower cost, high efficiency and tampering.

3. Problems and challenges

At present, China is vigorously carrying out energy reform, increasing the use proportion of renewable new energy, gradually getting rid of the dependence on coal - based traditional energy, and promoting energy conservation and emission reduction. Under the framework of energy Internet, this paper proposes the energy transaction architecture based on blockchain and constructs a free distributed transaction market, which is a bold attempt to decentralize energy transaction mode. However, despite the technical defects of blockchain [11] and some problems of smart contract itself [21], there are still some problems to be solved.

(1) Under the energy transaction mode of this paper, it is inevitable to involve the marketization of energy transaction and power auxiliary service transaction[12]. However, China's energy system reform is slow, and more buffer periods are needed. Second, large-scale access of distributed energy will produce great influence to power network, so you need to distributed power auxiliary services smoothly, and the current development of distributed new energy in our country is still not enough, RuWangLv are low, and in view of the distributed power auxiliary services related research is less, the lack of adequate theoretical and practical basis.

(2) At present, China's energy transaction is still managed and operated by state-owned enterprises, while the distributed energy transaction system based on blockchain allows private users to directly conduct power-oriented energy transaction, which is not in line with China's national conditions. Therefore, it is necessary for the government to deeply discuss feasible implementation methods and promulgate a series of reform measures[13].

(3) The combination of blockchain and smart contracts ensures the security of energy transaction to some extent, but energy needs to be transmitted from one end to the other through the physical network, such as power transmission through the grid and natural gas transmission through pipelines. There are still a series of human operations in this process. How to accurately collect and upload information and ensure the reliability of energy transactions in the process of human operations needs to be further discussed.

(4) Based on block chain energy trading platform, once the actual market operation, distributed market trading mode will greatly increase the complexity of system operation, and energy systems will be a lot of time energy trading and energy as the deal by the circulation of transmission network, the physical and information communication transmission network of transmission capacity, stability and compressive ability to ask for a lot[14].

4. Conclusion

This paper designs a multi-energy cooperative transaction based on smart contract transaction Aiming at the problem of multi-energy transaction in virtual power plants. Through the block chain incentive mechanism, the model organically linked the coordination control means of the virtual power plant and the independent grid-connection behavior of distributed energy, enabled the distributed energy to expand and participate in the bidding grid-connection structure of the virtual power plant, and improved the computing efficiency of the optimal degree of the virtual power plant[15]. The virtual power plant transaction mode based on intelligent contract designed in this paper can realize high penetration, high freedom, high frequency and high speed grid connection of distributed energy on the basis of ensuring safe and reliable operation of power system. In the next step, the virtual power plant will further study the mechanism and rule of macro-control distributed energy interconnection by issuing blockchain, and introduce node trading mechanism into the model to realize the free energy interaction of distributed energy in the energy Internet

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