Modeling analysis of typical equipment and construction of energy supply scenarios for electric energy substitution

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Abstract. This paper studies the design of clean electric energy alternatives based on electric energy alternative equipment. First, sort out the current research status of energy substitution at home and abroad, and determine the research focus of electric energy substitution; list the electric energy substitution equipment that is suitable for construction, industrial, commercial and other fields, analyze its technical characteristics and specific application scenarios; list each device To analyze the performance of the equipment, establish a multi-factor output model for energy storage and production equipment according to the key influencing factors of the equipment performance coefficient; finally, based on the above research, consider the substitutability of each equipment With complementary characteristics, the design is suitable for high-clean energy electric energy to replace typical structures.

1 Research status of electric energy substitution

With the continuous development of current social science and technology and social economy, energy usage is undergoing tremendous changes. An important indicator of the level of modernization of a country is the level of electrification. Electricity is a high-quality secondary energy source. Compared with primary energy, it is directly used as a terminal energy source. It has many advantages. It improves the level of electrification and converts fossil energy such as coal into electricity. One of the most efficient, environmentally friendly and effective ways. By analyzing the characteristics of energy use in typical industries, analyzing the main links and feasibility of replacing other energy sources with electric energy in various industries, and proposing technologies and equipment with greater feasibility (substitution potential) for electric energy substitution, it is determined that electric energy is used in various industries, tertiary industries and The competitiveness of residential energy consumption provides a foundation for improving the competitiveness of electric energy in the final energy market. At present, there are many related researches on the evaluation of electric energy substitution, mainly focusing on the competitiveness of electric energy in the terminal energy and the related benefits of electric energy substitution:

First, research on the evaluation of the competitiveness of electric energy in terminal energy. Electricity, as a commodity, has a great competitive relationship with other energy sources in the terminal energy consumption market. Through the evaluation and research on the

competitiveness of electric energy in the terminal energy, we can understand the advantages and disadvantages of electric energy compared with other energy sources. Therefore, relevant measures can be formulated to improve the competitiveness of electric energy and promote the development of electric energy substitution. Li Yuanyuan [1] constructed an analysis model of power competitiveness factors from the two aspects of results and impacts, and based on this, built an evaluation index system for power competitiveness in terminal energy, and provided evaluation ideas and methods. Based on the analysis of Beijing's terminal energy consumption, Zhang Ye[2] established the terminal energy market from four aspects: the competitive environment, power products, power supply enterprise capabilities, and power market occupancy capacity based on the main factors affecting power competitiveness. The competitiveness evaluation index system in energy, and the improved ideal point method evaluation method was used to evaluate the competitiveness of Beijing's electric energy in the final energy.

Second, research on benefit evaluation of electric energy substitution. The research on the benefits of electric energy substitution mainly focuses on the economic benefits, environmental benefits and social benefits of electric energy substitution. At present, due to the high technical content of power equipment, the price is often higher than that of traditional fossil energy equipment [3]; on the other hand, my country's electricity price is also higher than that of traditional energy sources such as coal and natural gas, so the economic benefits of electricity substitution are relatively high. Low [4]. However, electric energy is a clean secondary energy source and will not produce any polluting gas during use

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[5-8]. At the same time, studies at home and abroad have pointed out that the implementation of electric energy substitution can promote the modernization and intelligent development of power grids, and help alleviate energy poverty. Therefore, the environmental benefits of electrification [9-10] and social benefits [11-15] are relatively Higher. Zhang Bohua[16] analyzed the external factors that affect the implementation of electric energy substitution projects and their own capabilities, and divided them into three categories: external environment, company profitability, and social environment. Based on this, three A comprehensive evaluation index system for the benefit of electric energy substitution projects composed of eight first-level indicators, eight second-level indicators, and 23 third-level indicators. Taking the ground source heat pump project in Tianjin as an example, the economic benefits The environmental benefits were evaluated and the feasibility of the project was demonstrated.

2 Research on the applicability of typical energy equipment for electric energy substitution scenarios

2.1 Ice storage air conditioning

According to different cold storage media, it is divided into water storage and ice storage. The water-storage air-conditioning system uses water as the medium, combines the surplus valley electricity of the grid at night when the electricity price is low, and the sensible heat of the water, stores cold in the form of low-temperature chilled water, and uses chilled water as a cold source during peak periods. The ice-storage air-conditioning system uses the valley section of electricity at night to operate the refrigerator for refrigeration, and it is stored in the form of ice. During the daytime, the ice is melted to provide cold for air conditioning.

Scope of application: Mainly used in beer, food processing, pharmacy, dairy industry, etc., where the cooling capacity is large, and most of the air-conditioning load is concentrated in the daytime manufacturing industry. It can also be used in stadiums, cinemas, exhibition halls, etc., with large cooling loads. Long time occasions.

2.2 Conventional refrigeration unit

The influencing factors of chiller operation energy consumption mainly include internal factors and external factors. The internal factors include the chiller's own parameters, mainly including the number of chillers, the coefficient of performance of the chiller, COP, the coefficient of performance of part load IPLV, and the reasonable matching of the number of chillers; the external factors include the temperature of the supply and return water, the temperature difference between the supply and return water, and the water flow. Wait.

Scope of application: It can be widely used in residential buildings, schools, hospitals, business office buildings, factory workshops, shopping malls,

supermarkets, hotels and other buildings.

2.3 Ground source heat pump

The heat pump has the characteristics of renewable, high efficiency, energy saving, environmental protection and no pollution, and a wide range of applications. It can realize the energy transfer from low temperature heat source to high temperature heat source, and promote the heat of low temperature heat source to high temperature heat through the compressor.

Scope of application: public buildings such as schools, hospitals, hotels, office buildings and residential buildings such as villas and residential buildings.

2.4 Thermal storage tank

The heat storage tank is used as a heat storage and peak regulation facility. When the thermal load is low, the thermal power unit can basically maintain full load operation. The heat storage tank stores the rich heat in the tank. When the heat load increases, the heat storage tank will store it The heat in the tank and the constant heat supply of the thermoelectric unit are jointly supplied to the user (whether the peaking heat source is put into operation or not, depending on the situation) to meet the heat load needs.

Scope of application: It can meet the needs of various types of heating, hot water, drying, heat source supporting, etc., and meet the needs of large-scale heating and hot water supply, industrial steam, etc., suitable for residential communities, villas, commercial real estate and Tourist Area.

3 Analysis of output factors of electric energy alternative energy equipment

3.1 Ice storage air conditioning

The cooling efficiency calculation formula is:

$$\eta_{ic} = \frac{C_{wa}(\dot{m}_{wa} + \dot{m}_{ic})(T_{o,wa} - T_{e,wa}) + \dot{m}_{ic}h_{ic} + C_{ic}\dot{m}_{ic}(T_{o,ic} - T_{e,ic})}{Q_{ab}} \quad (1)$$

The calculation formula of the refrigeration performance coefficient COP of the ice maker is:

$$COP = \frac{C_{wa}(\dot{m}_{wa} + \dot{m}_{ic})(T_{o,wa} - T_{e,wa}) + \dot{m}_{ic}h_{ic} + C_{ic}\dot{m}_{ic}(T_{o,ic} - T_{e,ic})}{W} \quad (2)$$

In the formula: C_{wa} and C_{ic} are the specific heat capacities of water and ice, J/(kg·K); $\dot{m}_{wa}$ and $\dot{m}_{ic}$ are the mass flow rate and ice production rate of the circulating water inside the flake ice sliding ice maker, kg/s; $T_{o,wa}$ and $T_{e,wa}$ are the temperature of circulating water before and after flowing through the pan evaporator, K; h_{ic} is the specific heat of phase change of ice, J/kg;

$T_{o,ic}$ and $T_{e,ic}$ are the temperature of ice before and after ice making, K.

3.2 Conventional refrigeration unit

3.2.1 Number of chillers

The number of chillers is one of the factors that directly affect the energy consumption of chillers. In order to meet the different cooling load requirements of the building, the relationship between the number of chillers and energy consumption can be expressed as:

$$PWR = PWR_1 + PWR_2 + \dots + PWR_n$$

$$= \sum_{i=1}^n PWR_i \quad (3)$$

In the formula: n is the number of chillers; PWR is the total energy consumption of n chillers, kWh;

3.2.2 COP

The COP value is the ratio of the cooling capacity to the input power, and is one of the important indicators for evaluating the energy efficiency of the cold machine operation. The COP value of the chiller under design conditions can be expressed by:

$$COP = \frac{Q_0}{P_0} \quad (4)$$

In the formula: Q_0 is the cooling capacity of the chiller, kW; P_0 is the input power of the chiller, kW;

COP is one of the important factors affecting the energy consumption of the chiller. COP is inversely proportional to the operating energy consumption of the chiller. Under the same cooling capacity, the greater the COP value, the lower the operating energy consumption.

The relationship between energy consumption of a single chiller and COP:

$$PWR_i = \frac{Q_0}{COP} \cdot h \quad (5)$$

In the formula: PWR_i is the energy consumption for a single chiller, kWh; h is the running time of a single chiller, h.

3.2.3 Partial load performance coefficient IPLV

IPLV is the partial load efficiency index of air conditioning chillers expressed by a single value. It is based on the coefficient of performance value of the unit under partial load and the weighting factor of the unit operating time under various loads. One of the key indicators of machine operation energy efficiency.

Under many conditions in the air-conditioning system, the operation of the chiller is carried out under partial load. In order to control the energy consumption of the unit during partial load operation, it is necessary to make

certain requirements for the coefficient of performance of the chiller under partial load. The standard GB/T18430.1-2007 and GB/T18430.2-2008 of the chiller introduced the calculation formula of the integrated partial load performance coefficient IPLV:

$$IPLV = 2.3\%A + 41.5\%B + 46.1\%C + 10.1\%D \quad (6)$$

In the formula:

Coefficient of performance COP at A-100% load, kW/kW;

Performance coefficient COP at B-75% load, kW/kW;

Coefficient of performance COP at C-50% load, kW/kW;

Coefficient of performance COP at D-25% load, kW/kW;

3.3 Ground source heat pump

The coefficient of performance is an important indicator of the energy efficiency of the unit. COP (Coefficient of Performance) is the ratio of the cooling capacity (heating heat) to the input power of the unit when the air conditioner unit performs cooling (heating) operation under a certain working condition. The value is expressed in W/W. COP is the performance parameter of air conditioning units (integrated and split air conditioning units including air source, water source, ground source, etc. For vapor compression heat pumps, the heating performance coefficient COP_h is the ratio of heating capacity Q_h to input power P .

$$COP_h = Q_h / P \quad (7)$$

According to the first law of thermodynamics, if the heat dissipation from the compressor to the environment is not taken into account, the heating capacity of the heat pump Q_h is equal to the sum of the absorption from the low-temperature heat source (equivalent to the cooling capacity of the refrigerant) Q_c and the input power P ; and the coefficient of performance $COP_c = Q_c / P$ is the coefficient of heating performance can be written as:

$$COP_h = (P + Q_c) / P = 1 + COP_c \quad (8)$$

Another indicator is commonly used in English units, namely EER (Energy Efficiency Ratio) to evaluate the performance of refrigeration systems or refrigeration compressors. The national standard has begun to use EER and COP to express cooling and heating coefficients.

3.4 Thermal storage tank

The typical physical model of the thermal storage tank can be expressed as:

$$Q_{HS}(t) = (1 - \mu_{loss})Q_{HS}(t_0) + Q_{HS}^{ch}(\Delta t)\eta_{HS}^{ch} - \frac{Q_{HS}^{dis}(\Delta t)}{\eta_{HS}^{dis}} \quad (9)$$

In the formula: $Q_{HS}(t)$ is the heat storage capacity of the heat storage tank at time t ; μ_{loss} is the heat dissipation loss rate of the heat storage tank; $Q_{HS}(t_0)$ is the heat storage capacity of the heat storage tank at the initial moment t_0 ; $Q_{HS}^{ch}(\Delta t)$ is the heat storage capacity of the heat storage tank between t_0 and t ; η_{HS}^{ch} is the charging efficiency of the thermal storage tank; $Q_{HS}^{dis}(\Delta t)$ is the heat release of the heat storage tank between t_0 and t ; η_{HS}^{dis} is the heat release efficiency of the heat storage tank.

4 Typical scene design

The climate of Yunnan is basically a subtropical plateau monsoon type, with remarkable three-dimensional climate characteristics, numerous types, small annual temperature difference, large daily temperature difference, distinct dry and wet seasons, and abnormal vertical changes in temperature with terrain. The energy resources of Yunnan Province are mainly hydropower, coal, wind power and solar energy. Geothermal and biomass energy resources are also abundant, and natural gas and petroleum resources are scarce. Therefore, geothermal energy, solar energy, wind energy, and biological energy have good development prospects.

The integrated energy system contains a variety of energy supply and energy storage equipment, and the operation of the equipment is controlled to meet the cooling, heating and electrical loads in the area. Based on smart power distribution, build a multi-energy complementary power alternative scenario with electric energy as the core, gas as the key, heat transmission network as the extension, distributed power as the supplement, and energy storage system as the support, to meet end users' expectations. Electricity, heat, cooling, gas and other energy demand.

4.1 Electricity is the core

Distributed energy is connected to the energy network through electrical energy, and electrical energy can be flexibly converted to multiple energy sources, and various loads can meet user needs in the form of electrical energy. The future energy Internet will inevitably center on the power system. From a global perspective, in terms of energy utilization, electric energy substitution is considered an effective way to use energy efficiently. The strategic position of the power system in the world's energy utilization field determines the indispensable role of the Energy Internet in its core layout. It also reflects the interests of the power system in the energy Internet.

4.2 Gas is the key

Gas-fired central heating means that multiple buildings in one or several communities share a gas-fired boiler room for heating, using a secondary heating network, with intermediate heat exchange stations, and the external

heating network is large in scale, with a heating area of several million square meters M, the flue gas is discharged at high altitude. Internationally, natural gas has become the third largest commercial energy source after coal and oil. In addition to centralized heating and power supply, household heating and cooking, household gas heating water heaters, cooking and heating are all converted to natural gas, and the focus is on heat pumps, thermal storage electric boilers and other transformation methods to realize household heating and cooking Change electricity or heating electricity, cooking gas. Gradually replace the original energy use methods such as coal gas, effectively reducing the emission of pollutants.

4.3 Thermal network is an extension

At present, the heating and cooling of buildings in my country is mainly guaranteed by the consumption of fossil energy, and the primary energy utilization rate of the energy supply system is still at a low level. As we all know, fossil energy will inevitably be exhausted in the long run, and the consumption of fossil energy will also lead to further deterioration of the environment. Therefore, in addition to considering the cooling and heating cogeneration mode in the system design, we should also consider reducing the dependence on non-renewable energy in the use of primary energy, and strive to make the cooling and heating cogeneration system develop towards low energy consumption. The realization of the optimal operation of the cogeneration system is not only a guarantee to meet users' cooling and heating needs, but also the key to improving the energy efficiency of the system. For the cogeneration system, realizing its optimized operation is an important step to improve energy efficiency and reduce operating costs.

4.4 Distributed energy is a supplement

Compared with the traditional power system of centralized power generation, long-distance power transmission and large grid power supply, the distributed energy system overcomes some of the weaknesses of the traditional system, and highlights the saving of investment, reducing losses, improving system reliability, diversifying energy types, and reducing pollution And other advantages, it has become an indispensable and beneficial supplement to the traditional power system.

4.5 Energy storage/heat storage device is the support

Energy storage plays a very important role in the uninterrupted power supply, power peak shaving, improvement of power quality and performance of micro power supply of micro grids, and is the key to the safe and reliable operation of micro grids. Battery energy storage has the advantages of high energy density and easy operation and maintenance.

At present, a large number of wind abandonment problems caused by the "wind-heat conflict" during the winter heating period have also become a concern of the

whole society. The cause of the conflict is that the thermal power unit is heated by the "heat-based power" constraint, which leads to its peak regulation capacity. Significantly reduced or even lost. Under the condition of satisfying heat supply, improving the peak shaving capacity of thermal power units can increase the consumption level of wind power. In fact, the thermal power unit can realize flexible operation by configuring heat storage and decoupling its "power based on heat" constraint, thereby greatly improving the peak regulation capability.

5 Conclusion

This paper takes electric energy substitution as the core to carry out performance analysis and equipment modeling research of various energy equipment. It analyzes the electric energy substitution equipment and specific application scenarios that are suitable for construction, industrial, and commercial fields. On this basis, analyzes the substitutability and complementary characteristics of each equipment. Finally, taking the resource situation of Yunnan Province in China as an example, the implementation plan and basic planning structure for electric energy substitution suitable for high clean energy are designed.

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