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Comparative review and discussion on P2P electricity trading

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Abstract

The peer to peer (P2P) electricity trading without the need for utilities is expected to increase as the awareness of the shared economy has grown and the microgrid has spread. Furthermore, the development of renewable energy technology and the Internet technology will accelerate the dissemination of the new system. In this light, this study compares the major P2P electricity trading cases being promoted and reviews the potential development and future challenges. Since there have been little case studies of P2P electricity trading published, this study could be used as valuable information for government and corporations that are promoting or pursuing P2P electricity trading business.

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Keywords: peer to peer; electricity trading; electricity transaction; energy prosumer

1. Introduction

There has been growing number of peer-to-peer electricity trading (hereinafter referred to as "P2P electricity trading") cases developed in areas especially where the electricity trading is deregulated. In 2014, Vandebron, a Netherland-based startup, opened the world's first online market for energy that enables consumers to purchase electricity directly from independent producers. In October 2015, the UK's Open Utility launched a service using an energy trading platform that allows direct trading between commercial power consumers and renewable energy

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producers without going through power utilities. Similar projects are being promoted in other parts of the world such as Germany and the United States.

Although at the early stage, the P2P electricity trading without the need for utilities is expected to increase as the awareness of the shared economy has grown and the microgrid has spread. Furthermore, the development of renewable energy technology and the Internet technology will accelerate the spread of the new system [1–3].

Studies on P2P electricity trading have discussed generally regarding technology development. Since P2P electricity trading is still at an early stage in business, studies are focused on what technology to use in that trading. Alvaro-Hermana et al. [4] presented a novel peer-to-peer energy trading system between two sets of electric vehicles. Inam et al. [5] discussed the architecture and system analysis of microgrids with P2P electricity sharing. Kim et al. [6] proposed P2P energy loan service using block-based P2P loan process. On the other hand, there is an increasing number of studies examining the socio-economic impact of P2P electricity trading, with the expectation that P2P electricity trading will gradually spread. Giotitsas et al. [7] discussed the evolution of energy trading technologies and the impact on the global socio-economic structure. Roy et al. [8] reviewed the potential value of P2P electricity trading in the Australian national electricity market. Burger et al. [9] investigated in some cases using the blockchain technology in the electricity trading. However, overall, from a business model point of view, there was no comprehensive review. In this light, the aim of this study is to compare the major P2P electricity trading cases being promoted and to review the potential development and future challenges. Since there have been little case studies of P2P electricity trading published, this study could be used as valuable information for government and corporations that are promoting or pursuing P2P electricity trading business.

2. Concept of P2P Electricity Trading

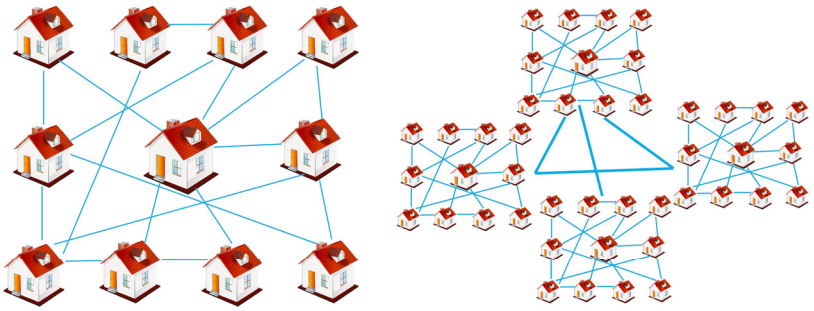
2.1. Similarities of P2P between Electricity Trading and the Internet

P2P electricity trading means that the end consumer becomes a prosumer (functioning as both energy producer and consumer) and exchanges remaining electricity with other consumers in the power grid. It is similar to the way people share information on the Internet.

P2P on the Internet refers to the notion of equal peer nodes simultaneously functioning as both "clients" and "servers" and sharing, exchanging information, where the traditional hierarchies are overturned [10]. Unlike B2C-based commercial transactions, where a few suppliers provide information to a large number of netizens, all members participating in the network become both providers and consumers in P2P.

In the electricity trading, P2P refers to cases where each node of the distributed energy system is given equal responsibility and plays a role in both production and consumption of energy. Energy prosumers in the network can make their energy available to others. The energy prosumers can be seen as part of a supportive network that allows over-produced energy from one node to be automatically used by other nodes in real time. 'Automatic' means that in the process of finding and exchanging excess energy, procedures can make energy transactions with little or no effort [11].

The Fig. 1 [12] below shows how energy consumers directly produce and trade energy. The Fig. 1a on the left shows the electricity trading between neighbors in a small scale, and the Fig. 1b on the right shows a group of small communities forming a bigger electricity trading group. Like P2P in the Internet, critical size is also important in P2P electricity trading. That is, the network is viable only when there are at least a certain number of participants.



(a) (b)

Fig. 1. P2P Electricity Trading Concept [12].

2.2. Differences in P2P between Electricity Trading and the Internet

The concept of P2P electricity trading is similar to that of Energy Internet. The Energy Internet is known to be introduced by Friedman, a New York Times columnist in the U.S. in "Hot, Flat, and Crowded" published in 2008. He argues that the energy production and consumption devices are connected to the network and the output and consumption can be effective through a control device [13]. P2P electricity can be regarded as a type of Energy Internet since the P2P electricity trading is available when the electricity production and consumption devices are connected to the network and checks how much energy the prosumer produces and consumes and the information on energy other consumers need.

However, it is differentiated in that the data transmission path can be determined in advance and buffering or delay occurs, or other information can be stored during transmission process while the electricity flow follows physical laws other than the information flow. The amount of power flowing into the grid through battery discharge must always match the amount of energy that goes out of the grid, such as consumption, loss, and battery charging. The electricity flow follows the Kirchhoff Law. According to this rule, at each electrical node, the inputs and outputs are always the same without buffering, storage, or delay. Even in an abnormal state of the power grid, the balance is maintained. However, in such a situation, conditions such as electrical energy quality degradation, equipment overload, forced load reduction and shutdown may occur [14].

In general, the expression that a particular user buys electricity from a particular power plant is simply an expression derived from a market clearing perspective. At the physical level, the electricity flowing into the electricity grid is the one that all consumers use together. If the grid is connected, it is physically inappropriate for a particular user to use electricity generated by a power plant. In theory, it is not possible for any user to identify what type of power is flowing into a plant. The application of the Internet to the energy sector is for supporting the optimization of the energy flow, not for applying the concept of the Internet mechanically to energy [14].

3. Methodology of the Comparative Review

P2P electricity trading is still unfamiliar around the world. Since the late 1990s, the use of ICT in distributed power distribution has been fully implemented in Europe, and it was expected that individuals would be able to exchange electricity generated from the distributed power sources in the future. Furthermore, the use of P2P in the grid as on the Internet has discussed since mid-2000s when the convergence of energy and the ICT began to emerge in earnest [11, 15]. In the mid-2010s, the P2P electricity trading system is being implemented as a real business type in the area where the energy market is deregulated. In this study, a total of five cases were collected and reviewed, covering both recently commercialized services and pilot services. Case names are Piclo, Vandebron, Yeloha, sonnenCommunity, and Microgrid Sandbox.

P2P electricity trading cases are compared based on the business model components. It has advantages that the business model characteristics of each case can be systematically compared. As for the business model components, each researcher presents various factors. Osterwalder and Pigneur [16] propose customer segments, value propositions,

channels, customer relationships, revenue streams, key resources, key activities, key partnerships and cost structure. Hamel [17] presents core strategies, strategic resources, point of contact with customers and value-creating network. Johnson et al. [18] propose value propositions, a revenue generating method, key resources, and core process, etc. There are also various studies on the business model components. Therefore, this study redefines criteria for a better understanding and comparison of the business models related to P2P electricity trading based on the relatively simple, but currently secured information. The business model is redefined as 'the structure in which the company provides the value that the customer needs and generates revenue,' which is composed of a business entity, customers, trading channels, value propositions and a profit structure.

4. Research Results

All of the five examples have similarities in that online Web sites provide a window for electricity suppliers and consumers to acquire information and conduct transactions. However, different business model components have different characteristics.

Piclo is a UK-based P2P electricity trading platform, which started its service as a pilot project with the support of the Energy and Climate Change Department (DECC) for six months from October 2015 to March 2016, and is expanding its service. The operator of the Piclo is Open Utility, which is supported by Good Energy, a renewable energy company. Regarding profit structure, it is known that the investment of government (DECC) and venture capital (Nominet Trust) is the main revenue source. Open Utility has developed software that connects the electricity providers and consumers whose preferences match and is responsible for attracting customers. Here, the company targets commercial electricity consumers who consume much more electricity than the individual consumers, aiming at renewable energy oriented companies. Good Energy is a 100 % renewable power generation power supplier that provides energy trading, contracting, billing and customer service on the Piclo base. Piclo matches electric power consumers and providers every 30 minutes (48 times per day) using a meter data, power generation cost, and consumer preference information. Electricity suppliers and consumers use Piclo's online services on their computers, smartphones, and tablets [19].

Vandebron's website allows consumers to purchase electricity directly from independent producers such as farmers who own wind turbines on their farms. Existing utility companies do not participate in this transaction. The company was established in 2013 and opened a direct market for renewable energy from April 2014. Customers input the desired type of contract (1 year or 3 years) and the amount of power required on the website. Then they can choose (among) the power producers, and each power producer has a web page that introduces him/her and the type of electricity generation. Vandebron emphasizes that P2P electricity trading benefits both consumers and producers. Producers no longer need to accept the price offered by the utility, so they can get a higher price per unit power. Consumers can save money because they do not have to accept the various charges that electric utilities charge for electricity bills. Vandebron does not charge anything in the middle but charges a monthly subscription fee of about $ 12 a month for both sides [20].

Yeloha allows owners of the solar panel will be installed to rent the place, a part of the electricity produced in the panel to be used, and matches those having difficulty in installing the solar panel to enable them purchase electricity from other panels. [1] The providers of the solar energy are both Yeloha and the site providers for the solar panel installation, and customers are general electricity consumers. It can be regarded as an example of P2P electricity trading in that the owner of the solar panel installation site participates as providers. The Yeloha's revenue structure is as follows: sharing profits with the providers of solar panel installation sites and charging fees to power consumers. According to the Yeloha, the provider of the solar panel installation site can receive a fraction of the power at no cost, and the power consumer can save 5 to 10 % to save on electricity bills [21].

sonnenCommunity is using batteries unlike other operators. Sonnenbatteries, a business entity, allows the installers of the renewable energy facilities to store the electricity from the renewables in their batteries and market the electricity

[1] As of February 2017, the Yeloha's service has been terminated. However, we included the case of Yeloha under the consideration of various business models.

stored in their batteries. Since it enables the owners of the renewable energy generation facilities to produce their electricity and to make money with their remaining electricity, there is a great potential to expand the supply of renewables. The system combines distributed generation, battery technology, and digital networking to create a new way to buy and sell power, replacing traditional power companies. sonnenCommunity subscribers can purchase a smart battery to save surplus power from their solar panels for 3,599 euros, and consumers pay 25 cents / kWh to power producers. For Sonnenbatteries, the battery sales are a primary source of their revenue [22].

The Micro Grid Sandbox is a new microgrid project in Brooklyn, New York that tests systems that enable power trading between neighbors, independent of the existing power companies. It is a pilot project to be implemented in the microgrid and is unique in that it uses the block chain technology called Etherum to minimize the role of intermediate intervention. The specific profit model for the business owner is not yet known, but it is expected to use this model as one of the future microgrid solutions [23].

Table 1. Comparison of Major P2P Electricity Trading Cases.

Case	Business Entity	Customer	Trading Channel	Value Proposition	Profit Structure	
					Supplier-Consumer	Business Operator Supporting Trading
Piclo	Open Utility (Platform building), Good Energy (Renewable energy power company)	Independent renewable energy suppliers and commercial power consumers using a large amount of energy		Matching the preferences of renewable energy providers and consumers and DUoS (Distribution Use of Service) information service	Marketing at the price preferred by suppliers, reducing the consumers' costs of DUoS and shaping image of clean energy consumer	Investment by government and venture capital
Vandebron	Vandebron-centered	Independent renewable energy suppliers and renewable energy preferred power consumer		Matching the preferences of renewable energy suppliers and establishing local clean energy community	Marketing at the price preferred by suppliers and reducing consumers' electricity fees	Charging a monthly subscription fee of about $ 12 a month for both providers and consumers
Yeloha	Yeloha-centered	Land owners who can provide sites for solar panel installation	Website	Installation of solar panel by the owner of the installation site and no charge for management cost	Reducing electricity fees of both the owners of the solar panel installation sites and consumers	Sharing profits with installer of the solar panels and charging fees to consumers
sonnenCo-mmunity	Sonnenbatteries-centered	Renewable energy-battery link suppliers and subscribers of sonnenCommunity		Stable power supply utilizing batteries and provision of surplus power pool	Suppliers securing more revenue than when supported by FIT and reducing consumers' electricity fees	Sales of batteries
Micro Grid Sandbox	Lo3 Energy (Micro Grid Developer), ConsenSys (Bitcoin Trading Developer)	Renewable energy suppliers in the microgrid and renewable energy preferred consumers		Minimizing intervention by applying block-chain technology	Marketing at the price preferred by suppliers and reducing consumers' electricity fees	Expanded application when the spread of microgrid in the future

5. Discussions and Conclusions

As we have observed in the above cases, the P2P electricity trading has been promoted in various forms, starting in the Netherlands, then Germany, the United Kingdom, and the United States. The cases vary as we have seen in the Piclo; an IT company operating P2P electricity trading online windows, a cooperative model of the power companies dealing with transactions, contracts, and billing, a P2P electricity trading using energy storage devices like sonnenCommunity, and a case applying new technology used in Bitcoin transactions while directly supporting transactions within the microgrid like Microgrid Sandbox. Additional business models are expected to emerge in the future, and the convergence type of other operators' business models will increase.

P2P electricity trading is supposed to contribute to expanding small-scale distributed resources and creating new markets. The main advantages of this system are the energy they generate on their own can be linked to the profit not

discarding it; the power generation can be made meeting the requirements of the end users; and the utilization of the resources can be optimized through the cooperative network between producers and consumers [11].

To make the P2P electricity trading viable, we should secure the profitability of the business first. In the examples we have seen above, all business models have a structure that benefits both prosumers who sell electricity from renewable energy and consumers that purchase electricity from the prosumers. To take an example of the German's sonnenCommunity, consumers pay 25 cents/kWh to power producers, which is lower than the electricity price paid to utilities for consumers and bigger than the profits earned from the Feed in Tariff (FIT) for prosumers. This business modle is possible when renewable energy or electricity supply costs are lower than the existing electricity rates. All of the cases examined in this study utilize structures that can benefit prosumers, brokers, and consumers in areas where the electricity market is deregulated. In the future, P2P electricity trading will continue to expand as the number of areas where electricity brokerage business is permitted increases and renewable energy and storage devices costs decrease.

It is also expected that the technological development of energy storage devices will play a major role. The electricity produced by the prosumer through renewable energy has irregular output. When these distributed resources are concentrated in some areas, the voltage rise may occur locally for a certain time and the electric quality may be deteriorated. Small-scale renewable energy producers generate irregular output electricity, but consumers want to be supplied with electricity in a stable manner. To address these inconsistencies and maintain the balance between supply and demand, special means are required. The Germany's Sonnenbatteries promotes P2P electricity trading business by combining distributed power generation, energy storage technology, and digital networking technology. To provide better services for maintaining the balance between supply and demand at Piclo, the UK's Open Utility also plans to submit a proposal to the Office of Gas and Electricity Markets (Ofgem), a UK electric gas regulator, to utilize energy storage systems (ESS). A significant technical challenge of the P2P electricity trading is that every node in a P2P network must be responsive to grid conditions, energy prices, and local energy supply and demand. The development of ESS is expected to contribute to solving these technical problems.

The recent P2P electricity trading is in its early stage, where it is still difficult for individuals to freely trade electricity, and the scale is also rather small. Thus, this study mainly examines what type of business is being promoted globally and the environment in which P2P electricity trading can be spurred.

Some view the P2P electricity trading as shared services such as Airbnb and Uber, and others think from an energy democracy point of view that the power distribution can be used without discrimination. More and more individuals are increasingly producing electricity, sharing or trading surplus electricity, raising their voices in the energy economy.

In the future, if the price of renewables is relatively competitive and the P2P electricity trading is more activated, the following should be taken into account: how the impact on the grid will be, how the increase of distribution network costs should be shared fairly, and how the existing centralized power supply system will be changed in the new electricity trading environment be harmonized with the new system. The environment in which P2P electricity trading is active will be different from the current electricity market, and the power load, the competition structure of the market participants, and the trading system will undergo major changes. Therefore, a number of issues that are not covered in this study should be additionally discussed in the future.

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