Participation of distributed energy resources and renewable energy resources in different electricity market modes

Wei Zhang1, a, Xinglang Xie1, Chaolin He1, Haixin Ma2
1Digital Grid Research Institute, China Southern Power Grid. Guang Dong, Guang Zhou, 510000, China
2Guangzhou Zenithsun Technology Co., Ltd. Guang Dong, Guang Zhou, 510000, China

a zhangwei7@csg.cn

Abstract. At present, the domestic power spot market has just started, and the impact of distributed power and renewable energy power generation on power dispatch and market transactions needs further analysis. The electricity market models in Europe, North America and Australia are analyzed in this paper, and their impact on the market participation of renewable energy and distributed power is explained. First of all, the characteristics of each market system are briefly described, and then the transaction data of the current market and the intraday spot are compared and explained. The advantages and disadvantages of various market transactions are analyzed. All the analysis is to provide insight into china’s spot market construction for distributed energy resources and renewable energy resources.

1. Introduction
With the development of the electricity market, more and more market participants are participating in the transactions in the current market and real-time market. Renewable energy and distributed power, as a kind of market participants with high flexibility, are greatly influenced by the trading mode and operation mode of the power market [1]. At present, China's power market construction is just in its infancy, and there is still a certain gap in relevant experience. Therefore, it is necessary to sort out the experience of foreign advanced power market operation, distributed generation and renewable energy participating in power market transactions.

Based on the mature experience of major European and American power markets, this paper first analyzes the overall situation of the participation of distributed power and renewable energy in the power market, and points out that different market models will have a certain impact on the participation. Then, the operation modes of the major power markets in Europe, North America and Australia, the market trading mechanism in the previous day and the next day are explained, and the trading behaviors of distributed power and renewable energy in the power market under different trading mechanisms are analyzed.
2. Overview of Renewable Energy and Distributed Generation Participating in Electricity Market

The liberalization of the traditional regulated electricity market has given birth to independent system operators (ISO), which is responsible for dispatching, distributing electricity, reliability and ancillary services. Under the background of the energy Internet, the newly-added market entities composed of distributed power generation and small energy storage use fans, solar photovoltaic equipment, diesel generators and distributed energy storage devices (DESD) to realize information exchange and energy exchange with other market participants through smart grid equipment. Renewable energy and distributed power are the most economical in this way. In this market structure, the meaning of power supplier is more extensive than that of traditional market structure. In the new market structure, the penetration rate of renewable energy is higher, and the bidding strategies of renewable energy are different in different market environments.

For "rational economic people", they all want to maximize their profits when they participate in market activities. In the actual market, in many cases, the decisions made by each market participant will be influenced by the decisions of other participants. Therefore, the new market mechanism should consider the mutual influence of all market participants. However, new energy and distributed generation are generally small in size, which can participate in the market competition flexibly and actively, which also makes the power market structure more complex and dynamic. The competition strategies reflected in different market models are also different, so the market participation of distributed generation and renewable energy in different models is different.

3. Overview of Development of Major Electricity Markets in Europe and America

The operation of the electricity market can be realized through vertical integration of monopoly or free market operation. Market-based power systems are organized into two-sided or transaction-based markets: financial (long-term hedging) markets, day-ahead dispatch markets and day-ahead markets (or real-time markets). In addition to energy markets, frequency control ancillary services (also known as balanced services) can be obtained through market mechanisms. The balanced market can be organized as a separate market or jointly managed with the energy market [2]. In this paper, the financial market refers to the hedging contract which has nothing to do with the physical delivery of electricity.

In general, the daily spot market operates as follows: the clearing price submitted by the supply and demand situation to the market is based on the intersection of supply and demand curve (usually forecast demand curve). Balanced services can be similarly marketed. Bidding services are provided in ascending order of supply curve. The demand curve represents the demand for services. The intersection of the two curves determines the price of the service.

Europe's intra-day market is usually continuous. All transactions are subject to quotation and payment. The intraday market serves as a balanced market to support the day-to-day market transactions. The price of the same product may vary in different trading periods. This paper reviews the current development of the electricity market.

3.1. European electricity market

Each EU member country regulates its own electricity market, but the ultimate goal is to integrate the electricity markets of all countries into a unified EU market. An important feature of the national market is that it can be traded on a bilateral basis within a certain geographical area and within an organized electricity market. The liquidity of the organized electricity market can be used to determine the share of electricity transaction in the organized electricity transaction about the total consumption of the system. The more liquid the market is, the more likely res and Der are to participate in the electricity market. Table 1 presents liquidity data for major European electricity markets (2015) [3].

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Table 1. Liquidity of European electricity markets

| Electricity market          | Country                  | Mobility (%) |
|-----------------------------|--------------------------|--------------|
| Nordic Library              | Nordic / Baltic          | 95           |
| OMIE                        | Spain / Portugal         | 79           |
| GME                         | Italy                    | 68           |
| EPEX UK                     | Britain                  | 53           |
| Epex Germany / Austria      | Germany / Austria        | 53           |
| EPEX Holland                | Netherlands              | 39           |
| EPEX Switzerland            | Switzerland              | 38           |
| Epex Belgium                | Belgium                  | 29           |
| EPEX France                 | France                   | 23           |
| CROPEX                      | Croatia                  | 2            |

Europe's electricity market and equilibrium market are generally two independent markets. The main reason is that there are two independent entities to manage the electricity market operation—the market operator focusing on electricity exchange and the power transmission system operator (TSO) focusing on market balance.

NEMO is responsible for organizing orderly power transactions, while TSO is responsible for balancing transmission network and system, i.e. organizing orderly balanced market. There may be more than one NEMO (as a competitor) and more than one TSO (as a natural monopoly) in a member country of the EU. Having multiple NEMOs in a country will bring competition between power transactions, promote the diversity of power products and the efficiency of power transactions. This article focuses on the analysis of Nord Pool and EPEX.

3.2. Nord pool
Nord Pool is a NEMO in the European Union. It has the strongest position among the Nordic and Baltic countries, namely the joint Nordic/Baltic electricity market. Due to network congestion, the market is divided into 15 bidding regions, each region can have different electricity prices [4].

The day ahead market for Nordic power banks offers four different products:
1. For single period trading orders, market participants specify the purchase or sales volume in each period.
2. Whole order, including two or three consecutive hours of purchase and sale of electricity.
3. An exclusive organization that activates one of several buying and selling blocks.
4. Flexible trading orders, market participants can decide the purchase and sale of electricity under certain trading price constraints.

The daily market can provide different products according to the time period, namely 15-minute, 30-minute, hourly and block products.

TSO in Northern Europe is responsible for monitoring the balance in the region by adjusting the configuration of auxiliary services, but electricity transactions within each country are carried out at home.

3.3. EPEX SPOT
EPEX SPOT is the most NEMO-like power market among the seven members, including Germany, Austria, France, Switzerland, UK, Belgium and Netherlands [5].

A few days ago, the market offered single-hour, block orders and smart block orders. Intelligent block refers to a large order set with link execution constraints that can be linked) and a special large order (a group of large orders that can execute at most one block order).

Block orders are executed in hours or in all countries except the UK for products on the market during the day. In the UK, daily orders are made in half an hour. In addition to the hourly and one-day
periods, Germany has also adopted an auction 15 minutes in advance on an hourly basis, while in the
UK it has carried out an auction half an hour in advance.

In general, the balanced market is organized separately by each TSO. Germany was the first
country to introduce joint bidding for operational standby. Every TSO in Germany and TSOs in
Belgium, the Netherlands, France and Austria can participate in the primary control standby market. In
addition, all German TSOs use common tendering procedures for secondary and tertiary backups.

3.4. North American electricity market
The North American electricity market (US and Canada) takes the form of traditional wholesale
electricity market or regional electricity market. The traditional market entities are vertically integrated.
The supply of customers is based on regulated electricity prices, and the market functions are
completed through bilateral transactions. The regional power market is coordinated by the regional
transmission operator (RTO), and its task lies in the management of the power grid and the power
market. The existence of bilateral transactions in regional power markets is generally achieved by
computer algorithms. Currently, there are 7 RTOs in the United States (about 2/3 of the power needs
are fulfilled through RTOs)-CAISO, MISO, SPP, ERCOT, PJM, NYISO and ISONE, and two
Canadian AESO and IESO. These entities operate power systems in their regions in a natural
monopoly manner.

Since RTO in the United States is responsible for the physical organization of the market and the
operation of the transmission system, power and balance services are usually implemented by
algorithms optimized together with power and balance services. The power balance service is
generated due to the overall requirements of the system, which can increase the total social welfare
and improve the utilization of system resources. Flexible resources are important to provide balanced
services, which can lead to higher value for DER. This article details the US RTO and CAISO power
markets.

3.5. CAISO
Independent system operators in California manage the power system and organize California and
some Nevada states to participate in the power market. CAISO uses different rules and conventions for
specific participants in the electricity market [6].

Technical data of traditional generator sets, such as maximum/minimum output, climbing rate,
minimum up/down time and economic data, such as start-up and power generation costs. Day ahead /
real-time bidding is based on different piecewise linear curves. If the minimum output of a generator is
close to its upper limit, it can be bid as a limited conventional generator.

Intermittent resources can participate in the electricity market by participating in intermittent
resource planning. They can give forecasts in the real-time market to avoid incurring expenses when
they deliver and forecast different plans. Electricity demand can also participate in day-to-day, real-
time and balanced markets, mainly through demand response or load participation. Users can bid for
their demand response services through demand service providers, and make profits in the day ahead
market and real-time market. The load participating in demand response can provide non rotating
reserve and demand reduction services in real-time and balanced markets.

The flexible output of the storage unit can be used as non-generator resources and pump energy
storage resources. Non-generator resources can be used as generators or loads, depending on system
requirements, and can be scheduled within the entire capacity range according to specific requirements.
When the water pump is pumped to the reservoir with higher altitude, the pump storage energy can be
used as load and as generator when generating electricity. The pump stores data that participates in
demand response similar to that of a multi-stage conventional generator.

A few days ago, we worked with the real-time market to optimize power and balance services:
up/down regulation, rotary standby and non-rotary standby. Adjustment refers to automatic secondary
backup, while rotating and non-rotating backup refers to tertiary backup.
3.6. Australian electricity market

The Australian Energy Market Operator (AEMO) is the national electricity market covering six states, including Queensland, New South Wales, Australian Capital Territory, Victoria, South Australia and Tasmania. The national electricity market is carried out according to the power bank. The rest of the country supplies electricity through vertically integrated companies or through bilateral contracts. Aemo is both a power system operator and a market operator. Therefore, it has the function of organizing electricity and balancing the market [7].

AEMO needs to submit three types of bids when calculating power demand: daily bid, default bid and secondary bid. The daily quotation can be regarded as the day-ahead market, while the secondary quotation is actually a real-time market. The default quotation reflects the marginal cost of power generation, which can only be submitted in order to maintain the safe and stable operation of the system without daily quotation.

Compared with the EU and the US, the biggest difference is that all bids in the Australian market are resubmitted at 5-minute intervals, and the real-time price is calculated based on the average value of six hours.

Balanced service, commonly called frequency control auxiliary service (FCAs), provides eight services in the power market: monitoring the rise and fall of FCAs, rapid rise / fall of emergency FCAs (6 seconds), slow rise / fall (60 seconds) and delayed rise / fall (5 minutes) [8]. Quotations and bids for FCAS services are defined and allocated to energy production or consumption through generator/load capacity. If the system FCAS does not meet all the quotation requirements, AEMO can change the bidding accepted in the electricity market to meet the FCAS requirements. Therefore, the process can coordinate and optimize the balance of power supply and demand.

4. Analysis on Participation of Distributed Generation and Renewable Energy

The European Union and the United States have very different ways of quoting electricity prices. The European Commission has adopted a new power plan [1] aimed at promoting fairness among all power market participants, including traditional units, renewable energy, distributed power sources, etc. The emergence of NEMO is consistent with the proposal of the European Commission. The same product can be realized by different technologies. This means that Nemo products are generally applicable to all technologies rather than specific technologies. The difference between demand bidding and supply bidding is the minus sign before bidding. Renewable resources will also use the same products as conventional units, but there is no need to balance actual and forecast power generation.

RTO provides access to different projects and uncertain technologies. The traditional unit submits variable cost quotation, while the demand response bidder submits the quotation within the range of acceptable change quantity. Res does not bid in the normal way, but in real-time market forecast of the power generation to reduce their unbalanced power. The U.S. electricity market is designed to promote equality between different technologies. By developing more specific products, it can make it easier for new market participants to enter the market.

Three regions are selected. The market quoted prices in a similar way the day before, and the market clearing price was set the day before. (See Table 2 for recent market parameters). The intra-day market and the real-time market differ in some parameters.
Table 2. Comparison of market parameter

| Electricity market | Deadline (D−1) | Trading term | Bidding volume | Minimum bidding interval | Lower limit (€/MWh) | Upper limit (€/MWh) |
|-------------------|---------------|--------------|----------------|--------------------------|---------------------|---------------------|
| Nordic Library    | 12:00         | 24h          | 0.1MW          | 1h                       | -500€               | 3000€               |
| EPEX Germany      | 12:00         | 24h          | 0.1MW          | 1h                       | -500€               | 3000€               |
| EPEX UK           | 15:30         | 24h          | 0.1MW          | 30min                    | -500€               | 3000€               |
| Epex Germany 15min| 15:00         | 24h          | 0.1MW          | 15min                    | -3000€              | 3000€               |
| CAISO             | 10:00         | 24h          | -              | 1h                       | -                   | 1000$               |
| AEMO              | 12:30         | 24h          | -              | 5min                     | -1000$              | 12500$              |

The studied European Union intraday market (EPEX and NordPool) uses a continuous trading platform in which supply and demand bids are integrated and prices are paid according to quotations [9]. OMIE uses different rules in the market within days [10]. On the other hand, the real-time market in the United States (and Australia) plays a correction role in the day ahead unit mix, that is, the real-time market participants' rescheduling is only based on the actual situation of the system. The EU's day ahead market and day ahead market can bring more profits to intermittent power supply.

Power and balanced market optimization can make better use of resources. However, the premise of the algorithm is a single entity responsible for the power market and balancing the market. TSO and NEMO need to work together when EU implements the algorithm. First of all, we need to refer to the design of the Australian market and adjust the scheduling when the market quota reserve is insufficient.

Germany and Britain are bidding for the second time in the market recently to introduce short-term products to the market so as to better balance intermittent distributed power generation and renewable energy within an hour. The practice in Australia shows that the quotation once every five minutes and the second bidding in the day ahead market will not have a negative impact on the market operation.

Scarcity pricing is an important advantage of flexible distributed generation. In a period of high flexibility requirements, prices can represent the actual conditions of upper and lower prices that are not subject to market restrictions. Both the upper and lower price limits actually exist in the current market, as shown in Table 3.

Table 3. Comparison of intraday market parameters

| Electricity market | Trade deadline | Transaction begins | Minimum bidding interval |
|-------------------|---------------|--------------------|--------------------------|
| Nordic Library    | 1h before delivery | After the day ahead electricity price is determined | 15min                   |
| EPEX Germany      | 30min before delivery | Ditto              | 15min                   |
| CAISO             | 75min before H-1 | Ditto              | 5min                    |
| OMIE              | 5min before scheduling | Ditto              | 5min                    |

5. Summary
This paper studies the market participation of distributed generation and renewable energy under different power market types. Firstly, the general situation of the participation of distributed
generation and renewable energy in the electricity market is analyzed, and it is pointed out that different market modes will have certain influence on the participation. Then, the main operation modes of electricity market in Europe, North America and Australia, the day before and day after market trading mechanism are explained, and the trading behaviors of distributed generation and renewable energy in electricity market under different trading mechanisms are analyzed. The analysis of this paper can provide reference for China's distributed generation and renewable energy to participate in the power market in the future.

References
[1] Kang Chongqing, Du Ershun, Zhang Ning, et al. Renewable energy participation in the power market: a review and outlook [J]. China Southern Power Grid Technology, 2016, 10 (3): 16 - 23.
[2] Bettina Dallinger, Hans Auer, Georg Lettner. Impact of harmonised common balancing capacity procurement in selected Central European electricity balancing markets [J]. Applied Energy, 2018, 222: 351 - 368.
[3] Christoph Weber. Adequate intraday market design to enable the integration of wind energy into the European power systems [J]. Energy Policy, 38 (7): 3155 - 3163.
[4] Zhang Zhigang, Wang Tao. Research on Nordic Power Market Transaction [J]. Tianjin Electric Power Technology, 2005 (s1): 16 - 21.
[5] Santos G, Fernandes R, Pinto T, et al. MASCEM: EPEX SPOT Day-Ahead market integration and simulation [C] // 2015.
[6] D. Hawkins, M. Rothleder. Evolving Role of Wind Forecasting in Market Operation at the CAISO [C] // Power Systems Conference and Exposition, 2006. PSCE ’06. 2006 IEEE PES. IEEE, 2006.
[7] Fouad Kamel, Marwan Marwan. Effective Demand Side Response Smart Grid Scheme on Electricity Market in Queensland Australia [J]. Journal of Materials Science & Engineering, 2012, 2 (2): 158 - 166.
[8] Shengqi Zhang, Yateendra Mishra, Gerard Ledwich, et al. The operating schedule for battery energy storage companies in electricity market [J]. Journal of Modern Power Systems & Clean Energy, 2013, 1 (3): 275 - 284.
[9] David Wozabal, Christoph Graf. On the Efficiency of the EPEX Day-Ahead Spot Market [J]. Ssrn Electronic Journal, 2011.
[10] Juan-Manuel Roldan-Fernandez, Manuel Burgos-Payan, Angel-Luis Trigo-Garcia, et al. Impact of renewable generation in the Spanish Electricity Market [C] // 2014 11th International Conference on the European.