Market Design for Renewable Energy Dissemination

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Keywords: Electricity Market, Renewable, Economics, Mechanism Design, Finance.

Abstract: Renewable energy has less environmental impact and little marginal cost. Due to this nature, it is desirable to disseminate it from the viewpoint of economic efficiency. On the other hand, because of the uncertainty of the supply of renewable energy and the specialty of electricity as goods, it is difficult to achieve efficient allocation even if the normal competitive market is applied as it is. Problems such as how to secure power capacity and how to deal with the risk of power outage are concerned in European countries that have already adopted measures to cope with these problems in practice. These problems suggest that a new market design is required for the power market.

1 INTRODUCTION

Since the 20th century, various technologies were developed to respond to the increasing demand for energy. However, it remains as a negative heritage such as environmental pollution caused by fossil fuel power generation and accidents caused by nuclear power generation and issues for the 21st century society. In Japan, the declining birthrate and the aging of society will proceed and it will be difficult to achieve sustainable development. One of the most important tasks of the society is energy sustainability including resource and safety. While as the population decreases, the energy consumption in the industrial sector can decrease, on the other hand, the mechanization to compensate for the decrease in workers progresses, the energy consumption accompanying this can increase conversely. It is necessary to incorporate it into society in a sustainable manner. Renewable energy has already been used as one of the major energies in various countries including Europe, North America, Canada and elsewhere. Also in Japan, after the nuclear accident, the spread of renewable energy has become a national consensus. Japanese government began the liberalization of electric power, and seek the way how to disseminate renewable energy in that market.

In order to disseminate renewable energy in the electric power market, it is necessary to deal with various problems. We outline the past research to deal with problems accompanying the introduction of renewable energies into the electricity market, and show the future prospect. The composition of the paper is as follows.

Section 2 briefly outlines the current state of renewable energy and the electricity market in several countries. We will introduce examples of European countries, and the US which have already introduced liberalized power markets and are proactively promoting the spread of renewable energy. In addition, we will introduce the cases in Japan aiming at dissemination of renewable energy.

Section 3 explains the basic theory of the electricity market. We will explain the point different from the goods handled in ordinary economics, such as inelastic demand curve and the difficulty in saving, while reviewing previous research. The specificity of the electricity market is a factor hindering efficiency, and understanding this is indispensable to consider the introduction of renewable energy.

Section 4 explains various problems caused by introducing renewable energy and introduces previous research including capacity market. Renewable energy such as solar photovoltaic and wind power is highly uncertain because essentially the amount of supply depends on weather and other changing environment. How to deal with the uncertainty is required when designing the market. Based on the above points, we will look at what kind of market design is necessary to promote renewable energy.

Maekawa, J. and Shimada, K.
Market Design for Renewable Energy Dissemination.
DOI: 10.5220/0006786703200324
In *Proceedings of the 7th International Conference on Smart Cities and Green ICT Systems (SMARTGREENS 2018)*, pages 320-324
ISBN: 978-989-758-292-9

2 THE CURRENT STATE OF RENEWABLE ENERGY

Western European countries can be said to be the most developed country of renewable energy among the world. They carried out various renewable energy promotion policies and called for active investment in mega solar, large offshore wind power plant and so on. In Spain, there exists a large amount of wind power plant, which generate 19% of total electricity. Moreover, they have about 40% share of renewable in electricity generation in 2015.
Germany also achieve 25% in renewable, also in the sunlight and wind power. German Chancellor Merkel pledged to stop all nuclear power plant and to raise the ratio of renewable energy to 35% by 2020. Although it was temporalily affected by the fixed purchase system and suffered from the electricity price, at the present time it also converged and is about to turn into a most developed renewable using country.
Scandinavia is a region with high motivation for renewable energy alongside Western Europe. Denmark has traditionally used coal imported from Russia, but in recent years it has focused on the introduction of renewable energy, especially wind power generation, in order to lower its dependence on Russia ing. Currently only wind power generation covers 40.6% in 2014. Similarly, Norway has mostly generated power by hydropower and Iceland, which has a special geographical environment, produces 28.9% of the power in geothermal power generation, boasting a 100% power generation share only by hydropower and geothermal power.
Although it is a US rich resource such as shale gas, the introduction of renewable energy is also progressing. In fiscal 2015, they have a share of 12.9% with renewable energy. The United States is still share target of renewable energy at the federal government level is not set, many of the state governments are doing a voluntary RPS set. Especially famous is the goal of California State's 33% by 2020 (including hydroelectric power generation and nuclear power not included). Former President Obama planed to double the renewable energy generation volume by June 2013 in the Action Plan on Global Warming Countermeasures by 20 years, while the state government plans to double the renewable energy generation amount in December and instructed to raise the ratio of renewable energy to electricity consumption to 20%, which is more than twice the current level by 2020.
Japan is now at a major turning point of energy administration. From the impact of the Fukushima nuclear power plant accident all nuclear power plants are stopped and depend on imports for most of raw materials such as petroleum and natural gas. In this situation, despite the large incentive to introduce renewable energy, the current renewable energy ratio is only 12.2%, only 3.2% except for hydraulic power. It can be said that it is considerably behind compared with the introduction situation of developed countries. Meanwhile, the trend toward liberalization of electric power is also slow, retail liberalization has finally just begun in 2016. The government is currently pursuing the liberalization of electric power and the spread of renewable energy in parallel under the Tohoku earthquake and the Fukushima nuclear power plant accident, but the resistance and the like of existing electric power companies are also large, and the outlook is uncertain.

3 OUTLINE OF ELECTRICITY MARKET

Power supply was commonly monopolized by government and government enterprises. However, as monopoly restrained price competition and the incentive for technological development to be born became problematic, liberalization tried in the United States from around 1990.
It was technological progress that supported the trend of liberalization. Electricity business has been regarded as rational because monopoly was considered reasonable economically because it was thought that it is difficult to individually manage shipping charges. However, due to the development of a gas turbine that can be installed at low cost, and the advancement of the information industry has made it possible to operate a large amount of electric power, technological liberalization became possible.
Started experimentally in the United States and the UK from the 1990s It is somehow liberalized in about half of the world by 2010. On the other hand, it is estimated that liberalization is the cause, like California big blackout that occurred from the summer of 2000 to the following year. A consensus has arisen as to whether some mechanism is necessary.
Electricity has characteristics not found in ordinary goods First of all, as the biggest feature, savings may require high costs. Many of the problems related to electric power are generated from this feature. If the supply amount exceeds the demand amount, it can not be stored, which may cause power failure. Also, because it is costly to throw out excess electricity, it is traded at a negative price, or repurchased by the power generation company may occur.

Since the marginal cost is almost constant with the same power generation method, the power generation

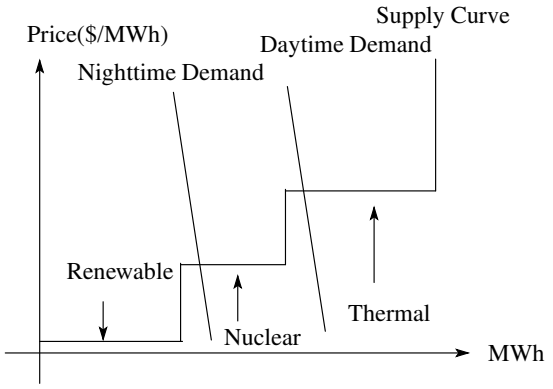

Figure 1: Electricity Market.

company efficiently generates power to the limit in a way that marginal cost is low according to demand. This representation is called merit order curve. Renewable energy such as sunlight, wind power, and hydroelectric power is located at the left end in the merit order curve because there is little marginal cost. From there, it is in line with nuclear power, coal, oil and natural gas. This is the supply curve of the power market.

Power demand is also characteristic. It is known that electricity demand is very inelastic to price. Naturally, it is a major reason why electricity is an essential item. Electric power is one of the infrastructure of modern society, and it is very difficult to live without electric power in developed countries. It is also affecting that almost no electricity can be saved. If electricity can be saved at low cost, it will be flexible with respect to price as it is possible to buy electricity when the price is cheap and to consume when the price is high. Also, although it is inelastic to price, the amount demanded increases and decreases greatly depending on time of day and season. It is necessary to move the personal computer in the office during the day and turn on the lights in the room, and it is necessary to adjust the temperature by turning on the air conditioner in the summer and winter.

The nature of such demand has naturally been a major factor justifying the supply side's monopoly. It seemed that centralized control is necessary because the supply must be adjusted in preparation for the increase or decrease in demand.

Since the supply and demand of electric power must be consistent, it is necessary to provide high power capacity in case of high demand. However, consumers are unaware of the outage cost and power capacity has a property as a kind of public good, so it is difficult to secure adequate power capacity in the normal electric power market. Mechanism other than the electricity market that secures capacity is called capacity mechanism. Because it occurs mainly with the expansion of renewable energy, it will be explained in detail in the next chapter.

Also, the transmission system is a matter not treated in normal economics. There is a limit to the electric power that can be transmitted at one time, and if it is overloaded, it will cause power failure. In addition, economies of scale are strongly present and often become factors for monopoly of power companies. For this reason, in many countries, electricity transmission and separation has been carried out, and power transmission companies are required to have strong neutrality.

By introducing renewable energies, more serious problem occurs. We introduce two main problem, instability and capacity.

4 THE MECHANISM DESIGN FOR RENEWABLE ENERGIES

The supply of renewable energy, especially sunlight, wind power generation is susceptible to weather.The instability of renewable energy is a major disadvantage because there is a characteristic that power supply must always be consistent with demand. In order to disseminate renewable energy in the power market, a mechanism to cope with this instability is indispensable. Until now, this instability did not become a problem because thermal power generators etc., which can flexibly control the amount of power generation, occupied a large proportion of power generation. However, in Germany and other advanced energy-conserving countries, the ratio of renewable energy has increased, so negative charges frequently occur in the power spot market.

Firstly, the unstable supply of renewable energy indicates that the cost for adjusting supply and demand will increase. It is necessary to be able to trade electricity until just before generated. Furthermore, it is important to increase the liquidity of electricity. Some researcher investigated the wind power generation in Germany pointed out the importance of increasing the liquidity of electricity(Holttinen(2005 (1), Ummels et. al(2006) (2)). Naturally, as prediction accuracy increases as approaching that day, being able to trade electricity to a point just before electricity in even finer time period will increase the liquidity of electricity.

In countries with advanced electricity liberalization, such as Europe, most power trading is traded in the market a day ago, but the inconsistency of ex post factual supply and demand has been adjusted in the imbalance market on the day. It is necessary to advance such market design. Also, trading is possible in units

of 15 minutes. Also, in order to cope with instability, it is also possible to deal with by placing a transmission network. In Europe, as a Congestion Management, cooperation lines with neighboring countries exist, power trading is flexibly carried out, and imbalance due to power generation with large fluctuations like renewable energy is being handled(see ETSO(2006) (3)). Although basic transmission power plan is decided the previous day, it responds to the last change through transaction.

Besides instability, there is a problem of how to secure capacity. Renewable energy is unstable, but since marginal costs are hardly applied, once fixed costs are paid, it is possible to supply electricity at a very cheap price. As a result, it is conceivable that electric power having a high marginal cost in the electric power market, for example, fire power, is driven out of the market.

Several mechanism are implemented in Capacity Problem. In normal microeconomics, entry and exit from the market through such price is essential to achieve efficiency. However, electricity like thermal power has advantages as a flexible power source that can easily control the amount of power generation as necessary. Renewable energy is unstable, so it is not always possible to supply sufficient power. There is a possibility that the electric power supply must always be consistent with the demand, so there is a possibility that a system for preparing for a situation of power tightness may be necessary(Joskow(2008) (4),Cramton(2013) (5)).

It is difficult to achieve efficient allocation even if the ordinary competitive market is applied as it is. There are concerns about how to secure electricity capacity in European countries that are actually proceeding, and how to deal with negative electricity prices due to oversupply. On the other hand, focusing on systems far from the market against such problems. For example, to solve the problem of pushing out thermal power generation, policies such as separately preparing a standby power supply are taken. However, it is undesirable for the government to intervene inadvertently in economics as it causes inefficiency.

If we take advantage of the knowledge of economics from now on, it will be necessary to take two viewpoint of mechanism design and finance.

Mechanism Design is one of the most powerful tool in economics. The goal is finding the system or rule which bring the efficient allocation.

For example, in auction theory, we can get the efficient allocation by second-price or first price auction. In these auction, bidders have incentives to tell the true value about the goods and the efficient allocation, in which the most highest bidder win, is achieved by these information.

For example, several capacity mechanisms such as Strategic Reserve, Capacity Payment, Capacity Obligation, Reliability Option are implemented. In any mechanism, the government or the capacity market measure the vlaue of capacity and determine the payment to the supplier of capacity.

In each mechanism, increasing the capacity is incentive compatible for the suppliers. In the liberalization of electricity, efficient allocation is achieved only if consumers and suppliers' incentive are satisfied. In the theory of mechanism design, we can find the efficient allocation with the incentive of players. Mechanism design is a necessary theory basis in electricity market.

There is also a strong persistence of the idea that capacity should be secured through the electricity market (Energy Only Market, EOM). For example, Texsus state's policy is based on EOM and the reserve power rate decrease in recent years.

For the instability problem, financial economics is useful tool. In financial economics, we can treat instability of asset return as a risk. Currently electricity is trimmed in approximately 1 hour or 30 minutes blocks. So, electriccities can be traded as time dependent goods. We can denote the time t electricity as x_t. If renewable energies increase, x_t varies. Let x_{tj} be the electricity at time t and state of enviroment j. j express the daylight hours, the rainfall, wind speed etc. For covering the risk, we need more various trade. In economic theory, efficient allocation can be achieved if we can trade every x_{tj}(Arrow-Debreu Economy). However, it's impossible to create all state electricity market. There are infinite environmental conditions j.

Financial economics have many tool for treating x_{tj} As for assets such as stocks, land, corporate bonds and government bonds, the profit varies greatly. The problems like how to cope with such fluctuations or how to reduce the risk or who is responsible for the risk is the fundamental consciousness of finance.

Since electricity is not simply a tradable item, it is also necessary to think in the field of mechanism design. Mechanism design is a field that considers efficient resource allocation methods that are not only in the market, as represented by auction theory. There are still many fields in economics that can be applied to research on electricity markets and renewable energy, such as finance and mechanism design.

It is desirable for society to build a theory to comprehensively analyze not only theories as current complementary tools but also the electric power market and renewable energy itself right.

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