Key Techniques of the Digital Energy Internet Park: An Example of State Grid Energy Internet Rongchuang Park in Lanzhou

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Abstract. The construction of the digital energy internet is of great significance to the formation of the global energy internet. This paper uses the Rongchuang park of state grid Lanzhou power supply company as an example. Particularly, the key techniques from "source, grid, load, and storage" were summarized. It is key for the building of the energy internet Rongchuang park to increase the proportion of clean energy production and consumption, improve the intelligent level of the power grid, fully tap the potential of load side energy conservation and peak shaving regulation, and promote the system flexibility by energy storage techniques. This work supports the technological development and breakthrough of the energy internet park.

1 Introduction

Digital transformation is of great significance to the reforms of the worldwide energy industry. Nowadays, the energy revolution and digital revolution combine together gradually. The form of the power grid is gradually approaching the energy internet, and power grid companies are also gradually turning to digital transformation [1]. In order to build a smart energy internet park that is innovative, coordinated, green, open, and shared, it is urgent to comprehensively build an energy internet technology system. State Grid Gansu Electric Power company has built the energy internet Rongchuang Park in Lanzhou, an important comprehensive energy infrastructure project to support the development of power industry technologies and promote the opening and industrial upgrading of the energy market. The energy internet Rongchuang park is the digital energy center of Gansu Electric Power Company and even China's northwest electric power enterprises. As the cell unit of the global energy internet, it has a forward-looking technology application role. The construction of its technical system can be a good example for the subsequent planning and construction, adjustment of new energy internet parks.

2 Scheme of the key techniques for the energy internet Rongchuang park in Lanzhou

The state grid energy internet Rongchuang park in Lanzhou insists on highlighting the green energy characteristics of the northwest region. It takes the integration and innovation of energy and the internet as a breakthrough and develops key techniques for electric generation, power grid, load, and power storage. The key techniques for the source, grid, load, and storage sides are introduced below.

3 Key techniques for power generation

The energy internet Rongchuang park focuses on developing clean energy and integral energy. The development of clean energy is the key point, accompanied by a full consideration of multiple energy needs. In addition, traditional energy should also be considered with a coordinated development to ensure a stable, safe, clean and efficient energy supply. All these techniques are also called "source side" techniques, which mainly include three aspects discussed below.

3.1 Renewable energy power generation technique

The breakthrough in renewable energy power generation is the source of innovation for building an energy internet park. Renewable energy includes wind, solar, geothermal, biomass energies, and so on [2]. Distributed wind, photovoltaic, biomass, and geothermal power generation have been developed in Gansu Province by considering the resource endowment, geographical environment, and development status. These measures can promote the energy structure transformation of Gansu province forward in the green and low carbon direction and fulfill carbon peak and carbon-neutral development. The key techniques include the following aspects, i.e., alternating current fault traversal technique of distributed wind power, transformation design technique, reactive power

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control technique, security and stability control technique, distributed photothermal and photovoltaic power technique, photovoltaic power electronic converter technique, and photovoltaic inverter control strategy.

3.2 Combined cooling, heating, and power (CCHP) system

In the design and planning of the energy internet Rongchuang park, the CCHP units employ small gas turbines to provide power [3], which is a key component of the coupling of electricity, heat, and gas. At present, the commonly used triple supply system in China is mainly the triple supply system with a gas internal combustion engine and gas turbine as generator sets. Its typical process is shown in Figure 1. The gas CCHP system will become the core unit of the energy internet Rongchuang park for multi-energy complementation and optimal configuration. Its capacity stability and development concentration are unmatched by other distributed renewable energy. Key techniques include the modeling technique of the CCHP system, energy supply, and demand prediction technique of the CCHP system at different time scales, multi-time scale optimal scheduling technique of the CCHP system, and capacity configuration technique of the CCHP system.

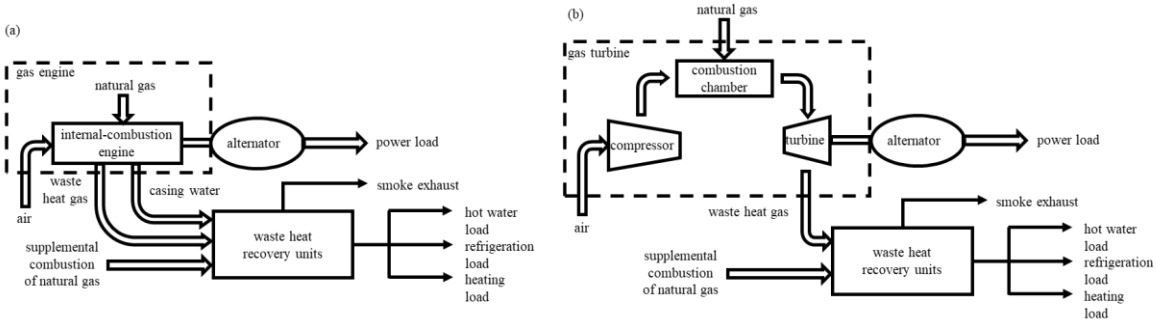

Figure 1. Processes of (a) typical gas internal combustion engine triple supply system and (b) typical gas turbine triple supply system

3.3 Heating/cooling supply techniques of heat pump system

The operating conditions of the heat pump unit are divided into direct supply conditions and energy storage conditions to realize the heating supply in winter and the cooling supply in summer. Under direct supply conditions, it operates in the daytime, and under energy storage conditions, it can operate for the whole day [4]. The heat pump unit and the energy storage tank constitute a water energy storage system, which can directly provide hot or cold water for users' air-conditioning. When working in the daytime, the heat pump supplies heat to the air-conditioning from the energy storage plate. When it is turned on at night, energy can be stored by providing hot water or cold water from the heat pump to the energy storage tank. In the above way, it can realize the intermittent operation of heat pump units, which is also conducive to the power peak shaving caused by the demand for heating and cooling. Key techniques include the development of efficient heat pump systems, control technique of heat pump systems, coordinated dispatching technique of heat pump systems, and other types of load/distributed power supply.

3.4 Renewable energy intelligent detection and power prediction technique

Wind power/photovoltaic output is characterized by randomness and volatility, whereas the power prediction deviation has no obvious impact on the access to the power grid of renewable energy currently in Lanzhou. However, the scale of distributed wind and solar power will have a rapid growth stage, and will be connected to the power grid, which will easily lead to problems such as an out-of-limit voltage of feeder nodes once connected to the power grid. It is necessary to employ new energy-intelligent detection and power prediction techniques to maintain a safe and stable power grid. It needs to establish a high-accuracy wind/photovoltaic power prediction system based on which scheduling plans can be scientifically formulated, and reasonable consumption space can be reserved [5]. Key techniques include high-precision power prediction technique based on real-time resources and operating data of distributed renewable energy, power prediction technique based on online interaction of distributed renewable energy, power probability prediction technique based on error dependency characteristics, resource monitoring network optimization layout technique for distributed renewable energy, quality control technique for large-scale distributed renewable energy operation data.

4 Key techniques for power grid

"Grid side" key techniques are important for the building of a safe and efficient power grid. In the long-term planning of Lanzhou's urban power grid to provide security for the construction of the new northern urban area and the main urban area and make a reasonable layout, it is expected to build four 330 kV substations. The key techniques for the power grid of the energy internet Rongchuang park are as follows.

4.1 Power system simulation and modeling

To build a smart power grid, it is essential to increase the accuracy, rapidity, and flexibility of the power system simulation. The power system model significantly impacts

the power system simulation calculation results. In critical situations, it may change the qualitative conclusions, cover up some important phenomena, constitute potential dangers of the system, and cause unnecessary waste. The energy internet has given new features for source, grid, and load, bringing new challenges to the corresponding modeling technique [6]. The required key technologies for power system modeling and simulation include the following aspects. Load modeling technique is necessary when large-scale distributed power is connected to the system. Based on the automatic modeling of primary and secondary equipment of the grid, the online dynamic identification technique of load and model parameters is important. In addition, the basic theory of power system simulation with widely distributed sources and grid loads of power electronic equipment is also very important for power system modeling.

4.2 Large power grid control and fault prevention technique

The steady-state control of the power grid includes three parts, i.e., optimal dispatching, real-time dispatching, and coordinated control. The integration and reconstruction of the control part on the power grid side can improve the anti-interference performance and steady-state control capability of the power grid. The blackout accident usually originates from a simple accident, which leads to a series of cascading faults. This process is affected by various uncertain factors and may be accompanied by overload or transient instability [7]. For the safety of the power grid, the following power grid steady-state control and fault prevention techniques should be developed for the energy internet Rongchuang park, including grid source coordination technique, deep peak shaving, and fast power regulation technique of thermal power units, reactive voltage regulation technology of wind power, photovoltaic and photothermal units, fault relay protection technique of power system, and new fault prevention system of the power system.

5 Key techniques for load regulation

The peak and valley of the Gansu province power grid become more obvious year by year, which brings great risks to the power grid security. The local thermal power units in Lanzhou are mainly used for system peak shaving and supporting a safe and stable power grid. The flexible loads such as office buildings, data centers, laboratories, and electric vehicles in the energy internet Rongchuang park can fully mobilize the "load side" resources to participate in system regulation. These have become the developing focus of the energy internet in Rongchuang park.

5.1 Flexible load interaction and dispatching management technique

Flexible load is defined to fulfil the requirement of power operation companies by altering the power and time of electricity consumption, which can significantly improve economic benefits [8]. The flexible load can change the history of one-way and passive adjustment of the original load due to its flexible adjustment capability. It can also change the uncertainty, rigidity, and other characteristics of load parameters. Flexible load optimal dispatching is the future development trend of the active distribution grid. With flexible load resources as the dispatching object, through the response between power supply and flexible load, appropriate response measures are taken to improve intermittent new energy consumption and optimize the allocation of multiple types of resources, which enriches the connotation of optimal dispatching. The key techniques of flexible load interaction and dispatching include the evaluation and analysis technique of flexible load interaction potential, the technique of flexible load participating in grid transaction and regulation, the refined load dispatching method of flexible load resource participating in grid dispatching plan, the optimization method of reserve capacity of flexible load resource participating in grid regulation and operation, and flexible load resources participate in the coordinated control technology of power grid frequency modulation.

5.2 Virtual power plant technique

Virtual power plant technique, as a demand response technique under a new form [9], optimizes the power consumption mode of users through internal load aggregators and energy storage systems and alleviates peak power load with considerable capacity and easy operation. The virtual power plant technique is significant for constructing the energy internet in Rongchuang park. The relevant key techniques include the modeling method of virtual power plants with large quantity/geographically dispersed distributed controllable resources, the modeling method of virtual power plants based on incentive and price-based demand response, the optimal scheduling technique of virtual power plants, including the capacity configuration or output optimization of virtual power plants for their own internal multiple power sources. The principle of energy and load establishment division under the demand of multi-energy coordination of the energy internet park, the combination method of virtual power plants, large-scale distributed power generation based on virtual power plants and the operation control system of multiple energy sources.

6 Key techniques for energy storage

Energy storage techniques include electric energy storage, heat storage/cold storage, and so on. These energy storage techniques greatly improve the flexibility and controllability of energy utilization and is significant for the future construction of the energy internet. In particular, distributed renewable energy and electric vehicles have been connected on a large scale to the Lanzhou power grid. There is a strong demand for electric peak-shaving through multiple types of energy storage to curb power fluctuations. Due to the shortage of land resources in Gansu province, the development of large-scale grid-side energy storage is quite difficult. The development of

energy storage mainly focuses on distributed energy storage and heat storage/cold storage.

6.1 Distributed energy storage technique

Battery energy storage is an important form of energy storage in distributed energy storage, which can be applied to the distributed user side, grid side, and electric vehicle battery resources [10]. The role of user-side energy storage in solving the structural problems of the power grid is gradually enhanced. This can actively respond to the demand of the power grid, smooth the curve of the power grid load, and achieve the goal of reducing the cost of electric peak-shaving and valley-filling. Adding energy storage on the user side is equivalent to adding storage links in traditional power production, which improves the carrying capacity of the power system. Electric vehicles in Lanzhou are increasing yearly, which will become one of the important ways to realize distributed energy storage in the energy internet Rongchuang park. The key techniques include the planning technique of renewable energy and coordinated energy storage, the capacity configuration technique, site selection and layout technique of distributed energy storage, the site and capacity determination technique of charging facilities, the local monitoring technique of distributed energy storage system, and coordinated control technique of multi-point distributed energy storage system.

6.2 Heat storage/cold storage and conversion technique

Thermal storage techniques mainly include sensible heat storage, latent heat storage, and chemical heat storage. Sensible heat storage controls the temperature change of thermal storage materials to achieve the storage and release of heat. The specific heat capacity of thermal storage materials is a crucial factor affecting thermal storage performance. Latent heat energy storage uses heat absorption and releases during the phase change process of materials to realize the storage and release of heat. Compared with sensible heat energy storage, latent heat storage has the advantages of higher energy density and a wider temperature range. Chemical heat storage achieves energy storage and releases by employing reversible chemical reactions, which can realize the wide temperature range cascade heat storage utilization. The energy density is more than ten times that of the other two heat storage techniques [11], but selecting heat storage materials is difficult. Presently, sensible and latent heat is still the main energy storage technique. In solar thermal power generation, thermal storage techniques can solve the intermittent and fluctuating problems of solar power and make its output continuously and stable in 24 hours.

The electricity consumption at night is less, which is a waste of power equipment resources. To modify the uneven power load day and night and the power consumption structure, the way of the user side's cold storage can be used to improve the resource utilization rate. Ice storage is the mainstream cold storage technique at present. Ice is made by using the low valley electricity price of the power grid at night, and water is dissolved during the peak of power consumption in the daytime. It can be used together with refrigeration units to meet the peak load demand, with considerable economic benefits. The ice storage technique applies to office buildings, laboratories, canteens, and other places in the park and has a relatively broad application space [12].

6.3 Electric hydrogen production/hydrogen energy storage technique

Hydrogen has the advantages of high energy storage density, high calorific value, environmental protection, carbon-free emission, etc. It is a high-quality secondary energy [13]. Common hydrogen production methods include hydrogen production from mineral fuels, hydrogen production from electrolytic water, thermochemical hydrogen production, and hydrogen production from biomass. With the advancement and maturity of the hydrogen energy storage technique, it will be widely used in energy storage and conversion systems to promote the coexistence of multiple types of energy storage under different energy forms. Under the standard state, the energy density of hydrogen is only 8.4 MJ/L, which is generally stored by high-pressure or low-temperature liquefaction. These storage methods have problems such as poor safety and high energy consumption. Solid hydrogen storage is the most promising hydrogen storage technology, and the corresponding materials can be classified based on physical or chemical adsorption. Solid hydrogen storage materials are not well developed in hydrogen storage capacity, thermodynamic and kinetic properties, reversibility, etc., and need to be improved. As the uninterruptible power supply in the energy internet Rongchuang park, it ensures the power supply of important loads in case of power failure. It adapts to the highly reliable operation in the energy internet Rongchuang park, hydrogen utilization technique, and integrated application technique of hot and cold electricity. It has also realized the safe and efficient application of hydrogen energy, hydrogen carbon joint conversion technique, expanded hydrogen energy utilization forms, and supports the interconnection between the power grid and fuel grid. The key technologies of electric hydrogen generation and energy storage include safe and efficient hydrogen production technology to meet the requirements of hydrogen resources in the energy internet area of the park and fast response technology of the hydrogen storage system.

7 Conclusion

The energy internet park is the developing trend of the future energy system. Key techniques of Rongchuang park in Lanzhou have been carefully introduced herein. First, improving the clean energy production and consumption ratio meets the low-carbon development needs of the energy internet Rongchuang park. It makes contributions to the carbon peak and carbon neutral undertakings of Gansu Electric Power Company. The

"source side" techniques mainly include new clean energy power generation and supply techniques, new energy power forecasting, and dispatching control techniques. Second, building a strong smart grid, improving the power grid carrying capacity, and operating security and stability are the basic and core competitive techniques of the energy internet Rongchuang park. The "grid side" techniques mainly include power system modeling and simulation technique, sending end power grid planning technique, distribution network operation and control technique, and power grid dispatching automation technique. Third, it is the key to constructing the energy internet Rongchuang park to fully tap the potential of load-side energy conservation and peak shaving regulation. The "load side" techniques mainly include flexible load dispatching management techniques and virtual power plant techniques. Fourth, energy storage technique can further improve system flexibility and is the key construction direction of the future energy internet. The "storage side" techniques mainly include the electricity/heat storage technique and the electric hydrogen generation/hydrogen storage technique.

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