Research on European Union Transnational Electricity Market Construction and Renewable Energy Transaction Mechanism

Pengcheng Zhou 1, * Jiawen Ye 1, Weicheng Chen 1, Liang Zhao 2 and Ming Zeng 1

1 School of Economics and Management, North China Electric Power University, Beijing, China
2 Nanjing Branch of China Electric Power Research Institute, Nanjing, China

*Corresponding author e-mail: zhoupengcheng810@163.com

Abstract. This paper studies the construction of European Union’s transnational electricity market and the mechanism of renewable energy power generation. This paper systematically summarizes the typical European Union countries’, such as Britain, Denmark, Spain, power market structure, policy, and trading mechanism, and studies the current situation of European electricity market under international supervision system. The research of this paper lays a foundation for clean energy power transmission and rationalization of intercontinental market and provides the basis for the construction of the transcontinental electricity transaction mechanism.

1. Introduction
The European Union electricity market reform began in 1990, and its main goal is to build a unified electricity market to promote the overall economic benefits. At present, in addition to very few countries, the European Union member countries have basically established electricity market and granted all end-users the option to purchase power. In April 2009, the European parliament passed a law, allowing the European Union to liberalize its electricity and gas markets. To achieve the goal of establishing a unified European electricity market, ERGEG initiated the regional electricity market plan in 2006. At present, the European regional electricity market is divided into seven regions, namely, Central West Europe, Northern Europe, Northwest Europe, Central South Europe, Southwest Europe, Central East Europe and the Baltic sea. Among them, the Central West Europe electricity market and the Northern Europe electricity market were operated earlier. The framework of five countries joint power market coupling among Belgium, France, Germany, Netherlands and Luxembourg consists of 6 parts, namely, TSO Background System, Power Flow Based Computing System, Bilateral Trading System, Market Entity, Market Joint & Matchmaking System and Electric Exchange Trading System [1]. Among them, the framework of trilateral market coupling among France, Belgium and Netherlands includes Power Exchange Institution, Transmission System Operating Mechanism, and Market Entity. In generation side, European countries have a high degree of marketization, and their generation prices are formed by the market mechanism. In transmission and distribution side, most European countries’ transmission and distribution prices are regulated by governments, and they adopt the regulation policy on retail electricity price.
2. Construction of European Union transnational electricity market

2.1. Electricity construction
As of the beginning of 2016, the total power generation installed capacity of the European Union was 908GW, and the power structure was still dominated by natural gas generation and coal power generation (38.6%), as shown in Figure 1. In 2015, the new power generation installed capacity of European Union was 28.9GW, which was mainly wind power and photovoltaic power generation, reaching 12.8GW and 8.5GW respectively. In 2015, the European Union's decommissioning power generation installed capacity was 18.2GW, of which coal, gas and fuel generating units were 8GW, 4.3GW and 3.3GW, respectively.

![Figure 1. The composition of EU installed capacity in 2015.](image)

By the end of 2015, the British government announced plans to close all coal-fired power plants by 2025, so as to better achieve the goal of reducing carbon emissions (a decrease of 50% in 2027 compared with 1990). With the implementation of coal power shutdown, the government will increase other power supply plans accordingly, and it is expected that natural gas generation, nuclear power and renewable energy generation will gradually become the main power source. At the same time, the interconnection of the power grid will be strengthened, and the import of electricity will be increased to meet the needs of the power supply [2].

2.2. Electricity grid construction
The EU has set a goal for the transnational transmission capacity of all member countries to reach 10% of their power generation capacity by 2020. Around this goal, the European Union will continue to increase financial support and promote the construction and upgrading of transnational power grids, so as to support the development of large scale electricity transactions and optimize the allocation of resources. [3]

The governments of Spain, France and Portugal issued a Madrid declaration about the energy cooperation plan. The cooperation plan includes two aspects of electricity and gas supply, and electricity aspects include: to build an undersea tunnel and two land transmission lines connecting Spain and France, and a land transmission line connecting Spain and Portugal, which will greatly improve networking capabilities of the European Union.

In June 2015, by providing technical support and regular monitoring to Portugal, Spain and France and other member countries, the European Commission has promoted the construction of natural gas
and electricity infrastructure in southwest Europe and promoted the interconnection between Iberian Peninsula and other European Union countries. At present, the European Commission has initiated two studies to support the work of the senior working group, which are to investigate the benefits, costs and technical feasibility of connecting the electricity and gas markets in southeast Europe. Currently, the proportion of Spanish and Portuguese transnational transmission capacity accounts for less than 4% of its power generation capacity. The senior working group will focus on the implementation of the European Union's 10% power transnational transmission goal, especially the two-power line construction of Biscayne Bay and Pyrenees Mountains. In December 2015, two new electricity transmission lines connecting Lithuania, Poland and Sweden were put into operation, which is the first time that the Baltic Sea countries are interconnected with the Swedish and Poland power grids. The LitPol Link line connects Lithuania's Alytus and Poland's Elk, and the Nordbalt line connects Sweden's Nybro and Lithuania's Klaipeda. The operation of these two lines will increase the electricity transmission capacity of 1200MW between these areas. Prior to that, the power network in the Baltic Sea area was connected to other European Union countries through only two lines (Estlink1 and Estlink2) between Finland and Estonia. This is another regional cooperation achievement under the framework of the Baltic Energy Market Interconnection Plan (BEMIP).

In early 2016, the EuroAsia inter-connector project, which connects the power grids of Israel, Greece and Cyprus to the European continental grid, launched a preliminary feasibility study, and the project entered the implementation phase. The project was first launched in January 2012, with a single-directional transmission capacity of 2000MW and a total length of about 1520km. The implementation of the project will put an end to the status quo of energy islands in Cyprus and the Greek island of Crete, help to solve the problem of electricity shortages in Israel, Cyprus and parts of Greece, and promote the realization of the goal for the transnational transmission capacity of all member countries to reach 10% of their power generation capacity. The project is listed by the European Union as one of the Projects of Common Interest (PCI).

2.3. Electricity market construction

In recent years, under the overall framework of the European unified electricity market, European Union member countries have continuously deepened their power market construction and strengthened regional energy cooperation [4]. In 2015, Latvia opened its retail market and established a Nordic and Baltic area general power exchange. In addition, Latvia, Estonia and Lithuania together with Germany, Poland, Finland, Sweden, Denmark and the European Commission signed the updated memorandum of Baltic Energy Market Interconnection Plan (BEMIP). According to BEMIP, the Baltic countries will gradually introduce the Nordic electricity market model, and take some measures, including: eliminate multinational energy trading restrictions, reduce cross-border electricity transmission congestion, increase system reserve capacity, deregulation price. Moreover, the Baltic countries need to further accelerate the construction of transnational transmission facilities, including interconnection lines between the Nordic countries, the Baltic countries and the Nordic countries, Poland and Germany, etc.

In March 3, 2016, a memorandum of cooperation was signed by 16 European grid operators, determining that Central West Europe and Central East Europe will establish a unified day-ahead market, and a general method to calculate the power transmission capacity based on the power flow. And the unified day-ahead market includes 13 Central European countries, such as France, Germany and Poland, etc.

3. Transnational Trading Mechanism of Renewable Energy

3.1. Nordic Market Trading Mechanism

The power structures of the four Nordic countries have some complementarities, which lead to frequent cross-border electricity transactions, and the cross-border electricity exchanges constitute up to 16 percentage of total electricity consumption. Especially, much renewable energy is traded among
Denmark, Norway and Sweden. When wind power generation exceeds its electricity needs in Denmark, the excess energy will be transmitted to Norway and Sweden, so that water resources for power generation can be saved in these two countries. When there is no wind in Denmark, hydropower stations in Norway and Sweden begin to operate and then electricity is delivered to Denmark.

The strong interconnection of the power grids in the Nordic countries makes power transmission to each other [5]. In 1965, Jutland in Denmark was linked to Sweden by cables. In the 1970s, Denmark was linked to Norway by cables that crossed the Skagerrak strait. Cables and lines laid on the ground, under the sea and in the air ensure that wind power can be delivered from wind turbines on the west coast of Jutland to users who need electricity around the Northern Europe. The electricity transmission between Nordic countries is frequent, electricity import and export in Denmark is about 10 to 11 billion kWh in one year, which is equivalent to 30 percentage of the country's total electricity consumption. The Danish power grid connects the Nordic countries with the European continent. The strong European power grid system is the precondition for the large-scale grid-connected generation of renewable energy and the optimization of the existing grid.

3.2. Spanish Market Trading Mechanism
Wind energy resources in Spain mainly concentrate in the northern and southern coastal areas, and wind farms are also mainly developed in large or medium scale fields. However, its electric load areas are mainly distributed in central Madrid and Barcelona in the east, which leading to a large amount of wind power to be regional transmitted. In recent years, Spain has mainly focused on 400kV backbone grids in power grid construction. From 2005 to 2009, 1,180 kilometers of new 400kV transmission lines were added, which accounted for 69.6 percentage of the new lines, and the substation capacity increased 21.9 percentage. In 2016, the installed capacity of wind power in Spain has reached 3000MW, and the scale will be further expanded. Therefore, Spain plans to continue to increase the construction of high-voltage transmission grids and issued a power grid planning program of 2019. From Galicia to Asturias in the northwest area, 500 kilometers of 400kV line was newly built, from Murcia to Andalucia in the south area, that is about 650 kilometers, from Manzanares to Brazatortas in the middle area, that is 500 kilometers. When strengthening the construction of domestic power grids, Spain also plans to strengthen networking with neighboring countries such as France and Portugal. Red Electrica de España (REE) and Electricity De France (RTE) jointly constructed a 400kV double-circuit on same tower transmission line that links Spain and France. Its maximum transmission power is 2160MW and it strengthens the connection with the power grid in European mainland and enables larger-scale transmission and consumption of wind power.

3.3. Nordic Hydropower Market Trading Mechanism
Nordic Hydropower can participate in the spot electricity market. The reason is that the Nordic electricity market includes both medium and long-term markets as well as the spot market, but the medium and long-term contracts are mainly financial in nature, and its uncertainty and physical delivery are realized by the spot market. The Nordic hydropower resources are mainly distributed in the north area, and its water energy transport needs long-distance transnational electricity transmission.

4. Conclusion
From the current status of the global electricity market, it can be found that the development level of electricity markets in various regions is uneven. In the EU, relatively complete power trading mechanism and a transnational power trading market have been formed. However, renewable energy potential in most European countries and regions is still not fully developed, and countries are still continuously improving the design of the electricity market to better use renewable energy sources. With the further development of the global energy internet and the large-scale renewable energy grid-connected, the EU actively promotes cross-regional and transnational electricity trade and strengthens the construction of backbone networks and transnational networks in order to optimize the allocation of renewable energy in a wide range.
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