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Investigation and Research on the Transformation of Thermal Power Generation under the Dual Carbon Background

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ABSTRACT

Based on China's energy structure, this work combines the emerging liquid air energy storage technology with the traditional thermal power generation technology to construct a steam-liquid air integrated energy supply system, realizing the integration and development of new energy and traditional technology. The energy supply system mainly uses surplus energy to drive the compressor to compress, cool and liquefy the air and then inject it into the low-temperature storage tank for storage, and a part of the electricity consumed in the liquefaction process is converted into low-temperature cold energy for storage. The heat energy generated by the compression process can be supplied to heat users. The stored cryogenic energy can be used to cool the circulating mass of the power plant, lowering the condensation temperature and improving efficiency. The system is also highly flexible in terms of peak shaving and valley filling under different conditions and with different operating modes to meet different energy supply requirements. At the same time, the system can be combined with various energy supply methods (wind, solar, etc.) to further improve its energy efficiency and economy, implementing the concept of distributed energy utilization.

KEYWORDS

Energy saving and emission reduction; Thermal power generation; Carbon neutralization.

1. INTRODUCTION

"Double carbon" is the abbreviation of carbon peak and carbon neutrality, and China strives to achieve carbon peak by 2030 and carbon neutrality by 2060. on December 10, 2021, the Central Economic Work Conference pointed out that we should correctly understand and grasp the carbon peak and carbon neutrality.

To achieve the "dual carbon" goal, we must adhere to the path of energy revolution with Chinese characteristics, the key is to firmly maintain national energy security. The gradual withdrawal of traditional energy sources should be based on the safe and reliable substitution of new energy sources, and based on the basic national conditions of coal-based energy, we should make good use of coal in a clean and efficient way, increase the capacity of new energy sources, and promote the optimal combination of coal and new energy sources. We still need to clean coal and other traditional energy sources and efficient use of good, in the future a relatively long period of time for the gradual withdrawal of traditional energy sources; on the other hand, to accelerate the development of new energy power generation supporting security facilities, strengthen the ultra-high voltage, power distribution network reconstruction and the construction of energy storage, to enhance the new energy consumption capacity. Therefore, it is imperative to update thermal power generation technology.

Domestic research and development of compressed air energy storage system, especially air liquefaction energy storage technology, started late.After 2000, air liquefaction energy storage, as an effective energy storage technology, began to receive attention from domestic scholars and research institutes due to the problem of facing the waste power consumption and peak shaving of large-capacity renewable energy sources.In 2015, the State Grid Global Energy Internet Research Institute cooperated with the University of Birmingham, and the two sides shared key technologies and engineering practical experience on low-temperature liquefied energy storage, and the former built a new 500k W energy storage test platform in 2018 to support the development of theoretical research, technical services, and standard formulation and revision work in the area of cold, hot, and comprehensive utilization of electricity technology.

Therefore, by combining the emerging liquid air energy storage technology with traditional thermal power generation technology, a steam-liquid air integrated energy supply system has been constructed, and the realization of the integrated development of new energy and traditional technology is just around the corner.

With the transformation and development of energy and the depth of the concept of sustainable development, the use of clean energy to replace traditional coal resources has become an inevitable development trend. In the future, green development technology will certainly become mainstream, green construction technology will be widely used, so the use of green technology to improve thermal power generation has become particularly important.

If the thermal power generation enterprises still use the traditional way, then in the future thermal power generation is likely to be completely replaced, which is the traditional power generation methods of the declining, but also the world's future industrial development trend. Therefore, combining the emerging liquid air energy storage technology with the traditional thermal power generation technology to build a steam-liquid air integrated energy supply system is in line with the green and low-carbon development system and the concept of sustainable development, which is conducive to promoting the transformation of traditional energy sources, and further promoting the realization of the goal of "dual-carbon".

In recent years, China has increased its environmental protection efforts and vigorously promoted the theory of sustainable development. Since the 18th National Congress of the Communist Party of China (CPC), the state has advocated green and low-carbon development, and the construction of ecological civilization has also become an important part of the "Five-in-one". Therefore, the energy conversion of thermal power generation, the use of green technology to improve the inevitable trend of traditional energy development, not only in line with China's concept of sustainable development, but also the implementation of environmental protection is of great significance.

The realization of carbon peak carbon neutral is to promote high-quality development of the inherent requirements, to unswervingly promote, but can not be accomplished at one time. Carbon dioxide emissions are directly related to the type, utilization and total amount of energy resources. The fundamental reason why China has become the world's largest carbon emitter is that the energy and its related industrial system rely mainly on fossil resources. Carbon peaking and carbon neutrality are essentially environmental issues and pricing power issues, and the energy revolution is an important means to achieve this goal. Therefore, the scientific and orderly promotion of the energy structure and related industrial system to low-carbon green development, the formation of advanced "clean, low-carbon, safe and efficient" new energy system will help to improve the quality of China's development and position in the global industrial chain, in order to obtain greater pricing power, and to promote the "dual-carbon" goal. to obtain greater pricing power and promote the achievement of the "dual-carbon" goal.

2. ANALYSIS OF THE CURRENT SITUATION AT HOME AND ABROAD

2.1. The current situation of foreign thermal power generation research

The International Energy Agency (IEA) released on February 8, "2023 Power Market Report" branch pointed out that from 2023 to 2025 global power demand growth will accelerate to an average of 3% per annum, renewable energy will dominate the growth of global power supply, along with nuclear energy to meet the vast majority of incremental power demand.

The report pointed out that the energy crisis and the impact of abnormal weather conditions in some areas, the surge in energy prices, resulting in 2022 global power demand growth slowed to 2%, lower than the level before the new crown epidemic. 2022 EU electricity demand fell 3.5% year-on-year, India power consumption growth of 8.4%, the United States power demand growth of 2.6%. The report statistics, the next three years global power demand growth will accelerate to an average of 3% per annum, of which more than 70% of the demand growth will come from part of the Asian region.

Coal-fired power plant market analysis: According to the data of world coal association (WCA), there are 510 coal-fired power stations under construction and 1,874 coal-fired power stations under planning, totaling 2,384. Among them, China, India and Indonesia together account for 71%, plus the Philippines, Vietnam, Turkey and Pakistan, which together account for 81%.

Gas-fired power plant market analysis: Between 1970 and 2012, worldwide gas-fired power generation grew at an average annual rate of more than 5%. gas emissions declined by 1.6%, or 118 million tons, in 2022. Europe's natural gas emissions are expected to decrease significantly, and the Asia-Pacific region has also seen an unprecedented decline. 2014 Global Energy Outlook report released by the IEA: the global power industry gas-fired power generation new installed capacity is expected to be in the range of 1,270GW during the period of 2014-2035, and the total installed gas-fired power generation capacity will reach 2,450GW in 2035, which will account for 25.1% of the total installed power capacity. The report "World Energy Investment 2016" released by the International Energy Agency IEA shows that in terms of the type of energy invested in the Middle East is more inclined to invest in gas-fired power generation due to the availability of better gas-fired power generation infrastructure.

2.2. The current situation of domestic thermal power generation research

China is rich in coal resources, in recent years the thermal power generation industry has developed rapidly, and has become the main mode of power generation in China, the information made public by the National Bureau of Statistics shows that: the cumulative value of China's power generation in 2022 was 838,683,000,000,000 kilowatt-hours, which realized a growth of 2.2% compared with the previous year. Among them, thermal power generation amounted to 5853.13 billion kWh, with the year-on-year growth rate slowing down to 0.9%. The country's share of thermal power generation has been hovering between 70% and 75% for several years now, but a historic change was achieved in 2022, with the share of the market occupied dropping to 69.77%. On an annualized basis, this is the first time that thermal power generation has fallen below 70% of the country's total power generation share.

3. RESEARCH CHARACTERISTICS AND INNOVATIONS

3.1. Innovation of research questions

The selected topic is novel and unique, with greater research value. Through the search of relevant literature on thermal power generation, it can be found that with the transformation and development of energy and the depth of the concept of sustainable development, the use of clean energy to replace

the traditional coal resources has become an inevitable development trend. The fundamental reason why China has become the world's largest carbon emitter is that energy and its related industrial system are mainly dependent on fossil resources. Carbon peak, carbon neutral is essentially an environmental issue and pricing power issues, and the energy revolution is an important means to achieve this goal. Therefore, the scientific and orderly promotion of the energy structure and related industrial system to low-carbon green development, the formation of advanced "clean, low-carbon, safe and efficient" new energy system will help to improve the quality of China's development and position in the global industrial chain, in order to obtain greater pricing power, and to promote the "dual-carbon" goal. to promote the achievement of the "dual-carbon" goal. In the future, green development technology will definitely become mainstream, green construction technology will be widely used, and the use of green technology to improve thermal power generation becomes particularly important.

3.2. Research perspective and method innovation

Multidisciplinary intersection and diverse research methods. Starting from the perspective of multiple disciplinary fields, this study adopts literature research, qualitative and quantitative research methods, and uses clustering method, Apriori algorithm model, random forest model, gray prediction model and other methods to dig deeper into the survey data. This study intends to understand the current status of thermal power generation and the acceptance behavior of new energy generation.

4. APPLICATION OF ENERGY SAVING AND EMISSION REDUCTION IN THERMAL POWER GENERATION

4.1. Existing measures for energy conservation and emission reduction in thermal power generation

new energy to help centralized heat supply to achieve energy saving and emission reduction

Heat source energy saving

At present, China's main measures in this regard are as follows:

(1) Encourage the development of cogeneration. Heat source is the first condition for the implementation of urban centralized heat supply. At present, there are three main forms of heat sources for centralized heat supply in China: cogeneration plants, regional boiler rooms and decentralized boiler rooms. The choice of heat source is crucial, it is related to the centralized heat supply system of energy saving and environmental protection issues, is to adhere to the strategic issue of sustainable development, China has now clearly stipulated to encourage the development of cogeneration, and vigorously develop cogeneration projects, and gradually replace the construction of boiler rooms.

(2) Increase the use of renewable resources. In the hot cogeneration of solar energy, incineration of straw and industrial waste materials, as well as the use of ground source heat pumps, the use of fuel cells and so on. At present, the use of these renewable resources should be selected and optimized according to the specific actual situation of the city. Thermal power plants to heat the main, electricity is a by-product. Thermal power plant to supply more heat, in order to save more energy, more efficiency. Many shrewd plant managers, try every means to extend the heat network, expand the scope of heat supply, increase the amount of heat supply, seize the heat supply market.

heat network operation energy saving

Determine the laying method according to the local actual situation. With the continuous development of direct burial heat preservation pipe technology in recent years, most of the pipe laying using direct burial laying method. Especially in recent years, rigid polyurethane insulation direct burial

technology in our country to promote the application. The results show that direct burial technology than trench laying has the following advantages: insulation number, long life, short construction period, covers an area of small, low project cost.

User energy saving

Energy-saving building construction. Requirements for building construction to be able to consciously comply with the building energy-saving design standards for engineering and construction, while actively organizing energy-saving renovation of existing buildings, the use of thermal insulation properties of a stronger national protection structure, strengthen the walls, windows, doors, roofs of the thermal insulation, while making full use of solar radiation heat

Reduce consumption

(3) Urban heating system reform continues to deepen the reform of the charging system, the quality of heat supply continues to improve, energy saving performance is also getting better and better. As people's living standards continue to improve, the demand for living comfort also rises, the use of heat metering system, the user will be able to make full use of the room temperature control device according to their own requirements to regulate the room temperature, according to the demand for heat, reducing the waste of heat.

Energy saving of urban heat supply transmission and distribution pipeline network

By adopting advanced informatization means, establish a set of comprehensive management platform from heat source, to heat network, to heat users, organize and analyze the complicated data on the site, through hydraulic calculation and other functional modules, make hydraulic working condition diagnosis and analysis of the information on the site of the pipeline network, so as to assist the users in solving the actual problems on the site, and to achieve the purpose of improving the level of production and management as well as energy conservation and reduction of energy consumption. In the construction of heating information technology at the same time, the need for step-by-step, planned implementation of the site of the basic data collection work, including pipeline network information on-site survey work, the user room temperature collection point layout work. Only if the site foundation work is done in detail, the informationization platform can play a big role. After the establishment of the information technology platform, can realize targeted in the secondary network pipeline installation of the necessary flow balance adjustment equipment, and the implementation of the necessary pipeline, valve wells renovation works, in order to achieve the purpose of effectively alleviate the problem of hydraulic dislocation.

the implementation of comprehensive heat network water balance technology transformation

Comprehensive heat network balance work, is to improve the heating system energy-saving transformation work of the foundation work. Heat network balance in the field implementation of the degree of refinement, determines the heating system energy-saving transformation project can ultimately realize how much heat and power saving effect.

4.2. The future direction of energy saving and emission reduction thermal power generation and recommendations

(1) We should improve the quality of electric coal, in the total working cost of thermal power generation, the combustion cost accounts for a large part of it. Therefore, the design of fuel coal type, scientific coal type can reduce the rate of fuel loss, improve the efficiency of fuel conversion, but also reduce the physical loss of fixed equipment, to reduce electricity consumption, increase the service life of the purpose.

(2) Optimize coal mixing to achieve efficient coal blending. Through the use of a variety of different types of coal, through a strict selection process screening, and then put into combustion after the scientific ratio, can effectively control costs. Coal ratio blending technology should be based on the

actual use of boiler coal combustion, taking into account the combustion characteristics of different types of coal, the implementation of different screening and proportioning methods. Coal proportioning should reasonably deal with the ash, volatility, heat difference and other aspects of the problem, so that the fuel is fully combusted to meet the combustion requirements of the boiler and match the boiler.

Innovative organization management

(3) Thermal power plants should actively implement organizational innovation management, set up an internal energy conservation and environmental protection supervision and leadership group at the same time to ensure that the group members from the management of the company to the general staff have, in the management authority on the top of the ceiling, starting from the management of the front-line staff to each workshop to develop a targeted supervision standards, the management of the staff of the management of the day-to-day management, management effectiveness and the front-line staff of the production methods and production efficiency to put forward their own requirements. The company has formulated targeted inspection standards for the daily management style and management efficiency of management personnel and the production style and productivity of frontline employees. Focus on inspecting the energy-saving and environmental protection efficiency of the internal staff of the enterprise.

Establish a standardized energy conservation management system

In the specific content of the system set up, should focus on the details of the work and requirements of the implementation of each department, each position, and try to develop quantitative indicators to facilitate the assessment of the later assessment. In addition, there should be provisions for hardware facilities, reasonable requirements for the working parameters of the unit in order to check and maintain the machine, and truly achieve personal implementation of responsibility and awareness.

the establishment of a standard performance appraisal system

In the internal assessment of personnel, the need to implement a reasonable and effective energy saving and environmental protection indicators according to the actual situation faced by enterprises, for the actual work of departments and individuals, scientific and effective rewards, penalties, rewards and penalties to achieve certain results, in order to improve the staff for energy saving and emission reduction of the positive degree of energy saving and environmental protection to promote energy saving and environmental protection of the enterprise transformation progress, and continue to move forward towards the national environmental protection requirements and standards. Requirements and standards.

In the enterprise system to ensure that, first of all, we need to establish a comprehensive and effective energy saving performance evaluation system, layer by layer implementation, responsibility to the person, through the standardization and optimization of the relevant indicators to achieve energy saving and environmental protection, reduce the energy efficiency of enterprise production work "have a law to follow".

5. OPTIMIZATION DESIGN AND SUGGESTIONS FOR ENERGY SAVING AND EMISSION REDUCTION IN THERMAL POWER GENERATION

5.1. Optimization Design of Linear Programming

(1) Problem restatement

On October 29, 2020, the Fifth Plenary Session of the 19th Central Committee of the Communist Party of China (CPC) proposed to accelerate the construction of a strong transportation country, promote the energy revolution, and accelerate digital development. In this context, air liquide energy storage technology has become a highlight in the future research of energy storage technology by

virtue of its superior performance such as small energy storage volume, high energy storage density, and the possibility of mobile storage. Based on China's energy structure, this work combines the emerging liquid air energy storage technology with the traditional thermal power generation technology to construct a steam-liquid air integrated energy supply system, realizing the integrated development of new energy and traditional technology.

(2) Design Program

This design innovatively combines the new energy storage technology with traditional energy technology, further analyzes the coupling relationship between the two, and constructs a steam-liquid air integrated energy supply system, and the detailed system flow chart is shown in Fig.

This system takes liquefied air energy storage system (LAES) as a foothold, and establishes LAES operation models under various working conditions; and in view of the basic framework of China's traditional thermal power plants, it constructs an efficiency model for traditional thermal power plants and discusses the efficiency constraints and improvement schemes; and then innovatively applies the liquefied air energy storage technology to the steam-liquid air integrated energy supply system, and further analyzes the coupling relationship between the two. Air Liquide Energy Storage Technology is applied to the operation of traditional thermal power plants, which improves the efficiency of traditional thermal power plants by means of using liquid air energy storage technology to absorb the valley power of the power plant, low-temperature lowering of the condensing temperature of the power plant, and the provision of cold and heat energy by-products, realizes the comprehensive utilization of energy in multiple ways and with high efficiency, and derives the optimal energy supply scheme through the thermodynamic analysis and calculation, so as to achieve the purpose of energy saving and optimization.

5.2. Energy saving and emission reduction thermal power generation innovative design

In the air liquefaction energy storage technology, the medium used is air available everywhere, and the required heat and cold energy can come from the heat and cold production of each link or the low-quality waste heat in the external environment, without the need to burn additional fuel to provide heat, which is environmentally friendly.

The cold and heat energy produced by each link of the technology is high-quality energy, which can be used for heating and cooling in addition to heat exchange in the rest of the links, thus realizing cogeneration of cold, heat and electricity and multi-level utilization, which is practical and highly efficient.

The steam-liquid air integrated energy supply system can achieve the purpose of peak shaving and valley filling by means of the liquefied air energy storage part, and can satisfy different ways of energy supply with a high degree of flexibility.

The steam-liquid air integrated energy supply system has a high degree of technical compatibility and can be combined with a variety of energy supply methods (wind, solar, etc.), overcoming the shortcomings of the conventional centralized power supply in the form of a single energy source.

Air Liquide energy storage technology occupies an important position in the energy revolution, combined with China's national conditions, combining the new technology with the main traditional energy technology, to provide new ideas for further reform of China's power industry feasibility analysis.

6. CONCLUSION

The steam-liquid air integrated energy supply system is based on the traditional thermal power plant, combined with the liquid air energy storage system, utilizing the surplus electric energy of the power plant, realizing the multi-level utilization of energy from a single excess of electric energy to heat, electricity, and cold energy, improving the flexibility of energy utilization, being able to adapt to the current demand for deep peak shifting, achieving the goal of diversified energy utilization, and realizing the scientific principle of using energy according to the quality of energy. The scientific principle of energy use has the advantages of environmental friendliness and high efficiency.

According to the thermodynamic principle, the main working processes of the system, such as compression, heat and cold storage, liquefaction storage and expansion, are modeled in terms of thermodynamics, and the operating parameters of the system are analyzed as necessary, which proves that the system has an excellent working capability;

Taking the actual 600MW unit as an example, the system was simulated and calculated with the parameters of full-load operation and peak-shifting operation of a traditional thermal power plant. Since the latent heat of vaporization and specific heat capacity of liquid air are not high, the effect of lowering condenser condensation temperature is not as good as expected, but after lowering the condenser vacuum, the coal consumption rate of the power plant can be reduced by about $3g/(kW \cdot h)$;

The heat, cold and power cogeneration model established in this paper can adjust the supply ratio of heat and cold users according to the load demand of the power grid, provide different energy supply solutions, and calculate the system heat and cold storage capacity and limit power generation capacity, which provides reference for the actual optimization system;

In response to the current problem that air-cooled units are forced to run at reduced loads during summer operation, surplus liquid air can be utilized as a spray cooling medium, and it is calculated that $0.044kg$ liquid air is needed to reduce the temperature of air per unit of mass, which is a low-cost and high-benefit system. In conclusion, this system is of great practical significance to improve the economy of the power plant, reduce air pollution, save coal resources, and enhance environmental friendliness.

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