Research on the development trend of virtual power plant in the spot market

Yicheng Mu

1 School of computer science and technology, Wuhan University of Technology, Wuhan, 430070, China

*Corresponding author’s e-mail: 1163600676@qq.com

Abstract. With the continuous promotion of power market reform, the spot market of electric power is gradually opened, and more and more flexible renewable energy can participate in market transactions. In order to ensure the safe and stable operation of power grid, virtual power plant has been developed. In the spot market, virtual power plants gather different resources and take part in market transactions as a whole. This not only benefits the virtual power plant itself, but also the whole power system. In order to study the impact of the spot market on the virtual power plant, this paper starts with the basic theory of the virtual power plant, then combined with the development of the spot market, studies the basic process of the virtual power plant participating in the market transaction, and explores the future development trend of the virtual power plant.

1. Introduction

At present, China is in an important period of power energy strategic transformation. The development of new energy is faster and larger. The clean and renewable energy, mainly wind energy and solar energy, is characterized by randomness, intermittence and volatility. Therefore, large-scale renewable energy access to the grid will have a huge impact on the grid. In order to ensure the safe and stable operation of power grid, a large number of renewable energies are wasted, resulting in low efficiency of energy utilization. Therefore, as a solution to clean energy consumption and green energy transformation, virtual power plant is of great significance to the development of China's power market. Combined with the current situation of power market construction, this paper studies the development of virtual power plant.

2. Basic theory of virtual power plant

Virtual power plant (VPP) refers to the combination of controllable load, distributed power supply (DER) and energy storage system, and then this combination participates in the operation as a special power plant in the grid. Each part of this combination is connected with the control center. Through the two-way information transmission of the smart grid, the power flow at the machine end, the load at the receiving end and the energy storage system are uniformly dispatched. Finally, the power generation loss is reduced, the peak load of the grid is reduced, the greenhouse gas emission is reduced, the resource utilization is optimized, and the power supply reliability is improved.

Virtual power plant can play an important role in solving clean energy consumption and green energy transformation.

It can alleviate the negative effect of distributed generation. Virtual power plant is a visual self-organization for large power grid. It can not only generate electricity by combining multiple
distributed resources, but also realize energy saving storage by adjusting controllable load, adopting time-sharing price, interruptible price and energy storage in user time. The coordinated control optimization of the virtual power plant greatly reduces the impact of the previous grid connected distributed resources on the large grid, reduces the scheduling difficulty brought by the growth of distributed resources, makes the distribution management more reasonable and orderly, and improves the stability of the system operation.

It can effectively utilize and promote distributed energy generation. In recent years, distributed energy sources such as distributed photovoltaic and distributed wind power are growing rapidly in China. Its large-scale and high proportion access brings a series of challenges to the balance of power system and the safe operation of power grid. If these distributed generation participate in the operation of large power grid in the form of virtual power plant, the impact of its fluctuation on power grid can be eliminated and efficient utilization can be realized through internal combination optimization. At the same time, virtual power plant can make distributed energy obtain the maximum economic benefit from the power market, shorten the cost recovery cycle, attract and expand such investment, and promote the development of distributed energy.

It can promote the optimal allocation of power generation resources by market means. The most attractive function of virtual power plant is that it can aggregate many kinds of distributed resources to participate in the operation of power market. Virtual power plant acts as an intermediary between distributed resources and power dispatching institutions, and represents distributed resource owners to perform market clearing results. From the perspective of other market participants, virtual power plants are traditional schedulable power plants. Because of its diversified power generation resources, virtual power plants can participate in both the main energy market and the auxiliary service market, participate in the operation mode and scheduling framework of various power markets, and play a positive role in promoting the extensive optimal allocation of power generation resources.

3. Operation mechanism of spot market
The concept of spot market is relatively medium and long-term: it mainly carries out day ahead, day in, real-time electric energy trading, standby, frequency modulation and other auxiliary services trading.

From the perspective of spot market construction, it is now in a rare historical opportunity period. Mainly in the following three aspects.

The policy keeps improving. The 19th National Congress of the Communist Party of China proposed to establish a modern market system. The central economic work conference held in December 2018 proposed that we must adhere to the supply side structural reform as the main line and unswervingly, and deployed relevant reform work. In the recent two sessions, the government work report clearly proposed to deepen the reform of the electricity market. All of these provide a good political environment and policy basis for the construction of electricity spot market.

Continuous improvement of economic system of electric power industry. From the current situation of the development of the power market, the elements of the power market are basically established. That is to say, what is a commodity, who is the buyer and who is the seller, has been established. The proportion of market-oriented electricity is increasing. What's more, there are new market trading models developing.

The development of spot market is the general trend. For example, in terms of public opinion, the role and significance of the spot market in the market system has been fully interpreted. At the technical level, the introduction of non-subsidized parity or even low-cost online policies for wind power and photovoltaic power generation has cleared the way for possible conflicts between the market and green power consumption. All of these make the development of the spot market possible.

From the international experience, there are two operation modes in the spot market of electric power.

Mode 1: the trading parties of bulk power shall sign medium and long-term power trading contracts on the OTC market. The extra or insufficient power shall be sold or supplemented by the power
purchasing enterprises directly entering the spot market of power. This mode is generally adopted in the UK, Germany and other European countries. In this mode, the market rules are relatively simple, and because the price of bulk electricity has been locked through the medium and long-term contracts, only a small part of excess or shortage electricity has been found out and filled through the spot market, so the risk of market price fluctuation is small. However, the over-the-counter trading mode of medium and long-term trading is difficult to reflect the short-term price signal, and the role of competition and market regulation mechanism is relatively limited.

Mode 2: All power of the power plant is involved in spot trading. For medium and long-term transactions, the power plant will enter into a bilateral price difference contract with the power purchaser off-site (first, in the price difference contract, both parties agree on the reference price and electricity quantity). After that, the power plant and the buyer will still trade in the spot market according to the price of the spot market, but if the spot market price is lower than the reference price agreed in the price difference contract, the buyer shall pay for the insufficient part of the power plant; otherwise, the power plant will return the part of the spot market price higher than the reference price specified in the contract to the buyer. The reference capacity in the CFD is not binding and does not need to be enforced). The characteristic of this mode is that the market competition is fierce at this time. The price fully reflects the market's immediate supply and demand change information, and the efficiency of resource allocation is higher, but the market rules are complex. When the construction of the spot market is not perfect, the risks of price fluctuation, safe operation of the power grid and the safety of users' electricity use are relatively large, which is adopted by the United States, Australia and other countries.

At present, three pilot areas of Guangdong, Gansu and Shanxi have started the trial operation of electric power spot market, and the rules are being worked out in Mengxi, Zhejiang, Shandong, Fujian and Sichuan. Guangdong, as the first spot market pilot in China, adopts second mode.

4. Operation process of virtual power plant participating in spot market
The goal of virtual power plant is to combine distributed energy optimization into an organic whole, make it as a special power plant to participate in the operation management of power market transactions, provide power auxiliary services, and make the virtual power plant in the optimal operation point through coordinated control, so as to maximize the overall benefits. Virtual power plants participate in different market operations, and will make different operation strategies according to market rules. The basic operation process is shown in the figure 1.

Figure 1. Basic process of virtual power plant participating in spot market
Power plant submits the power generation plan based on the analysis of historical power generation and existing energy reserves, combined with the forecast of weather information, generation point information and load information on the second day.
The virtual power plant needs to coordinate the electricity price of each power producer, not only to ensure that the power producer can benefit from the investment within a reasonable time range, but also to make the virtual power plant obtain a competitive price. When calculating the electricity price of virtual power plant, the government’s subsidy for the electricity price of aggregated renewable energy generation in virtual power plant should be taken into account; for the price of electricity reserve, an agreement should be reached with the operators of virtual power plant and aggregated generators in advance.

According to the characteristics of electricity price, output power, power quality and power reserve, the virtual power plant makes the generation plan for the next day. In addition to the ideal scheduling scheme, the virtual power plant also needs to develop alternative scheduling scheme in case of power shortage or surplus.

According to the power generation plan and the electricity price and quantity quoted by the power producer, the virtual power plant shall establish the electricity price of the virtual power plant, and determine the grid access point and injection power.

After internal coordination, the virtual power plant will sign a generation agreement (including electricity and electricity price) with the market operator, and then check whether the agreement meets the system network conditions such as power flow and congestion. If the signed agreement does not meet the network conditions, the virtual power plant will inform the generators who violate the constraints to adjust their own generation plan.

When the generation schedule meets the system network constraints, the system will notify the virtual power plant to conclude the generation contract. The virtual power plant will coordinate with the power producer to make the generation plan for the next day according to the saleable energy in the power dispatching contract.

According to the generation plan, the virtual power plant controls the output power of each power producer, optimizes and adjusts the actual network situation, and enters the generation results into the database, providing historical data and basis for the accurate generation prediction later.

5. Development trend of virtual power plant in the spot market

The virtual power plant participates in the power market operation by aggregating multiple distributed units. It can not only give full play to the characteristics of the traditional power plant, such as stable output and mass sale of electricity, but also has good complementarity due to the aggregation of a variety of power generation units. The power market that virtual power plants participate in includes day ahead market, real-time market, auxiliary service market, etc., which can establish day ahead market, bilateral contract, balanced market, mixed market and other market models. Considering the uncertain factors such as output, load and real-time electricity price of renewable energy in virtual power plant, the scheduling and bidding model is established under different market environment, which makes virtual power plant more applicable.

Multiple distributed generation units aggregate according to certain rules or objectives, participate in the power market or auxiliary service market as a whole, and finally distribute the benefits to each distributed generation unit. Virtual power plant as an intermediary, according to the rules of dynamic combination algorithm or dynamic game theory, the dynamic combination of multiple distributed generation units is flexible. The real-time and flexibility of dynamic combination can avoid the cost problems caused by real-time imbalance and the combination deviation problems caused by power plant shutdown, load and renewable energy output prediction errors.

6. Conclusion

After the completion of the spot market, short-term electricity trading can be realized, which can not only help power users find price signals, but also promote the consumption of renewable energy.

As a technical means to solve the problem of renewable energy consumption, the real-time fluctuation of spot price of electric power will greatly increase the complexity of the control system of the virtual power plant, and the comprehensive operation optimization combining the real-time and
predicted price signals of spot power and the operation parameters of the system itself will bring great challenges to the control technology of the virtual power plant. But at the same time, the real-time fluctuation of spot price of electric power will bring huge opportunities for the profitability of virtual power plant, which can not only improve the economic benefits brought by the effective regulation of virtual power plant, but also promote the market-oriented development of virtual power plant technology.

In the future, the virtual power plant will optimize the internal resource combination, follow up the power price and realize the efficient utilization of resources by means of technical means and aiming at the maximization of benefits.

References
[1] Wei Zhinong, Yu Shuang, sun Guoqiang, sun Yonghui, Yuan Yang, Wang Dan. Concept and development of virtual power plant [J]. Power system automation, 2013,37 (13): 1-9
[2] Chen chunwu, Li Na, Zhong PENGYUAN, Zeng Ming. International experience and Enlightenment of virtual power plant development [J]. Grid technology, 2013,37 (08): 2258-2263
[3] Liang Zhifei, Chen Wei, Zhang Zhixiang, Ding Junce. Discussion on the construction mode and path of the southern regional electric spot market [J]. Electric power system automation, 2017,41 (24): 16-21 + 66
[4] Ma Hui, Chen Hugo, CHEN Ye, Liu Wentao, Lin Shaohua, Zhang Xuan, Baiyang, Luo Gang, Lai Xiaowen, Wang Yang. Mechanism design of electric spot market in South China (starting from Guangdong) [J]. China Southern Power Grid technology, 2018,12 (12): 42-48
[5] Yuan Guili, Chen Shaoliang, Liu Ying, Fang Fang. Economic optimal dispatch of virtual power plant based on time-sharing price [J]. Grid technology, 2016,40 (03): 826-832
[6] Zang Haixiang, Yu Shuang, Wei Zhinong, sun Guoqiang. Two level optimal scheduling of virtual power plant considering safety constraints [J]. Electric power automation equipment, 2016,36 (08): 96-102 Jiang Guoqi. Research on China's comprehensive energy market system construction [D]. CPC Central Party School, 2013.
[7] Wang Xuanyuan, Liu Dunnan, Liu Zhen, Liu Mingguang, Wang Jiani, Gao Yuan, Wang Xiongfei, song Yonghua. Operation mechanism and key technology of virtual power plant under the power Internet of things [J]. Grid technology, 2019,43 (09): 3175-3183.
[8] He Qilin, AI Qian. Bidding strategy of electric power market with demand response virtual power plants under the environment of power sales side liberalization [J]. Electric power construction, 2019,40 (02): 1-10.
[9] Wang Xian, Zhang Huajun, Zhang Shaohua. Game model of wind power and electric vehicles as virtual power plants participating in power market [J]. Power system automation, 2019,43 (03): 155-164.
[10] Fang Yanqiong, AI Qian. Day to day interaction mechanism of virtual power plant considering internal response willingness [J]. Modern power, 2019,36 (03): 88-94