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International Telecommunication Union
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Recommendation

ITU-T Y.2073 (05/2023)

SERIES Y: Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

Next Generation Networks – Frameworks and functional architecture models

Framework of trusted electricity brokerage for distributed energy resources

ITU-T Y-SERIES RECOMMENDATIONS

Global information infrastructure, Internet protocol aspects, next-generation networks, Internet of Things and smart cities

GLOBAL INFORMATION INFRASTRUCTURE	Y.100-Y.999
INTERNET PROTOCOL ASPECTS	Y.1000-Y.1999
NEXT GENERATION NETWORKS	Y.2000-Y.2999
Frameworks and functional architecture models	**Y.2000-Y.2099**
Quality of Service and performance	Y.2100-Y.2199
Service aspects: Service capabilities and service architecture	Y.2200-Y.2249
Service aspects: Interoperability of services and networks in NGN	Y.2250-Y.2299
Enhancements to NGN	Y.2300-Y.2399
Network management	Y.2400-Y.2499
Computing power networks	Y.2500-Y.2599
Packet-based Networks	Y.2600-Y.2699
Security	Y.2700-Y.2799
Generalized mobility	Y.2800-Y.2899
Carrier grade open environment	Y.2900-Y.2999
FUTURE NETWORKS	Y.3000-Y.3499
CLOUD COMPUTING	Y.3500-Y.3599
BIG DATA	Y.3600-Y.3799
QUANTUM KEY DISTRIBUTION NETWORKS	Y.3800-Y.3999
INTERNET OF THINGS AND SMART CITIES AND COMMUNITIES	Y.4000-Y.4999

For further details, please refer to the list of ITU-T Recommendations.

Recommendation ITU-T Y.2073

Framework of trusted electricity brokerage for distributed energy resources

Summary

Due to the rapid spread of distributed energy resources, the demand for intermediary trading (i.e., brokerage) of surplus electricity for electricity prosumers in electricity markets is significantly increasing. To support the transparency of brokerage transactions in the trading process, various technologies such as blockchain can be applied to applications that require mutual trust between users. Thus, Recommendation ITU-T Y.2073 provides a framework of electricity brokerage for distributed energy resources taking into account the blockchain technology for trust provisioning in electricity markets. After introducing key characteristics, core technologies and service scenarios for electricity brokerage with the necessity of the blockchain technology to ensure trust, this Recommendation mainly presents requirements, architecture overview specifying related interfaces and functional blocks for the blockchain enabled electricity brokerage.

History *

Edition	Recommendation	Approval	Study Group	Unique ID
1.0	ITU-T Y.2073	2023-05-14	13	11.1002/1000/15529

Keywords

Blockchain, distributed energy resources, electricity brokerage.

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In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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Table of Contents

Recommendation ITU-T Y.2073

Framework of trusted electricity brokerage for distributed energy resources

1 Scope

Due to the rapid spread of distributed energy resources, intermediary trading (i.e., brokerage) of surplus electricity for electricity prosumers in electricity markets is essential to support the transparency of brokerage transactions in the trading process. Thus, this Recommendation provides a framework of electricity brokerage for distributed energy resources with the blockchain technology for trust provisioning in electricity markets.

This Recommendation covers the followings:

– Key characteristics, core technologies and service scenarios for electricity brokerage;

– Requirements for electricity brokerage based on blockchain technology;

– Architecture overview specifying related interfaces and functional blocks.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T Y.2071] Recommendation ITU-T Y.2071 (2015), *Framework of a micro energy grid*.

[ITU-T Y.2072] Recommendation ITU-T Y.2072 (2018), *Framework for an energy-sharing and trading platform*.

3 Definitions

3.1 Terms defined elsewhere

This Recommendation uses the following terms defined elsewhere:

3.1.1 distributed energy resource (DER) [ITU-T Y.2072]: An energy generation and energy storage facility located at the customer premises or power transmission and distribution systems.

3.1.2 energy storage [ITU-T Y.2072]: Energy storage provides storage functions of electricity using various types of batteries.

3.1.3 renewable energy certificate (REC) [ITU-T Y.2072]: A tradable, non-tangible energy commodity that represents proof that energy was generated from an eligible renewable energy resource (renewable electricity) and was fed into the shared system of power lines that transport energy.

NOTE – An REC is also known as a "green tag", "renewable energy credit", "renewable electricity certificate", or "tradable renewable certificate".

3.2 Terms defined in this Recommendation

This Recommendation defines the following terms:

3.2.1 electricity broker: A market participant who aggregates distributed energy resources owned by prosumers and sells their surplus energy to electricity markets on their behalf.

3.2.2 electricity prosumer: A market participant who has distributed energy resources that are available to supply surplus energy to a power grid.

3.2.3 electricity brokerage market operator: A market operator who monitors and controls electricity brokerage and trading between electricity brokers and prosumers.

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

ADER Aggregated Distributed Energy Resource

dApp decentralized Application

DER Distributed Energy Resource

ESS Energy Storage System

REC Renewable Energy Certificate

RPS Renewable Portfolio Standard

RTP Real-Time Pricing

5 Conventions

In this Recommendation:

The keywords "**is required to**" indicate a requirement which must be strictly followed and from which no deviation is permitted, if conformance to this Recommendation is to be claimed.

The keywords "**is recommended**" indicate a requirement which is recommended but which is not absolutely required. Thus, this requirement need not be present to claim conformance.

6 Introduction to electricity brokerage

6.1 Electricity brokerage

Due to the rapid spread of distributed energy resources (DERs) [ITU-T Y.2071], it is important to support an open service platform with the capacity for more effective electricity markets and electricity trading in order to increase the efficiency of the electricity grid and reduce electricity grid wastage [ITU-T Y.2072]. With an energy sharing and trading platform, the demand for intermediary trading (i.e., brokerage) of surplus electricity for electricity prosumers in electricity markets is significantly increasing.

Electricity prosumers with small-scale DERs have difficulty in effectively maintaining DER facilities at a low cost and in selling surplus energy and renewable energy certificates (RECs) at a good price in electricity markets due to lack of expertise in energy resources. In addition, the intermittent nature of DERs leads to unpredictability in grid operation and reduction in power supply flexibility.

NOTE – DERs are typically in the range of 3 KW ~ 50 MW; however, small-scale DERs are in the range of less than 1 MW.

To solve the above problems, electricity brokerage is essential. This Recommendation specifies a framework of an electricity brokerage platform from a global perspective. Small-scale electricity brokerage combines various DERs (e.g., renewable energy such as wind power and solar power, demand response resources and electric storage devices) into a portfolio, thereby enhancing the predictability of electric power generation. In addition, it provides a variety of information and supplementary services to support the decision-making of electricity prosumers, and services for assuring the reliability of the consumers for licensing, construction, maintenance and safety management, etc.

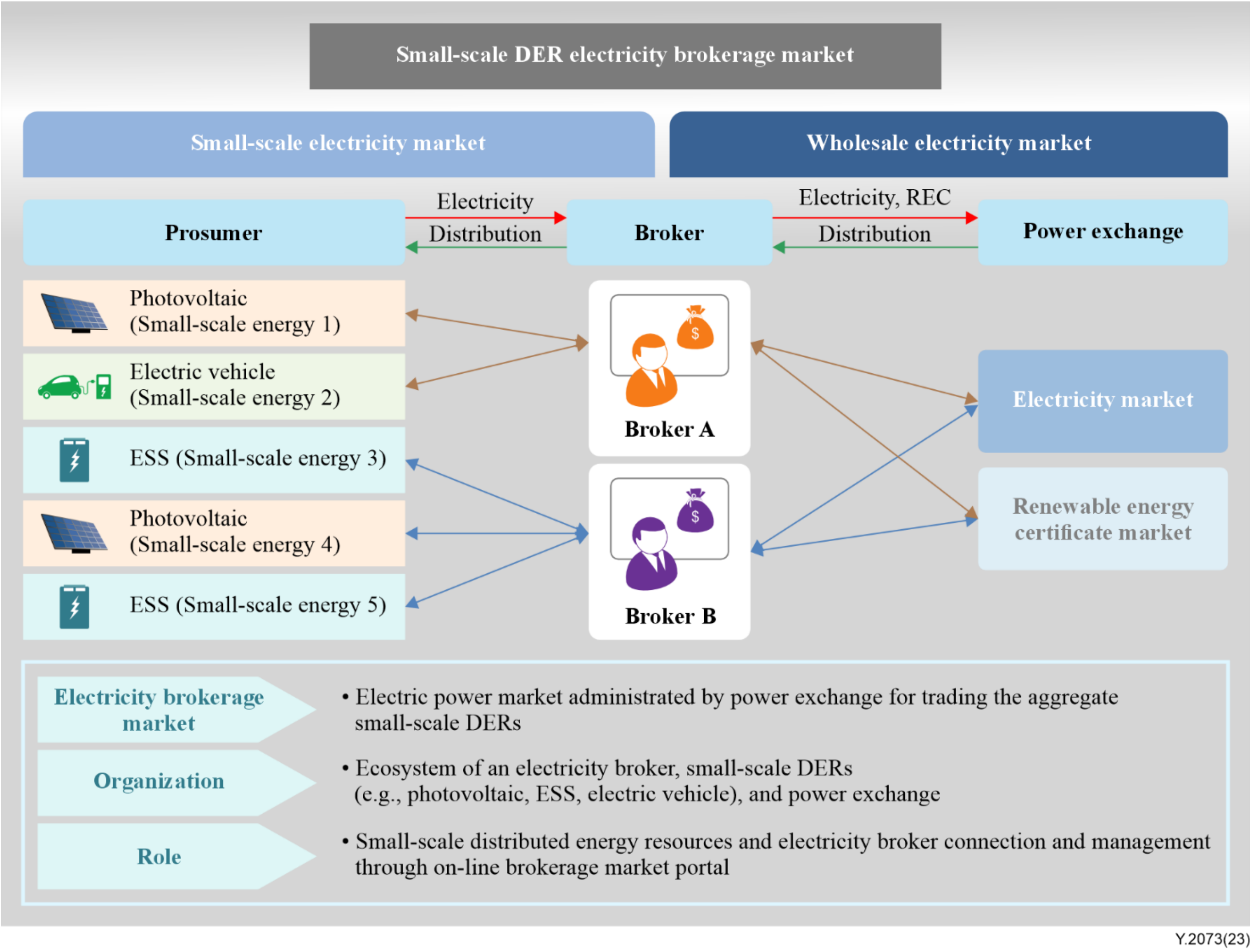

Figure 1 – The concept of small-scale electricity brokerage

Figure 1 shows the concept of small-scale electricity brokerage. The brokerage agency (i.e., broker) provides an intermediary service for trading the aggregated electricity and RECs in the electricity markets based on brokerage contracts with small electricity suppliers (or prosumers). Such an intermediary service needs a sort of common brokerage platform for small-scale DER integration and their surplus energy trading in order to maximize its customer's profit through optimized DER operation and electricity sales bidding.

With a brokerage platform, various supplementary services can be provided to customers. Examples of the services include DER maintenance services, DER data analysis (e.g., power generation forecasting, energy storage system (ESS) optimal scheduling, photovoltaic fault diagnosis) and DER business feasibility assessment services. The brokerage services deal with very sensitive information such as meter data for customer profit settlement. This could make some disputes such as a contractual default, data inconsistency and so on. The cost of solution for the disputes may be excessive. In order to solve the problem, the data integrity and transparency of the brokerage services should be ensured. For this reason, various technologies such as blockchain can be applied to the brokerage service platform. Brokerage contracts or transaction data can be secure on the blockchain. In addition, blockchain-based brokerage platform automatically processes customer profit settlement in real-time by transparently sharing the brokerage transactions and related processes with prosumers through smart contracts.

A blockchain-based electricity brokerage platform involves the following key considerations:

– Group identification for authentication and access control of prosumers participating in electricity brokerage transactions;
– IoT-based meter data management for data collecting, analysing and controlling DERs to support electricity brokerage transactions;
– Distributed ledger to prevent forgery and alteration of data in power generation and electricity brokerage transactions;
– Smart contract to guarantee the transparency of brokerage contract and automated transactions;
– A decentralized application (dApp) to provide smart contract-based supplementary services in electricity brokerage;
– Quantification, distribution and transaction management of the amount of energy for automating the electric power generation and the settlement of electricity brokerage transactions.

6.2 A service scenario for electricity brokerage based on blockchain technology

Considering the support of blockchain technology for transaction transparency (see the use case in Appendix I), this subsection describes a service scenario for electricity brokerage based on blockchain technology.

1) Resource registration

An electricity prosumer requests a power generation resource to be registered in an electricity brokerage market. After the request is approved by the brokerage market, the transaction on the resource approval is generated and stored on a blockchain. Then, the transaction is shared with market participants who have appropriate access rights to the blockchain.

2) Brokerage contract

The electricity prosumer requests the registered resource to be delegated to one of the electricity brokers participating in the brokerage market. Once a broker signs a contract on the delegation of the resource with the prosumer, the brokerage contract transaction is stored on the blockchain. After that, the transaction is securely shared between the contractors through the blockchain.

3) Resource aggregation

The broker creates a virtual large-scale power generator by grouping small-scale resources delegated from electricity prosumers and requests the newly created virtual power generator to be registered on the brokerage market. Upon the registration approval of the virtual power generator, the transaction on the registration approval is stored on the blockchain. The energy produced by the generator becomes reliably tradable on the brokerage market through the blockchain.

4) Energy trading

The broker predicts the amount of energy produced by the registered virtual power generator and places a sales order for the predicted power generation in the brokerage market. The trade for the sales order is transparently processed through the smart contracts deployed on the blockchain. Then, the transaction on the energy trade is stored on the blockchain.

5) Metering and settlement

Electric power meters measure how much electricity is generated by the power generation resources involved in the energy trade. The measured meter data or their hash values are stored on the blockchain. Based on the data and electricity price information, the settlement of the trade is processed through the smart contracts deployed on the blockchain.

7 Requirements for electricity brokerage based on blockchain technology

7.1 General requirements

Blockchain allows prosumers to sell and purchase energy in a manner that has greater transparency, enhanced security, improved traceability, increased efficiency and speed of transactions, with reduced costs. To support reliable and secure energy trading, this Recommendation considers a blockchain-based electricity brokerage platform with the following general requirements.

– It is required to ensure the transparency of electricity brokerage processes among a prosumer, a broker, and a brokerage market;
– It is required to process electricity brokerage transactions in real-time;
– It is required to keep private data secure;

NOTE 1 – Private data includes electricity brokerage contract data and electric power metering data.

– It is required to automate electricity brokerage processes through smart contracts;
– It is required to store electricity brokerage transaction data in a distributed, immutable and shared ledger;
– It is required to regulate the electricity transaction with attributes for service requirements of the electricity brokerage client.

NOTE 2 – The attributes include time tolerance, security considerations, etc.

7.2 Requirements for each stakeholder

1) Requirements for electricity brokers:
   – It is required to create electricity brokerage contracts and electronically sign the contracts on a brokerage platform;
   – It is required to create an aggregate DER (ADER) as a portfolio of DERs on a platform;
   – It is required to create bids for the sale of the power and energy of ADERs on a platform.
2) Requirement for electricity prosumers:
   – It is required to register DERs available for electricity brokerage on a platform;
   – It is required to retrieve electricity brokerage contracts stored on a platform and electronically sign the contracts.
3) Requirements for electricity brokerage market operators:
   – It is required to approve the registration of DERs and ADERs on a platform;
   – It is required to automate bidding for the sale of the power and energy of ADERs on a platform;
   – It is required to store on a platform the meter data on energy consumed or produced from DERs;
   – It is recommended to store electricity price information on a platform;
   – It is recommended to automate profit settlement based on the meter data and electricity price information stored on a platform.
4) Requirements for all stakeholders
   – It is required to retrieve DERs, ADERs, bids and meter data stored on a platform.

8 Architecture overview of an electricity brokerage platform

Electricity brokerage markets can ensure the reliability and transparency of their operation process by sharing brokerage transactions with market participants based on a blockchain. The following describes the electricity brokerage procedure for DERs in electricity markets.

– Resource registration: Electricity prosumers (e.g., DER electricity producers) register their DERs as a power generation resource in an electricity market.

– Brokerage contract: Electricity prosumers delegate the registered DERs to electricity brokers through brokerage contracts.

– Resource aggregation: Electricity brokers group small-scale DERs into an ADER so that its energy can be tradable in an electricity market.

– Brokerage trading: Electricity brokers sell the generation power and energy of ADERs as a form of energy product to electricity consumers through an electricity market.

– Profit settlement: Electricity brokers settle sales revenue and commission after electric power and energy delivery according to the contracted energy supply schedule.

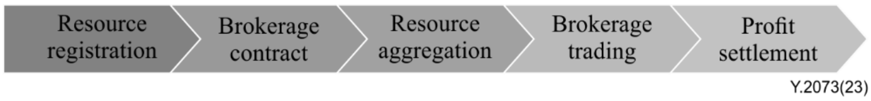

Figure 2 – Electricity brokerage procedure for DERs

Regarding the electricity brokerage procedure shown in Figure 2, Figure 3 shows the conceptual diagram of blockchain-based electricity brokerage platform.

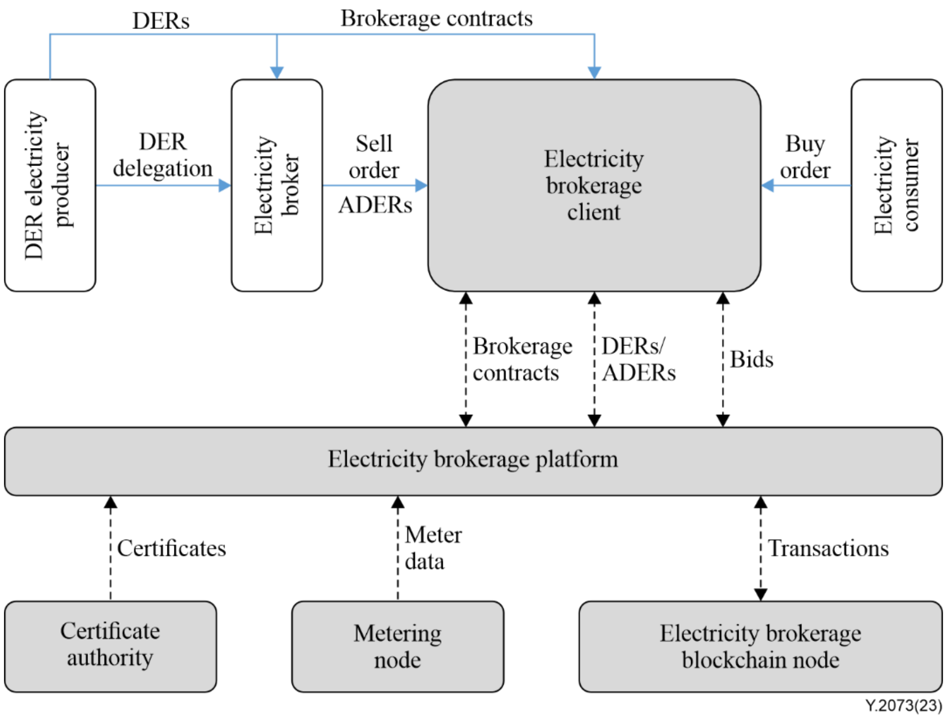

Figure 3 – Conceptual model of blockchain-based electricity brokerage

The following describes the functional components for blockchain-based electricity brokerage:

– **An electricity brokerage client** is a decentralized application that enables market participants to take part in a reliable and transparent electricity brokerage market through the electricity brokerage platform. It also provides functions for market participants to realize their relevant operations.

– **An electricity brokerage platform** provides electricity brokerage clients with common energy brokerage market functions (e.g., identification and access control of market participants, DER/ADER registration, brokerage contract and bidding) through the interaction with other functional components.

– **An electricity brokerage blockchain node** validates the transactions sent from electricity brokerage clients and generates the data blocks that contain the validated transactions based on a consensus mechanism. It also shares the generated blocks with other blockchain nodes on the same blockchain network.
– **A metering node** generates the energy metering data of DERs periodically, and requests to process the data to blockchain nodes through the electricity brokerage platform so that the original or hashed value of the metering data can be stored in a blockchain.
– The **certificate authority** is responsible for issuing and validating the digital certificates for the identification and access control of market participants in order to protect the confidentiality and privacy of brokerage transactions in a blockchain.

9 Security considerations

In electricity brokerage transactions, data privacy is very important. On the one hand, the authentication mechanism of energy stakeholders should be well designed; on the other hand, as specified in general requirements, private data should be well secured. Also note that the information should be isolated for different DERs. The details are outside the scope of this Recommendation.

Appendix I

A use case: Blockchain-based renewable energy certificate trade platform

(This appendix does not form an integral part of this Recommendation.)

I.1 Overview

With the ubiquity of the renewable energy supplement, many countries have tried to encourage the deployment of renewable energy sources to overcome climate change issues, and the concept of the renewable portfolio standard (RPS) has been introduced. The RPS is a regulation that an energy generation company must follow; that is, power generation companies must produce a certain portion of their entire power generation using only renewable energy sources. The main purpose of the RPS is to increase the usage of renewable energy sources. However, the power generation companies have difficulty in achieving mandatory renewable power generation with its own renewable generator because the renewable energy sources have uncertainty and risk to achieve the target electricity supply amount due to many external causes such as weather and the natural environment. Therefore, the concept of the renewable energy certificate (REC) was introduced, which makes possible to trade the quota for the RPS (generated by renewable energy sources) between energy generation companies. To satisfy the required energy generation from the RPS, an individual generation company is able to purchase REC from other renewable energy generation companies.

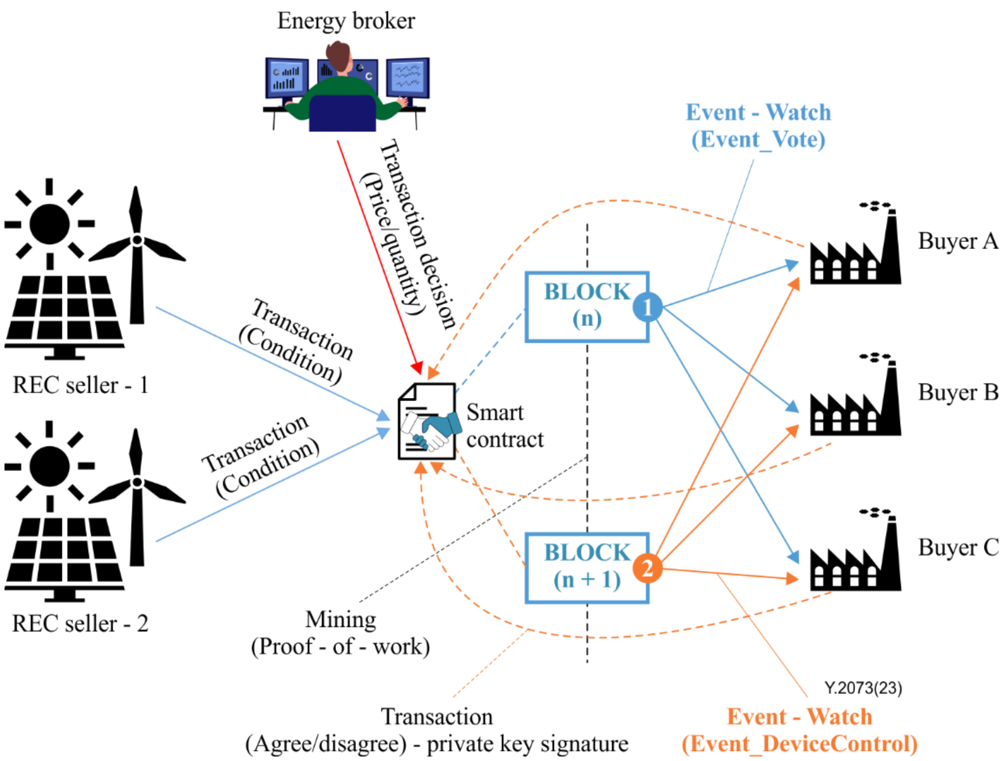

Figure I.1 – Blockchain-based REC trading model

There are two main ways to deal with REC trading. One is a fixed-pricing-scheme-based transaction with a long-term period contract. As an example, a "feed in tariff (FIT)" policy is one possible tariff policy for the fixed pricing scheme in which the energy generation company purchases the entire electricity generated from renewable energy facilities under the standard price announced by the government. The other is a dynamic-pricing-scheme-based transaction through a spot market.

In the former case, there is no problem because the fixed transaction price is constant. However, in the spot market (the latter case), the transaction price is changed dynamically by sensitively reflecting the daily trading volume and/or desired price of the market participants. In addition, in case of trading in the spot market, the transaction results and the retained amount of REC should be recorded in a timely manner and updated based on the real-time trading results. In order to efficiently solve various consideration factors due to the expansion of the spot market, a REC transaction model based on blockchain technology is introduced as shown in Figure I.1. In this model, transaction records between market participants are automatically recorded in blocks. In addition, other market participants are allowed to confirm the block that contains information on previous transactions with the bidding amount and transaction prices. With this approach, it is possible to keep a reasonable price for transaction and to induce a user's participation in the market.

I.2 Blockchain-based certification trading platform

As mentioned above, the transaction of REC in the market is essential to meet the requirements of energy generation facilities for RPS. The blockchain technology in the market not only ensures the automation of transaction and the anonymity of each participant but also makes possible to store transaction records safely in distributed storage.

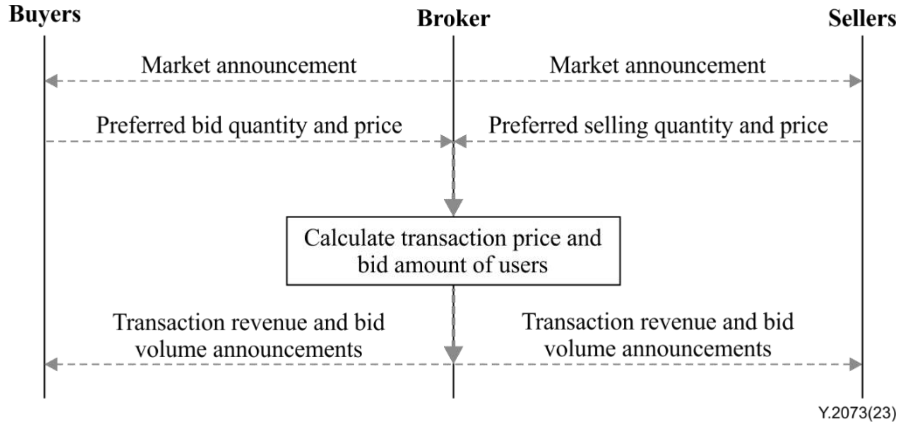

Figure I.2 – A REC transaction scenario based on blockchain technology

Figure I.2 shows a REC transaction scenario with three major market participants: the broker, buyer and seller. The broker announces to the participants (i.e., buyers and sellers) that the REC spot market will take places. When buyers and sellers have been informed about the holding of the REC market, they will decide the amount of REC for transaction and the desired price they need within a certain time period. In the case of the broker, the market is terminated by notifying the sellers and the buyers about the amount of transaction quantity and profit after the bidding result based on the desired decision-making process with the consideration of transaction information collected from the participants. The results and progress of such transactions are handled with blockchain technology. Therefore, information on the number of RECs held by each participant is also recorded in a block.

I.3 Description of market participants

In a particular scenario, the role of the market participants could be described as follows:

– Information announcement task: The broker decides a specific time to announce the market operation for the REC trading.
– Sales information: Sellers participate in the market with retained REC quantity and the desired price.
– Bidding information: Buyers participate in the market submit the desired transaction quantity and price to maximize their own profit.
– Requirements for gathering information:

- The whole of the data is periodically transmitted to the server within a certain time period;
- It is essential for the participants to submit their desired bidding price and quantity;
- The user should be informed of previous transaction prices and any penalty charge in the market.

– Expectation:
  - The transaction result could be stored in the distributed storage safely;
  - The whole of the transactions are operated anonymously without exposing the user's personal data;
  - Sellers can maximize their profit depending on how they participate in the market;
  - Buyers ensure their future profits by buying at a particular price.

1) Broker

Since the transaction process is automatic based on a real-time pricing scheme in the market rather than on the individual decision of each participant, a broker is necessary in the market to determine the trading object and transaction price.

– Transaction price:

  In the market, there are multiple sellers and buyers to maximize their own profit according to the transaction of REC. The most typical pricing decision method is an auction theory (e.g., double auction, naive auction) which derives the proper transaction price to maximize overall social welfare or an individual market participant's profit. In particular, most energy markets use the double auction method, which leads to reasonable pricing decisions in an environment where market participants of various attributes coexist.

– Revenue distribution and records:

  In the REC trading market based on blockchain technology, the broker has two specific roles in the market. One is to distribute the profit for the sellers and REC bid amount for the buyers who succeeded in the bid. The other is to record the amount of individual participant's transaction quantity and manage the additional required REC amount of buyer in the market.

2) Seller

A seller has renewable generation facilities with enough capacity. They are given different weights according to the characteristics of the generators (e.g., photovoltaic energy, other renewable energies), not just the capacity of the equipment they have. In addition, they are weighted depending on the location of the plants and the linkage of energy storage devices.

– Sales price:

  It is necessary to determine a reasonable selling price considering the previous transaction records and forecasting the price changes in future. In addition, the sellers need to minimize the risk of failing to sell REC in the market by considering the price of other competitors in the spot market. In general, REC price tends to rise over time, but not always, so sellers need to determine a reasonable selling price based on the future expected price and their current sales volume.

– Sales quantity:

  Sales quantity is an important factor in determining the income of the sellers. They can sell their own RECs through either the general trading market or the spot market to maximize their profit. When the sellers participate in the general trading market, they can trade their REC at a stable price; however, they could miss the opportunity to sell in the spot market with a relatively higher price. On the other hand, it is possible to sell the electricity with a relatively high price in the spot market; however, the price of electricity in the market could decline due to the huge volume of supply provided from other sellers. Moreover, a loss could be incurred because a bidding process does not take place in time. With the consideration of these cases, the sellers should determine their sales volume reasonably.

3) Buyer

Buyers are market participants who generally obtain the amount of REC that they have to meet in a certain period of time by participating in the market. Generally, this refers to power generation companies, power generation subsidiaries, public institutions and many private operators in the system. To obtain REC at a higher rate and a stable low price, various approaches are needed.

– Bidding price:

  The bidding price must be set by simultaneously considering all of the expected value that the buyers will have. They should take a reasonable strategy based on the penalty that is incurred when they fail to meet the real-time pricing (RTP) requirements within a given period, the average bidding price of other buyers, and the previous transaction records. In addition, it is necessary to determine a reasonable price considering the expected effect of participating in the general market rather than the spot market.

– Bidding quantity:

  The amount of bidding quantity should also be taken into account both the expected profit from the buyer's choice and the prior forecast of other buyers' strategies. In addition, buyers also need to consider the current portion of their REC holdings and remaining time.

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