Research on green development framework of the virtual power plants

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Abstract. In order to accelerate the construction of an internationally-leading energy Internet enterprise with Chinese characteristics, this paper analyses the connotation of the green development of virtual power plants by combing the green development requirements of the energy and electric power industry. In addition, this paper constructs the evaluation index system framework of the green development of virtual power plants and analyses the social benefits of virtual power plants.

1. Introduction
The company implements the spirit of the 19th National Congress of the Communist Party of China thoroughly, grasps the development trend of the new round of energy revolution and the company’s development direction accurately, and puts forward the strategic goal of building an internationally-leading energy Internet enterprise with Chinese characteristics. As an emerging business form that conforms to the integration of the energy revolution and the digital revolution, virtual power plants (VPPs) is based on the smart grid, strengthens the connectivity of network and the application of advanced information, communication and control technologies which is an inevitable outcome of the development of the energy Internet [1,2,3]. By analysing the green development requirements of energy and electric power industry, this paper constructs the evaluation index system framework of the green development of VPPs, analyses the social benefits of VPPs, and lays a foundation for promoting the green development of energy and electric power industry.

2. Green development requirements of energy and electric power industry
With the deepening of economic globalization, countries all around the world are increasingly interdependent in economy, politics, society, culture and other aspects. How to realize the green development of human society has become a common concern of governments of all countries and the international community. In 2015, the UN Green Development Summit adopted the programme named<Changing Our World--The 2030 Agenda for Green Development>.

The UN green development goal will help China to carry out international cooperation in the field of green development. And the contents closely related to energy and electricity as shown in Table 1.

For the energy and power industry, the specific requirements of green development are mainly manifested in the following aspects: reducing the price of energy obtained by users, improving the reliability of energy supply, improving the level of clean energy consumption, improving energy
utilization efficiency, and accelerating the process of energy conservation and emission reduction in the power industry.

Table 1. Green development requirements for the energy and power industry in 2030.

| Number | UN 2030 green Development Requirements | The content |
|--------|----------------------------------------|-------------|
| 7.1    | By 2030, everyone will have access to affordable, reliable, and sustainable modern energy. | Reflecting the energy is cheap and reliable. |
| 7.2    | By 2030, the share of renewable energy in constitute of global energy will increase substantially. | Reflecting the situation of clean energy consumption in power grid. |
| 7.3    | By 2030, global energy efficiency will double. | Improving energy utilization efficiency and accelerating the process of energy conservation and emission reduction in the power industry. |
| 12.5   | By 2030, waste generation will be significantly reduced through prevention, emission reduction and recycling. | Reflecting the amount of waste production. |

3. The green development index system framework of virtual power plant

3.1. The promoting effect of virtual power plant on green development

VPPs aggregate distributed power supply, controlled load, electric vehicles and energy storage device into a virtual controllable collection. It operates as a special “power plants” to participate in power grid operation adjustment and power trading, harmonizes the contradiction between smart grid and distributed power supply, excavates energy value and benefits brought by the power grid and users. Compared with traditional power plants, VPPs can integrate various resources which scattered in the power grid based on the physical architecture of the traditional power grid and rely on the Internet and modern information and communication technology to carry out cooperative optimization operation control and market transactions [4,5,6,7]. Its market operation can provide more incentive measures and market models for the development of flexible resources such as distributed power supply, electric vehicle, energy storage and controllable load [8, 9, 10, 11]. Specifically, VPPs has the following four aspects of promoting the green development as shown in Fig.1.
3.1.1. Reducing energy price and improving energy supply reliability
With the help of energy storage equipment, the virtual power plant technology can reserve the low rate electric energy in the trough period and release it in the peak high rate period which can greatly reduce the average electricity price of users. At the same time, due to the access of self-owned energy storage equipment and distributed power supply, the secondary power supply can be guaranteed under extreme circumstances in a specific region and the power supply reliability within the region can be improved.

3.1.2. Promoting the share of clean energy
As renewable energy becomes the main direction of global energy development in the future, VPPs will become a regional multi energy aggregation mode to realize large-scale consumption of renewable energy generation and promote the proportion of clean energy to increase year by year.

3.1.3. Improving the problem of excessive peak valley difference in power grid
The trend of peak valley difference in recent years in Zhejiang Province is shown in Fig.2. Each customer adjustable power resource of the VPPs can be aggregated into a controllable aggregate. According to the requirements of power grid operation and its own situation to regulation actively, realizing “the elasticity of demand, supply and demand coordination” and improving customer’s energy efficiency. In addition, it provides better guarantee for safe operation of power grid and clean energy consumption.

3.1.4. Improving energy efficiency
The introduction of VPPs will bring the intervention of third-party energy service providers inevitably. Energy service providers as the personal stewards of energy provide customers with energy management and other value-added services to further improve energy management level and energy efficiency.

In conclusion, the development of VPPs conforms to the development concept of green, low-carbon and environmental protection which can support the strategic transformation of China’s clean energy and the green development of the energy and power industry effectively.
3.2. The green development index framework of virtual power plant

In order to guide the VPPs promoting the green development of energy and power industry, combining with the characteristics and functions of the VPPs, a comprehensive evaluation index framework was proposed from the aspects of reliability, economy, schedulability, renewable energy consumption capacity, energy conservation and emission reduction capacity, etc. The specific indexes are shown in Table 2.

| Primary indicators | Secondary indicators | Effect |
|--------------------|----------------------|--------|
| Economy            | Comprehensive economic income | Bring benefits to users and reduce electricity prices |
| Reliability        | Time probability of power shortage | Reliability of power supply |
|                    | Expected value of insufficient power |        |
| Schedulability     | Regulating peak valley difference | Ensure to participate in dispatching and ensure the safety of power supply |
|                    | Regulatory accuracy |        |
| Renewable energy consumption capacity | Renewable energy consumption rate | Raise the level of clean energy consumption |
| Energy conservation and emission reduction capacity | The reduction in carbon emissions | Accelerate the process of energy conservation and emission reduction in the power industry |

4. The social benefit analysis of virtual power plants

4.1. Promoting power grid construction

Reduce investment in power plant construction. According to the statistics of power continuous load in recent years, the annual accumulative time of peak load is relatively short, and it is costly to meet this part of peak load by increasing the installed generating capacity. Using VPPs to reduce this part of peak load can reduce the investment of peak load installed capacity effectively.

Reduce investment in power transmission and distribution facilities. Through the construction of VPPs, the investment in the expansion and transformation of power transmission and distribution facilities can be reduced, and the fixed capacity cost can be saved. It can be determined according to the average cost of less or delayed substations, transformers, transmission lines and their supporting equipment.

4.2. Promoting energy conservation and emission reduction

The electricity consumption and electricity generation reduced by VPPs participating in medium and long term peak shifting and standby trading can be converted into carbon dioxide emissions through
carbon emission coefficient, and then monetized through carbon market price to reduce fossil energy consumption.

4.3. Saving social resources

4.3.1. Reducing the cost of power outage
VPPs can reduce peak load, shorten the power outage time caused by power restriction and reduce the scope of power outage during peak hours, thus reducing the economic loss caused by power outage to power users.

4.3.2. Saving land resources
Virtual power plant is conducive to delaying the construction of conventional power plant investment and saving land-using area. Compared with traditional power plants, VPPs rely on information means to aggregate resources which will save a lot of land resources.

4.3.3. Reducing standby costs
VPPs can replace conventional power generation enterprises to provide the same standby auxiliary services for the power system, which is beneficial to optimize the start-stop schedule arrangement of units, reduce the start-stop times of thermal power units, and thus reduce the related standby costs.

4.4. Promoting industrial transformation
Promote the transformation of electricity selling companies into comprehensive energy service providers. The VPPs is widely connected to users, and the traditional one-way energy transmission chain is bidirectional, which is conducive to the transformation of power sales companies to comprehensive energy. While reducing the average price of users, it can provide personalized comprehensive energy services to end users, breed demand response ecological mechanism, and improve the refinement level of urban energy management.

Promote the development of related industries and improve the refinement level of urban energy management. VPPs integrates Internet information technology with electric power field deeply, promotes the construction of ubiquitous power Internet of things, changes the mode of energy production and consumption, and has a significant driving effect on the development of distributed energy and information industry. It provides a broad application space for the development of big data analysis, machine learning and prediction technology, and can promote billions or even tens of billions of scale production industry development.

Alleviate the contradiction between power supply and demand, reduce social conflicts and promote social harmony. The VPPs is beneficial to improve the power supply capacity of power enterprises. In the past, the main way to solve the power supply and demand balance was to cut off power supply, which had a negative impact on the national economy and people’s life. Under certain power resource environment, VPPs can realize scientific, economical and orderly use of electricity by improving the way of using electricity, so as to improve the power supply capacity of power enterprises, dissolve the contradiction between power supply and demand, reduce social conflicts and promote social harmony.

4.5. Promoting the development of the energy Internet and building a sharing ecosystem
With the development of VPPs technology, new forms of energy interconnection based on ecological sharing are realized through the innovation of business models of VPPs. The VPPs continue to innovate their business models, enhance the vitality and the ability to create value of enterprises, promote the collaborative development of market subjects. The role of VPPs can be described from the following three aspects:

4.5.1. The power generation enterprises
Provide new energy generating units with additional peak-regulating auxiliary service capacity, reduce the total cost of peak market and promote the consumption of new energy. Relieve the pressure of traditional thermal power deep adjustment and improve the utilization efficiency of existing units. Reduce the system’s investment requirements for new energy.

4.5.2. The grid company

Improve the observability, controllability and real-time response capability of the adjustable resources which scattered in the distribution network, and enhance the safe and stable operation level of the power network. Improve the equipment efficiency and reduce the investment and construction of power grid.

4.5.3. The power consumer

Provide a new type of customer that combines production and marketing such as distributed photovoltaic, charged vehicles, user-side energy storage the way of “electricity sales”. Regenerative boiler, intelligent building, industrial and commercial users can choose their electricity behavior actively according to the price signal to reduce the energy cost.

VPPs adhere to the concept of energy interconnection, emphasize the integration and coordination of source network and charge storage across space, and improve the security level of power grid. It has become an important means to solve the problem of resource shortage and environmental pollution in China, and also an important driving force and implementation carrier to promote the development of energy Internet.

5. Conclusion

In this paper, based on the strategic goal of building an internationally-leading energy Internet enterprise with Chinese characteristics, the green development index of VPPs is constructed, and the social benefits of VPPs are analysed. The VPPs plays an important role in improving the market structure and the value system of the power market, increasing the liquidity and flexibility of distributed resources, improving the operation efficiency of the power market and the utilization efficiency of the energy system, and promoting the green development of the power industry. It is an important force for the company to achieve the strategic goal of an internationally-leading energy Internet enterprise with Chinese characteristics.

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