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A Proposal on an Electricity Trading Platform Using Blockchain

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Abstract. This paper proposes a platform that transfers electric power among consumers individually using digital grid technology that can digitally control power and blockchain technology. In this platform, each individual estimates excess or shortage of electric power based on each amount of their electricity consumption and generation, then the consumers conduct power trading at the electric power market made with blockchain. Finally, the consumers conduct power interchange based on the trading result.

Keywords. Power Distribution, Digital Grid, Blockchain, Distributed Control, Power Market

Introduction

With the progress of the introduction of distributed power generation, the future power grid is expected to be a network in which millions of users are connected bi-directionally. It can be said that we are in the era of the internet of the energy. There, it is possible to interchange renewable energy generated and power storaged by countless power generation consumers. However centralized management of these users is not time efficient. There is a need for a mechanism of distribution of electric power that improves the overall efficiency and stability which is based on distributed management by individual users. However, there are technological difficulties to realize electrically interconnected individual pairs, also in terms of infrastructure functions of electric power, demands for the system security are high. Therefore establishing a system that responds to distributed requests in transactions which each individual raises is difficult both technically and economically.

However, in recent years it has become possible to solve these challenges by using blockchain technology developed for cryptographic currency such as bit coin. The blockchain is a technology to store history data shared with a peer-to-peer distributed server using a digital signature function or a hash function. Also in the power

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controlling technology, the technology of electricity interchange between consumers is developed by Werth et al. [1] and Abe et al. [2] - [4], and demonstration experiments are also being reported. They realized power interchange between peer-to-peer using the software defined system. Some applications of blockchain technology to electric power interchange have been reported mainly in Europe and the United States including innogy, Brooklyn Microgrid and ConsenSys as of 2017 [5-7]. However, their applications mainly focused on a record ledger of the power interchange result, and there is no function that matches the supply and demand, nor interchange function such as power control.

Therefore, this research aims to establish a system that enables market matching and electric power interchange by the blockchain technology and the digital grid technology. This system enables the user to purchase electric power through the electric power market based on individual preferences.

1. Outline of proposed platform

The power interchange trading platform we propose is based on the concept proposed by Tanaka et al. [8], which aims to automatically procure the electric power according to the consumer's preference based on the power consumption and power generation amount measured by the IoT sensor etc.

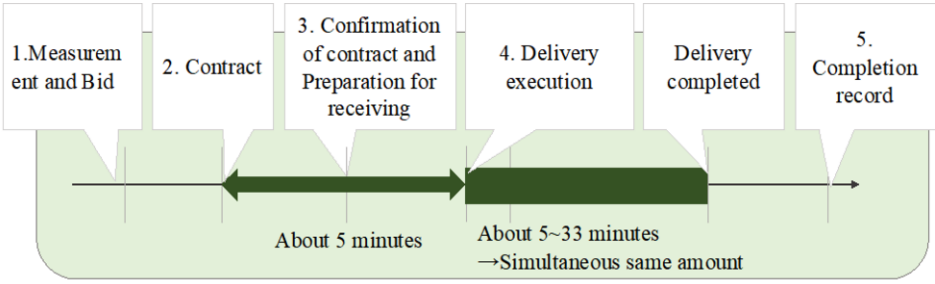


Figure1. Flow of electricity interchange transaction.

In the execution of automated trading (contract and delivery), we provide a market that automatically matches the electricity supply and demand, and conducts electricity accommodation based on the contract result. In doing so, we also keep track of when, where, and how electricity was generated.

The flow of this system is as follows. (See Figure1)

1. Measurement Bid
2. Contract
3. Confirmation of contract and Preparation for receiving
4. Delivery execution
5. Completion record

The minimum unit of transaction is 0.1 kWh. The system configuration is shown in Figure2. We set up communication devices called DGR (Digital Grid Router) and DGC (digital grid controller) at the consumer's residence. The blockchain system on the cloud conducts payment settlement and record the transaction.

At the beginning in 1. measurement bid, DGC measures the amount of electricity, power generation, charging rate, etc., and predicts demand and supply up to the next 24 hours and judges the bid according to the policies of each user. Based on the results, DGC performs a bid to each of the power market which is prepared on the blockchain every 30 minutes. Next, in 2. contract, the Smart Contract on the blockchain which received the bid matches the supply and demand by the market function of the continuous double auction and records the result of the contract in the blockchain. The information is deployed to other nodes constituting the blockchain network. Next, in 3. confirmation of contract and preparation for receiving, the DGC reads the contract result written in the blockchain, grasps the time and the amount of electric power scheduled for power interchange, and in 4. delivery execution, the DGR executes power delivery when the contract execution time comes. After this execution, the DGC reads the value of the smart meter corresponding to the Measurement Act, reports the amount of the interchange energy to the blockchain, and in 5. completion record, the completion of the proccess is recorded on the blockchain.

On this platform, we use Etharium [9] as a private blockchain. In addition, as a market function, the continuous double auction method with the Smart Contract was developed. In order to improve the efficiency of block generation, PoA (Proof-of-Authority [8]) is used. In addition, the digital grid technology developed by Abe et al. [2] - [4] is used as the power interchange unit (hardware).

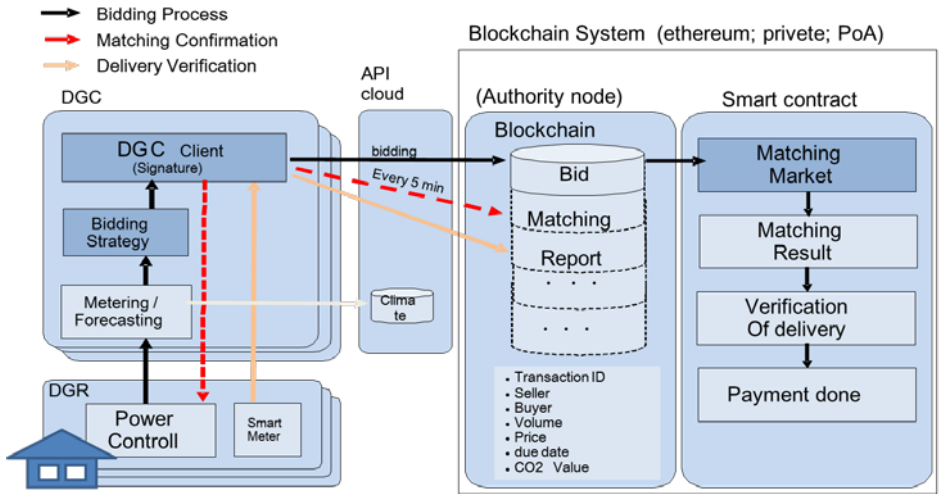


Figure 2. System configuration.

2. Details of bidding method

2.1. Connection between DGC and blockchain

As shown in Figure 2, each home's DGC accesses the blockchain through the API cloud. In the API cloud, there is a server operated by a service provider contracted by the DGC, and the DGC can connect to that server. As a proxy for DGC with limited

computing resources, this server is responsible for connecting to the block chain. However, the DGC has a secret key, and by attaching a digital signature to the message, it prevents the server from tampering with the message contents. Figure3 shows the substrate and outer appearance of DGC.

In this study, Ethereum's private network consisting of multiple authority nodes is adopted as a blockchain. In this blockchain, the Proof of Authority [10] method is used as a consensus algorithm. This is a scheme in which if any one of authority nodes succeeds in authentication, the block is added to the block chain with the digital signature of the authority node. Every 5 seconds, Authority nodes responsible for block generation are switched in a round robin fashion. In the future, it is possible to replace consensus algorithms or substitute blockchains other than Etharium depending on the system requirements and business model.

Figure 3. Substrate and outer appearance of DGC.

2.2. Continuous double auction

With this platform, it is possible for the DGC to buy required power or sell unnecessary power in the next 24 hours through the electricity spot market held every 30 minutes. The continuous double auction method was adopted as a matching method this time. The continuous double auction method is a matching system in which transactions are automatically established and the price is continuously formed when price of sale and purchase are matched under the rule of price priority and time priority. On the other hand, in the Itayose method, the selling and buying order are gathered by the bidding deadline for each spot market, and the price on the spot market is decided so as to match the selling and the buying quantity. The market price will change discontinuously for each spot market. The reasons why we chose the continuous double auction method are that making contract several hours ahead is possible and that the market liquidity is higher than that of Itayose because of the continuity based on price/time priority.

Table 1. Example of bidding situation at a specific time.

Sell [kWh]	Price [yen/kWh]	Buy [kWh]
16	Over	
3	21	
30	20.8	
15	20.7	
12	20.6	
10	20.5	
20	20.4	
10	20.2	
20	20.1	
	19.9	40
	19.8	5
	19.7	10
	19.6	50
	19.5	20
	19.4	9
	19.3	4
	19.1	12
	UNDER	18

Outline of continuous double auction system is as follows. For example, suppose that the bidding situation of the market from 14:30 to 15:00, one of the 48 markets at a specific date and time, Table 1.

In this case, look at the selling column on the left side, selling orders are arranged at prices higher than 20 yen/kWh, such as 20 kWh at 21.1 yen/kWh, 10 kWh at 20.2 yen/kWh, and 20 kWh at 20.4 yen/kWh. Likewise, if you look at the right side buy column, buy orders are lined up at prices lower than 20 yen/kWh, such as 40 kWh at 19.9 yen/kWh, 5 kWh at 19.8 yen/kWh, 10 kWh at 19.7 yen/kWh. At this time, if a certain DGC gives a sell order at 20 yen/kWh or more, it will be ordered by time in the selling column of that price. Also, if you order buy orders with less than 20 yen, they will be ordered in order of time in the buying column of that price. In this situation, no contract is estblished. On the contrary, if you issue a sell order at a price lower than 20 yen/kWh, you can sell at the highest value of buying at that point regardless of the price you specified. For example, if you pot a sell order of 5 kWh for 19.5 yen/kWh, the deal is executed with the highest bidding bid at 19.9 yen/kWh. As a result, the purchase order of 19.9 yen will be reduced by 5 kWh, and a buy order of 35 kWh will remain.

On the contrary, if you put a buy order at a price higher than 20 yen, you can buy it at the lowest price at that point regardless of the price you specified. For example, if you issue a buy order of 26 kWh at 20.3 yen/kWh, the lowest price of 20.1 yen will be contracted for 20 kWh and the remaining 6 kWh will be contracted at the next lowest

of 20.2 yen/kWh. As a result, the bidding situation is updated to the state where the unsold 4 kWh is displayed in the column of 20.2 yen. In order to allow electricity to be interchanged in real time as much as possible, the market hold every 5 minutes is also partially adopted. Each power market is 30 minutes long, but each DGC can bid on that market if the current market remaining time is over 15 minutes. Also, to enable flexible bidding strategies, you can make multiple bids on a single market. In addition, there is a function to cancel a bid (order) that has not been contracted.

2.3. Connection between DGC and blockchain

The flow of power interchange is as follows:

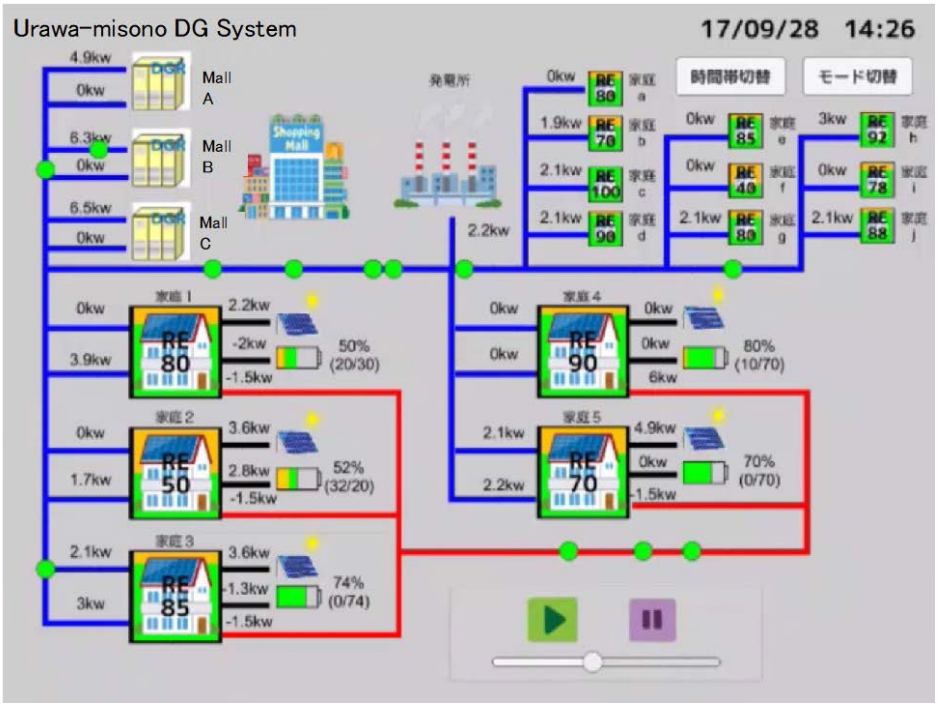
1. First, the DGC estimates the situation in the next 24 hours and decides the bidding policy for the spot market of every 30 minutes.
2. Request a bid to the service provider's server with a transaction (message with signature).
3. The server of the service provider receives a request from the DGC and transfers (broadcasts) the transaction of DGC to the Authority node of Ethereum.
4. The Authority node of Ethereum executes a Smart Contract on the blockchain which realizes the continuous double auction method according to the transaction.
5. The server of the service provider as the observer node receives the update status of the blockchain.
6. The DGC confirms the contract result of the bid to the server of the service provider every minute. If you have made a contract, the implementation of electricity exchange is recorded to the schedule of the DGC.
7. Every 5 minutes, the DGC reviews the bid of the market within 30 minutes ahead. Also, the DGC updates forecasts from the current smart meter value every 30 minutes and review the current overall bidding.
8. If the time for power interchange come, implement power interchange as contracted with the DGR. Implementation results are written in the blockchain via the service provider.

3. Outline of demonstration experiment

The platform proposed in this paper is used in a digital grid demonstration project "Development of digital grid router (DGR) and power interchange settlement system to accelerate the introduction of renewable energy Demonstration". We are planning to conduct the demonstration test in the Urawa Misono district in FY2019 after finishing the equipment development by FY2018. Figure4 shows the image of the demonstration experiment. In this demonstration, we plan to introduce solar power generators into shopping centers, and to interchange power among ten houses without power generation and five houses with power generation. By exchanging power, the customers don't need to adjust the storage battery capacity to the individual maximum demand, and the problem of the phase difference of the demand transition is resolved. Therefore customers can reduce the required equipment. In the future, we will

distribute electricity based on socio-economic principles while respecting decision-making of each user by a distributed method rather than a centralized management method for a large number of participating users.

Figure4. Example of power interchange execution



4. Conclusion

In this paper, we propose a scheme to procure electric power based on the policies of each user and power control using digital grid technology with blockchain. By interchanging using the market mechanism, the amount of power demand and the amount of power supply can be determined so as to be simultaneous equal for every 30 minutes, which is a constraint when using the grid. From now on, we plan to clarify issues to realize these distribution mechanisms on the current electricity network. In the future, we will also consider installing an electric power identification to measure the individual renewable energy ratio and realize bidding with priority for renewable energy.

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