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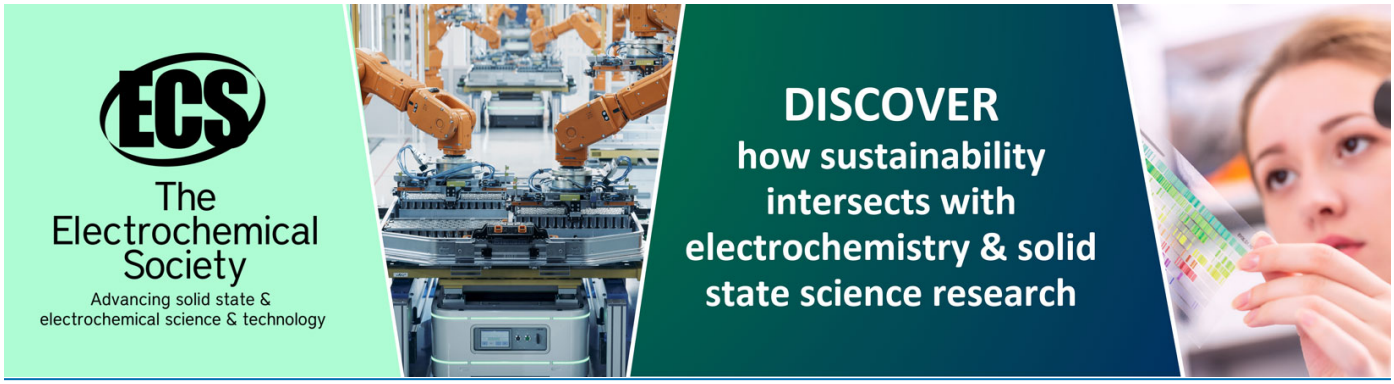

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Analysis of the status and key technical issues of self-provided power plants in the future comprehensive energy application field

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Abstract. Many problems have been exposed in the development of the self-provided power plants, how to reform the self-provided power plants is very important. The construction of a comprehensive energy system covering self-provided power plants has become a new reference idea, which can guide the development of self-provided power plants in the direction of comprehensive energy. This article first introduces the development status of self-provided power plants and the concept of integrated energy system in detail, then analyses the potential relationship between self-provided power plants and integrated energy systems based on the characteristics of self-provided power plants, and then introduces three main applications of the self-provided power plants in the field of integrated energy applications in the future, and finally put forward the main problems related to the smart development of captive power plants and give some relevant suggestions.

1. Introduction

With the rapid development of the economy and society, fossil energy is drying up, environmental pollution is increasing, the deficiencies in the use of energy are gradually exposed and need to be resolved. Accelerating the development and of renewable energy, improving energy efficiency, and exploring new energy utilization methods and other solutions have received much attention. The concept of integrated energy system also provides a new direction for solving such problems [1]. As an important unit in the process of integrated energy application, self-provided power plants cannot be ignored. Exploring self-provided power plants in the field of comprehensive energy applications in the future has also become a research hotspot.

2. Status analysis of self-provided power plant

Self-provided power plants were generated and emerged in the 1980s, and mainly refer to the power plants established by high-energy-consuming enterprises, which aim to generate electricity power to meet their own electricity demand. At that time, in order to quickly promote domestic economic development, high-energy-consuming enterprises have accelerated investment and construction, which has led to a rapid increase in power demand. To alleviate the contradiction between supply and demand of electric energy, the government proposed "multiple power supply" and "multi-channel power supply" to guide enterprises to generate electricity independently, so many high-energy-consuming enterprises invest in building their own power plants, and the number of self-provided power plants increases accordingly [2,3,4]. Self-provided power plants have played an important role in alleviating the tight supply and demand of electrical energy, which has effectively promoted the development of the domestic economy, but at the same time exposed many problems caused by the development of self-provided power plants, which needs attention and concern. First of all, most of the self-provided power plants are coal thermal power units. The emissions of the units mostly contain components that pollute the environment, however the environmental protection facilities in the plant are not in place. This causes the units to meet the demand for electrical energy while also causing serious environmental pollution. Secondly, most of the self-provided power plants are invested and constructed independently by enterprises, with independent management and independent operation, and lack of restraint management by relevant departments. Some self-provided power plants have equipment violations and low operating levels. When the unit of the self-provided power plant is in normal operation, it can provide power to the enterprise, and the local public network is used as a backup; when the unit fails to meet the load demand of the enterprise, the enterprise directly accesses the power from the public network in the region. The characteristics of autonomous operation have caused the public network to fail to formulate the electricity sales plan in a timely and accurate manner, greatly ruined the reliability of the local power grid operation, and easily caused a large-scale power outage. In addition, a large number of self-provided power plants concentrate power generation, resulting in insufficient peak shaving capacity of the power grid, excess power generation by new energy sources, and inability to deal with problems such as waste of resources in a timely manner. To this end, it is necessary to conduct an in-depth analysis of the self-provided power plant, fully explore the advantages of the self-provided power plant, use it reasonably and restrict management, which can not only improve the problems of self-provided power plant, but also greatly alleviate the current contradictions of the energy environment.

3. Development of integrated energy system

The integrated energy system refers to the comprehensive utilization of multiple energy sources, which is mainly to promote the development and utilization of distributed energy and improve the comprehensive utilization efficiency of energy, integrate various forms of energy, and realize the coupling, complementarity and coordination among multiple energy flows planning and optimizing operation [5,6]. The current research on integrated energy mainly involves energy types including electricity, heat, natural gas, and cold. Some scholars also consider transportation [7]. The links involved in integrated energy include: energy transmission, energy distribution, energy conversion, energy consumption and energy storage. Some scholars have studied many aspects of integrated energy system. Article [1] gave a detailed description of the development concept and research focus of the two concepts of integrated energy system and energy internet, and compares the differences between the two. Article [6] on the benefits of integrated energy system in low carbon it elaborated in detail, pointed out the advantages of the integrated energy system in low-carbon emissions, and gave the overall research framework of the low-carbon system. Article [8] focused on the research of the integrated energy system containing electricity, gas and heat, through model analysis establishes a set of expected accidents to analyse the safety of the system.

The integrated energy system breaks the existing mode that all kinds of energy systems operate independently and are not connected with each other. It can organically coordinate and cooperate with all kinds of energy sources so as to couple multiple energy sources, and comprehensively utilize all

kinds of energy sources, and shift the use of energy from traditional energy to clean energy, which realizes the interaction between supply and demand of energy systems, mutual coordination, complementary advantages, clean and efficient, also improved energy utilization, and has obvious ecological and economic benefits. This is an important form of energy utilization in future society.

This article links self-provided power plants with integrated energy applications, the relationship between self-provided power plants and integrated energy is found by analysing their respective characteristics. The article focuses on exploring the status of self-provided power plants in the field of integrated energy applications in the future, and attempts to propose the key technical issues faced by development, and provides reference for subsequent research and development.

4. Application analysis of self-provided power plant in the future comprehensive energy field

To study the application of self-provided power plants in the field of integrated energy in the future, it is necessary to closely link them according to the characteristics of the two. Both the flexibility of self-provided power plants and the comprehensiveness of the integrated energy development must be considered. This section mainly introduces three typical applications of self-provided power plants in the future integrated energy system, as follows: comprehensive smart energy development based on self-provided power plants, mutually beneficial development between self-provided power plants and new energy, and full-grid energy supply covering self-provided power plants system.

4.1. comprehensive energy development and utilization

Self-provided power plants mainly generate electrical and thermal energy by burning coal and other fossil fuels, and supply them to the internal load of the enterprise. While generating energy, the unit also generates a large number of additional products, if these products are not treated, it will inevitably cause a great deal to the environment pollution. At present, the most ideal and most economical way is to introduce related industries around self-provided power plants and build an integrated energy system mainly based on self-provided power plants, which aim to absorb excess products [9]. For the fly ash, gypsum, slag and other wastes generated by power generation in the power plant, industries such as cement plants, commercial mixing stations, gypsum board plants, and slag board plants can be introduced to absorb them; wineries, drying plants, and other plants can make full use of excess steam, water and other products of self-provided power plants; by installing waste heat power generation equipment, low temperature waste heat and waste gas recovery and utilization devices, absorption refrigeration units, the waste heat of the unit can be recycled. At the same time, in order to promote the consumption of electric energy during the trough period, storage power plants and power-to-gas plants can be built around the power plant. Self-provided power plants can obtain profits by selling excess electric power in to maximize economic returns. The schematic diagram of comprehensive energy development and utilization centered on the products of self-provided power plants is shown in Figure 1 below.

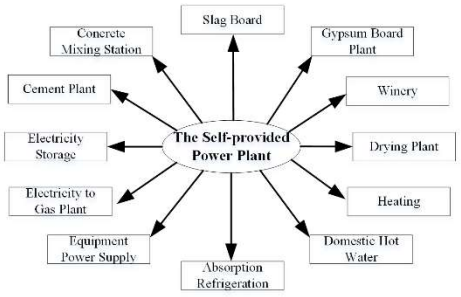

Figure 1. Schematic diagram of comprehensive energy development and utilization including self-provided power plants

The integration of multiple industries to build an integrated energy system can make full use of the products between each other and improve the energy efficiency of the area, which can not only obtain environmental benefits, but also save economic costs. Cogeneration power plants are generally considered to be a typical integrated energy system due to their non-single output energy. This section takes a cogeneration power plant as an example, introduces a power-to-gas plant around the power plant, build a multi-energy flow integrated energy system with complementary electric energy and natural gas, introduces it as a typical application case to study the key issues faced by the self-provided plant into the application of integrated energy systems. The overall structure of the system is shown in the Figure 2 below.

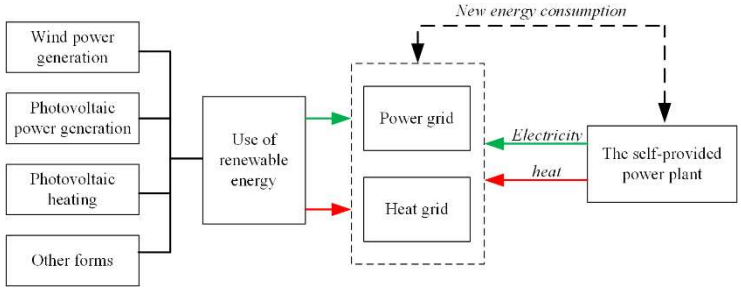

Figure 2. Integrated energy system with self-provided power plant and electricity-to-gas plant.

Compared with traditional coal-fired generating units, gas-fired generating units operate flexibly, start quickly, and generate fewer pollutants, which has obvious environmental advantages. The gas-fired cogeneration unit mainly refers to natural gas as the fuel, generating electricity through the gas-steam combined cycle unit, and reusing the tail gas waste heat after power generation to produce high-temperature hot water to meet the heat load demand. The cascade utilization of tiered energy effectively improves the efficiency of energy use. Electricity to natural gas technology mainly refers to the conversion of electrical energy to natural gas. The main process includes two steps: electrolysis of water to produce hydrogen and oxygen; hydrogen and carbon dioxide in the methanation reaction device to generate Methane and Water. In the whole reaction process, carbon dioxide is recycled as an energy carrier, and no harmful gas is emitted. It is a zero-carbon emission energy use method.

The combination of gas-fired combined heat and power plants and electricity-to-natural gas plants can utilize products from each other, which can effectively promote the coordinated use of energy within the region, reduce environmental pollution, and promote the implementation of coal-to-gas policies [10]. When the power supply of the self-provided power plant is greater than the demand, the excess power is sent to the electricity-to-gas plant to produce natural gas, and the natural gas is sent to the pipeline network to achieve indirect storage of electrical energy; When the demand for electricity is greater than the supply, the natural gas is directly delivered to the gas turbine unit of the self-provided power plant, and the electrical energy load and the heat load are supplied through power generation. In the whole process, the combination of self-provided power plants and electricity-to-natural gas plants break the original coal-based energy structure, achieved various forms of energy collaborative supply cooperation such as electricity, heat, gas, and water, and constructed a smart energy system based on self-provided power plants, and this energy system is low-carbon and comprehensive.

4.2. New energy consumption and transformation

With the gradual depletion of fossil energy and the increasingly serious environmental pollution, more and more attention is focused on the development and utilization of renewable energy. The advantages of various new energy sources have been fully exerted, including wind power, photovoltaic power, and solar power. These renewable energy sources have already accounted for a large proportion of the energy supply, effectively alleviating the energy shortage and promoting the clean development of power grids and heat networks. However, due to the specific characteristics of renewable energy itself, such as large regional differences, uneven temporal and spatial distribution, and other aspects. Also, there are

restrictions on long-distance transmission of energy. If the generated energy is not consumed in time, it will cause a large amount of wind and light abandonment, and the problem of waste of such energy has attracted widespread attention. Fully mobilizing self-provided power plants to participate in new energy consumption is considered to be an effective solution. As early as 2015, the relevant department pointed out in the document "Guiding Opinions on Strengthening and Regulating the Supervision and Management of Self-provided Coal-fired Power Plants" [11] that vigorously develop clean energy and replace self-provided coal-fired power plants, we should effectively strengthen the use of energy promotes the reduction of coal combustion, and promotes the development of China's energy and electricity market in a healthy direction.

Taking electric energy as an example, when the new energy generation surplus, some generators of the self-provided power plant can be shut down. The electric energy load originally provided by the self-provided power plant is transferred to the public network. When the peak shaving capacity of the power grid is insufficient, the energy supply cannot meet the load demand, the self-provided power plant should be coordinated to increase the operation of the unit, so that the self-provided power plant can not only meet its own load demand, but also maintain the stability of the large power grid. The same is true for the regulation of the heat network, and it is necessary to set up the coordination mechanism and operation strategy of district heating according to the actual situation, to ensure the economic benefits of self-provided power plants and the correct supply of energy in the district. The application of self-provided power plants to the new energy consumption can ensure the stable operation of the power grid and heating network in the region, and also avoid the waste of energy, achieving a mutually beneficial and win-win situation between the two. The schematic diagram of the structure of self-provided power plant to promote the consumption of new energy is shown in Figure 3.

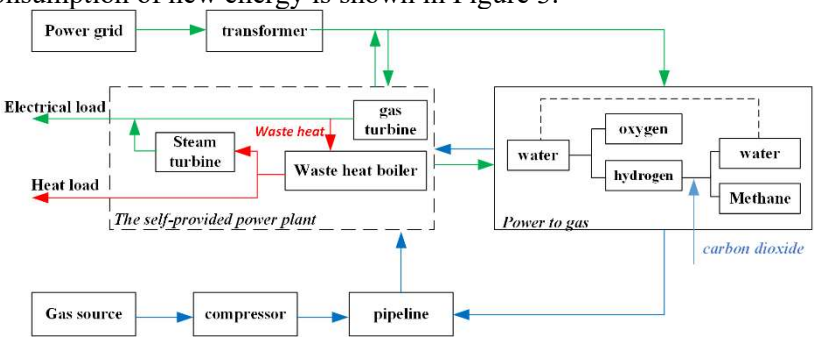

Figure 3. Schematic diagram of coordinating captive power plants to promote the consumption of new energy.

Self-provided power plants are involved in the operation of new energy consumption, and they face and solve many problems, such as alternative mechanisms, trading of power generation rights, and unit switching plans. At present, some scholars have studied many problems about the self-provided power plants participating in the consumption of new energy. The article [12] proposed a transaction model for the replacement of electricity between self-provided power plants and new energy, taking economic interests as the starting point, the trading rules are designed from the three aspects of matching rules, execution rules and settlement rules, and the transaction mode of electricity replacement is analyzed. Article [13] is mainly aimed at the risk factors in alternative trading of self-provided power plants when promoting the consumption of new energy. The author established a model to analyze the trading profit, risk value and other parameters of self-provided power plants in different market environments. This can be used as a reference for trading decisions and risk assessment of captive power plants participating in new energy consumption. Article [14] based on the peak shaving compensation mechanism of the self-provided power plant, established the economic benefit model of self-provided power plants and new energy companies, to study the trading model of power generation rights of the two. Article [15] aimed at the serious phenomenon of wind and light abandonment in some areas of China, a transaction mode of power generation transfer between self-provided power plants and new energy companies was proposed within the framework of the existing power market trading policy, the goal is to promote self-

provided power plants to undertake public peak shaving responsibilities, which can improve the ability of the grid to adjust peak consumption. At present, the government has greatly strengthened the control of self-provided power plants, and the policies and measures related to the implementation of new energy consumption are also being gradually improved. By reasonably scheduling the relationship between self-provided power plants and new energy systems, the mutually beneficial development between the two can be effectively achieved.

4.3. District Energy Network

Due to the long-distance transmission of electric power, hot water, and natural gas through transmission lines and pipelines, there is a line loss and energy loss that cannot be ignored. The internal supply of regional energy can effectively avoid excessive waste during energy delivery. Self-provided power plant as a single energy individual, there are many links in the plant such as energy generation, transmission, and use. Self-provided power plant can be regarded as a large "energy source" or a large "energy load" ", but it has been in a state of spontaneous self-use for a long time. If the self-provided power plant is included in the local energy network, unified management and planning will be carried out to build a regional energy network [16,17], the self-provided power plant can meet the electricity and heat needs of surrounding enterprises and residents while meeting its own load demand, thereby achieving the supply stability of the regional energy network. Incorporate self-provided power plants into the regional energy network, and negotiate between the self-provided power plants and energy companies to ensure the timely supply of all electrical and thermal loads and the stability of the regional energy network under the premise of maximizing economic benefits. This changed the previous situation of the independent development and not communicating with each other, and can avoid the loss of long-distance transmission of electrical and thermal energy. Energy companies and self-provided power plants have certain economic benefits. This is an important application of power plants in the field of integrated energy in the future.

5. Key technical issues

With the advancement of new comprehensive energy systems, the development of energy systems has changed from the traditional development of multiple single systems to the unified development of multiple energy flow systems. More and more types of energy are involved. The links related to energy conversion, transmission and use are getting closer and closer, and the self-provided power plant as an important role in the energy field cannot be ignored. Due to the long-term free-style development, many problems have been exposed to the self-provided power plant, and the development of the self-provided power plant has been closed to the bottleneck. It is urgent to reform the self-provided power plant and seek a method to standardize the development of the self-provided power plant [18,19]. The integration of the self-provided power plants into the development of integrated energy has become an important way. This section briefly introduces the key issues that need to be resolved in the process of self-provided power plants participating in the development of integrated energy applications from three aspects: government, energy enterprises, and self-provided power plants.

The government should introduce policies to promote the integration of self-provided power plants into the development of integrated energy systems. Self-provided power plants are managed and operated independently by the enterprise. The information about the operation of the units, power generation and utilization, and equipment operation and maintenance status of the self-provided power plants rarely interact with the outside world. The government should issue relevant policies to encourage the self-provided power plants to actively interact with the energy companies to cooperate and communicate. In response to the problems of environmental pollution and non-standard operation of self-provided power plants, the state has successively formulated policies on environmental protection, safety, and operation management of self-provided power plants, encouraging existing self-provided power plants to actively transform into clean, environmentally friendly and efficient power plants, and guiding self-provided power plants to actively participate in comprehensive energy construction, but the implementation of relevant policies is not in place. The barriers between captive power plants and

existing public power plants, power grid companies, energy companies and other institutions need to be broken. It is necessary for the government to continue to introduce management standards and measures in line with local actual conditions within the development framework, so as to break down the barriers between self-provided power plants and existing public power plants, power grid companies, energy companies and other institutions, so that the self-provided power plants comply with national management standards in the comprehensive utilization of energy.

Energy companies should do a variety of research on incorporating self-provided power plants into the construction of integrated energy systems. The existing research and analysis for a single energy system is relatively mature, however, since the application of integrated energy systems involves multiple forms of energy, the spatial and temporal scales of multiple energy flows are different, and the coupling characteristics between each other are complex, research on integrated energy systems is still in its infancy [20,21]. So, it is necessary to ensure the stable and reliable operation of each energy system. The impact of self-provided power plants cannot be ignored. It is necessary to establish a grid connection specification for self-provided power plants, develop energy quality auxiliary devices, and develop multiple multi-agent operation analysis software to find the business model and benefit balance point between major operators and self-provided power plants, realize optimal planning and configuration of regional networks, to ensure the safe operation of integrated energy systems and the self-provided power plants.

The self-provided power plants should actively participate in the construction of integrated energy systems. Many of the energy problems facing today are no longer single-sided, but are influenced by multiple parties. With the economic development, the supplementary effect of self-provided power plants on the power grid is not as obvious as before, on the contrary, it has been controversial because of many problems, the development direction of the self-provided power plants in the future society is worth pondering. Participating in the application of comprehensive energy and promoting the efficient use of multiple energy sources is undoubtedly a good choice for the self-provided power plants. For this reason, the self-provided power plants should be active to change the mind and turn the passive into the active, these plants must combine their own advantages, use rich and affordable power and steam resources as a springboard for enterprise reform and development, and actively participate in the construction of comprehensive energy applications.

6. Summary

This article mainly introduces many problems in the development of the self-provided power plants based on the development status of the self-provided power plant, and proposes a way to integrate the self-provided power plants with the development of integrated energy. Through three typical application analyses, it focuses on the status of self-provided power plants in the field of integrated energy applications in the future, and at the same time puts forward the key issues that need to be resolved to develop integrated energy applications for self-provided power plants, which can provide reference for future research.

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