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RESEARCH PROGRESS AND TREND OF SOLID ELECTRIC HEAT STORAGE TECHNOLOGY

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ABSTRACT[1]

Solid electric heat storage technology is an important part of energy conversion and utilization technology, which plays a key role in wind power, clean heating and flexible peak regulation of coal-fired units. The development of solid electric heat storage technology has a great significance to improve the utilization efficiency of renewable energy, enhance the peaking capacity of thermal power generation and relieve the grid dispatching pressure. In this paper, the development status, application, development trend, advantages and disadvantages of solid heat storage technology are summarized.

Keywords: solid electric heat storage、peak load regulation、clean heating、research progress

1. INTRODUCTION

Clean energy will be developed in the development process of energy Internet and utilized rapidly, and the position of renewable energy in clean energy will also be gradually elevated. Renewable energy power generation has randomness and intermittence. The grid connection of renewable energy power generation will have a huge impact on the traditional power grid, resulting in voltage fluctuation, frequency fluctuation and other conditions, which will endanger the safety of the power grid[1]. It is the key to the development of clean energy that how to improve the utilization rate of renewable energy, enhance the peak regulation capacity of thermal power plants and alleviate the pressure of power grid dispatch. Energy storage can not only improve the efficiency, safety and economy of conventional power generation and transmission, but also realize the smooth fluctuation, peak regulation and frequency modulation of renewable energy. It is not only an important means to meet the large-scale access of renewable energy, but also an important part of the distributed energy system and electric vehicle industry, which plays a pivotal role in the energy Internet. Meanwhile, for the consideration of environmental protection, energy conservation and emission reduction, China vigorously promotes "coal to electricity" and clean energy heating.

As countries put energy storage technology into strategic planning, the investment scale of energy storage market keeps increasing, and the bottleneck of emerging technology research and development keeps breaking through, the industrial chain and business model of energy storage industry gradually mature, and the electric storage and heat industry has been vigorously developed, among which solid electric storage and heat technology is the best.At present, solid electric storage heat is widely used in regional heating and deep peak adjustment in thermal power plants. The summary is as follows.

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2. PRINCIPLE OF SOLID ELECTRIC HEAT STORAGE

Solid electric heat storage equipment is a kind of heat source equipment, which can be used to directly replace the traditional boilers fueled by coal, oil and gas[2]. Solid electric heat storage is a kind of heat storage method that converts electric energy into heat energy and stores it in solid electric heat storage materials by means of cheap power period at night trough. High temperature and high pressure solid electric heating heat storage system using resistance heating mode, the electric energy into heat energy, heat transfer by radiation and convection heat transfer of heat transfer and stored in the heat storage material, when need to use this part of the heat, heat the air by convection heat transfer way, air flows through the soda heat exchanger to heat supply to heating system. High temperature and high pressure solid electric heating heat storage units by the following systems: hot body, heating system, heat storage system, the wind circulation control system, external heat subsidiary circulation system and so on, also including its affiliated system equipment: hot water circulating pump, softened water equipment, the GIS system, constant pressure filling water system, control system, heat metering device and the temperature measurement device[3], as shown in Figure 1.

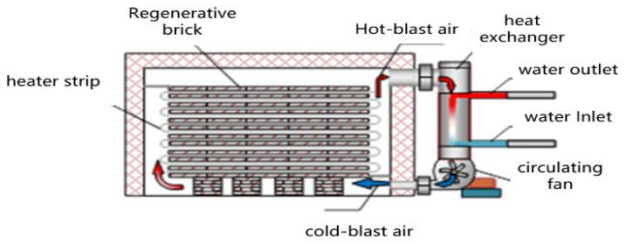

Fig.1 Schematic diagram of the structure of the solid heat storage system

The above structure can be roughly divided into two parts: heat storage body and heat exchanger, which are independent of each other to achieve water and electricity separation, with high equipment safety and stability. The heat storage part can be directly connected to the heat storage body by 380V-110kV high voltage, and the principle of resistance heating is adopted to make the heat storage unit release heat and store heat. When the temperature of the heat storage body reaches above 750℃, the heat exchanger heats the cold water in the pipe through the air and water heat exchanger.

2.1 Characteristics of solid electric heat storage

Solid heat capacity of the electric heat storage materials for a quarter of the commonly, but due to the density of solid electric heat storage materials more than 1.5 times greater than that of water, heat storage temperature can reach 750 ℃ above, make the same volume of solid electric heat storage material accumulation of heat capacity than water heat storage capacity is big, the much smaller energy storage body, with solid electric regenerative energy storage device does not need to be under pressure, and have no special requirements, its shape makes the area and equipment investment is greatly reduced.(1) High temperature heat storage. The temperature has reached the highest level in China. The solid alloy up to 750 ℃ can store heat, breaking through the temperature limit of high temperature storage, and is still in a safe state. Heat storage per unit volume is the highest in China, reducing floor space and customer cost.(2) High efficiency. Nano-porous insulation materials are adopted to achieve excellent insulation effect, with an efficiency of more than 95%, which can ensure the night and day loss of less than 3.2% and reduce energy waste.(3) Low operating costs. Work entirely on electricity generated by cheap overnight valley electricity, wind or solar power. The operating cost of the same heat is 40% ~ 50% of the operating cost of direct heating electric boiler, 60% ~ 70% of natural gas and 35% of diesel.(4) Automatic control. Heating in trough period or receiving automatic command control of power grid dispatching center, heating or releasing heat at any time and at any temperature, without personal care. (5) Zero emissions. Zero emission, zero pollution, pure electric heat pipe heating, not affected by the climate. (6) Safety. The protection device is complete, safe and reliable [4].Solid electric heat storage and energy storage device not only overcomes the shortcomings of traditional heat storage mode, but also has many advantages such as environmental protection, high efficiency, energy saving and safety, etc. It is expected to replace some traditional heating equipment [5]. However, it also has some defects, such as high construction cost in the initial stage and easy breakage of heating wire and heat storage magnesium brick.[6]

2.2 Structure composition of solid electric heat storage

Heat storage bricks are mainly composed of 95# magnesium, 92# magnesium, magnesite iron brick, magnesite carbon brick, red brick, high alumina brick and graphite. The electric heating wire is mainly made

of ni-cr alloy, fe-cr alloy and so on. The air duct provides circulating air loop, including inlet and outlet air chamber, heat exchanger chamber, heat exchanger return air chamber and fan blower. The heating wire is mainly made of ferrochrome aluminum and nickel-chromium alloy. The insulation layer consists of inner tank, fire protection layer, insulation layer, sealing layer and shell. Power distribution cabinets include high-voltage and low-voltage power distribution cabinets, intelligent electric control cabinets, and some special application sites also include high-voltage power transformer cabinets, high-voltage switchgear cabinets, etc. The fan USES high temperature centrifugal fan, common belt drive centrifugal fan and direct link centrifugal fan two kinds. Heat exchangers include air-hot water, air-air, air-steam, air-heat oil, etc. According to the structure, the heat exchanger is divided into shell and tube type, high efficiency fin tube type and high frequency welding spiral fin type.[7]

3. APPLICATIONS OF SOLID ELECTRICAL HEAT STORAGE

3.1 Depth peak adjustment for thermoelectric units

Because electricity cannot be stored, most of the electricity generated by thermal power plants during the heating period is wasted, which is a practical and unsolvable problem facing the world. At present, the operation mode of "using heat to determine electricity" has become the main factor restricting the peak load regulation ability of heating units. Therefore, on the premise of meeting the requirements of users, the traditional operation mode of heat supply units with heat storage devices and decoupling heat supply units has become a scheme to improve the peak load regulation ability of heating units. In the daytime when the electric load is large and the thermal load is small, the thermoelectric unit runs under high load to store heat in the heat storage device. In the hour section of electric load at night, the output of the unit is reduced (or even shut down) for peak regulation, while the insufficient part of heating is compensated and supplied by heat storage device [8].In Denmark, which has a high wind power utilization rate, an important means to realize its future 100% renewable energy system is to improve the peak regulation capacity of heating units by using heat storage devices. Based on the coordinated dispatching model of wind abandon and absorption of thermoelectric generating unit with heat storage and power generation and electric boiler, the calculation example results show that electric boiler heating has the best economy in the limit of wind abandon and absorption.

3.2 "Coal to electricity" clean heating

The main heating modes in north China in winter are coal fired boiler central heating, gas fired boiler heating, electric heating and heat pump heating. In the past few decades, coal-fired boilers have been playing a leading role in central heating. With the increasing attention of the international community on energy utilization and environmental protection, China has put forward the "coal to electricity" project. Clean heating refers to the use of natural gas, electricity, geothermal, biomass, solar energy, industrial waste heat, clean coal (ultra-low emissions), nuclear energy and other clean energy, through efficient energy use system to achieve low emissions and low energy consumption of heating. Solid electric heat storage for heating, is the transformation of energy consumption mode, to improve energy efficiency has a very important significance. Solid electric heat storage is suitable for use in areas where there is no central heating and gas source, but there is sufficient electricity, power supply policy support and preferential price. Using electric energy, there is no waste and management difficulty caused by discharging waste water, waste gas and waste residue. No combustion process, high safety and reliability. Heat storage devices can usually reduce the maximum power load of the power system and have the effect of reducing the peak-valley difference of the power system.

3.3 Wind-solar complementary electric heat storage system

The output of wind power is uncertain and often shows the characteristic of inverse peak regulation. Thermal storage heating with heat storage capacity, the electricity power can be adjusted according to need, has characteristic of adjustable load, thus to coordinate the operation of wind power, thermal power and thermal storage heating, can improve the load capacity of thermal power unit, and make the heating of the heat storage is mainly used to abandon the wind power to work to improve the acceptance of wind power, reduced the wind power. At the same time, the increase of wind power consumption and the reduction of coal consumption of the system also bring additional benefits. Analyzing and calculating the increment of comprehensive benefits and giving reasonable subsidies to the heating side of thermal storage can make up for its poor economy, which is conducive to the promotion

and application of thermal storage and wind power consumption. The combined mode of wind power and thermal storage heating is shown in FIG. 2.

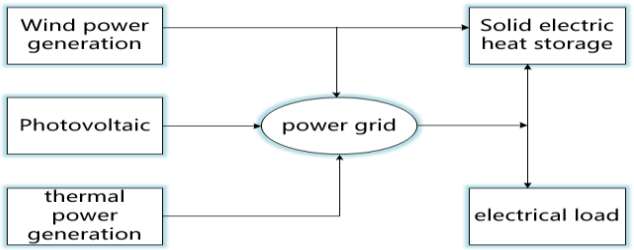

Fig.2 Wind-solar hybrid power and heating system

4. DEVELOPMENT TREND OF SOLID ELECTRIC HEAT STORAGE

Ackn In foreign countries, solid-state electric heat storage technology is mainly based on thermoelectric heaters, most of which use sensible heat storage, such as Fe3O4, etc. Sensible heat storage materials are used to store and release heat using the change of material temperature. Due to its abundant raw materials and low cost, solid electric heat storage devices have been popularized in Western Europe. In 1980-1981, British manufacturers of electric thermal energy storage devices sold 146,300 sets of equipment to industrial and civil use, 175,400 sets in 1981-1982, and 248,300 sets in 1982-1983.In 2015, electrochemical energy storage, mechanical energy storage and thermal energy storage also developed rapidly, with thermal energy storage accounting for 43% at most. Domestic solid heat storage technology mainly adopts 92# magnesite brick or 95# magnesite brick and other materials in heat storage. Large centralized heat storage devices and small electric heaters have been commercialized. At present, many domestic companies have developed high-power magnesite brick thermal storage technology.

Thermal energy consumption accounts for about 40% of the total energy consumption of the whole society, with obvious comprehensive benefits of heat storage and a wide range of applications, it can effectively stabilize the output of renewable energy, serve the consumption of renewable energy, promote the replacement of electric energy, and alleviate air pollution. By 2020, the market size of domestic energy storage industry will exceed 200 billion, among which the two largest sectors are supporting energy storage of scenery power station, distributed power generation and micro-grid energy storage, followed by new energy vehicle energy storage, charging station market, communication base station energy storage, military equipment and base, government agencies, and micro-grid in remote areas. In the future, large-scale high temperature and high voltage thermal storage equipment will replace traditional cogeneration units as the main force of central heating, freeing up more power generation margin for more clean energy power generation. More and more researches believe that energy storage may be the foundation to realize the reform of future energy system, and the key link to coordinate the application of energy Internet, distributed power supply, micro grid, smart home, etc. Global institutions' prediction of the future global and Chinese energy storage market scale shows that the energy storage market has huge development potential.

REFERENCE

[1] the National Development and Reform Commission and other ten ministries and commissions. Winter Clean heating Planning in Northern China (2017-2021) [R]. 2017.

[2] Zhang Ximin, Ren Zelu, Mei Fiming. Heat transfer [M]. Beijing: China Construction Industry Press, 2014.

[3] Xing Zuoxia, Zhao Haichuan, GE Weichun, Zhu Jianxin, Tian Zheng. Study on thermodynamic calculation method of solid state electrothermal energy storage system [J]. Journal of Solar Energy, 2019, 40 (02): 513 521.

[4] Ge Ping, Yang Bin. Study on the Application of solid Energy Storage heating device in Electric Energy substitution [J]. Power demand side Management, 2016, 18 (01): 34 36 48.

[5]BAI Shengxi, ZHAO Guangbo, DONG Peng. Solid electric heatstorage equipment and its economic analysis[J]. Electric Power,2002, 35(6): 79–80.

[6]Yue Yunli, Zi Zhenning, Li Shunxin, Zhao Dongyuan, Zhao Min. Study on the applicability of Electric Heat Storage Technology in the Field of Clean heating in Zhangjiakou.

[7]Zhu Weidong, Ren Zhiyuan, Xiang Chengbing, Zhong Weihua, Xu Qingtao. Solid heat storage technology and its application [J]. Comprehensive Utilization of Resources in China, 2018, 36 (09): 77 79.

[8]Tang Haifeng, Hua Zhengsheng, Wang Yong, et al. Summary of research progress on methods for improving deep peak regulation capacity of heating units [J]. Science and Technology Innovation News, 2015 (14): 15-16.