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The Application Status and Energy Saving Analysis of Heat Pump Technology Under Dual Carbon Target

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Abstract

This paper introduces the significance of energy conservation and the current situation of energy utilization in China, and focuses on the development prospect of heat pump technology. Since the proposal of carbon peaking and carbon neutrality has made higher requirements for carbon emission reduction in different industries, the energy structure in China will make important adjustments accordingly. The research focuses on the way to reduce carbon emission in conventional industries and making full use of renewable energy. Among different energy saving and emission reduction technologies, heat pump technology has been widely used in civil, industrial and agricultural areas due to its remarkable performance of energy saving and emission reduction. There are many kinds of heat pump technology, but there are great differences in specific applications. How to make effective use of heat pump technology has become an important direction of our current development. It is a problem we must solve to study the current situation of heat pump technology and then realize energy saving.

Keywords

Carbon Peak; Carbon Neutrality; Energy Conservation and Emission Reduction; Heat Pump Technology.

1. Introduction

After the heat pump technology was proposed in 1854, it has experienced a tortuous development process, and has now entered a stage of comprehensive and rapid development. Especially under the environmental pressure of energy crisis and global warming, heat pump technology has become the focus of attention of all countries[1]. The research, application and promotion of various heat pump technologies have also risen to a height of continuous attention. On September 22,2020, China proposed at the 75th United Nations General Assembly that it would strive to achieve carbon peak by 2030 and carbon neutrality by 2060. Carbon peaks, that is, carbon dioxide emissions no longer increase, and then slowly decline after reaching the peak ; carbon neutrality, or net zero emissions, refers to the capture, utilization or storage of carbon emissions necessary for human economic and social activities through forest carbon sinks and other artificial technologies or engineering methods, so that the net increase of greenhouse gases emitted into the atmosphere is zero[2]. Therefore, in the context of limited national policies and energy, improving energy efficiency and focusing on energy conservation have become an important step in our future development[3].

2. Basic Working Principle of Heat Pump

Heat pump is a device that transfers the heat of low-temperature objects to high-temperature objects by inputting a small amount of high-grade energy. According to the driving mode, it can be divided into compression heat pump and absorption heat pump. The compression heat pump uses Freon and other working fluids as the circulating medium, and realizes the transfer

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of heat from the low-temperature heat source to the high-temperature heat source by consuming electricity or mechanical work. The coefficient of performance (COP) can reach 3.0-7.0. The absorption heat pump is divided into heating type and heating type according to the purpose. The heating type refers to the use of a small amount of high-temperature heat source heat energy to generate a large amount of medium-temperature useful heat energy, and the heating COP can reach 1.6~2.4 ; the heating type refers to the use of a large number of medium-temperature heat sources to generate a small amount of high-temperature useful heat energy, and the heating COP is 0.4~0.6[4]. This paper takes the steam compression heat pump system as an example. The compressor driven by electric energy generates compensation work, so that the working fluid can continuously absorb heat from the low temperature environment and release heat to the high temperature environment. In essence, the heat pump is a thermal energy lifting equipment, which consumes energy during operation. At the same time, it continuously excavates the energy contained in the surrounding environment and utilizes it. In terms of the structure and principle of the equipment, the working principle of the refrigeration process and the heat pump process is the same, and there are some differences in the purpose. If the cooling capacity Q_o produced by the evaporator is used to cool the ambient temperature, the process is called a refrigeration cycle. Similarly, if the energy Q_k released by the condenser is used to heat the ambient temperature, the process is called a heat pump cycle[5].

3. Application of Heat Pump Technology

3.1. Application of Heat Pump Distributed Household Cooling and Heating Field

Reference [6] analyzes that solar energy is easily affected by the climate environment through the combined use of solar heat pump and ground source heat pump technology. When it encounters rain and snow weather, solar energy will inevitably fail to meet the actual needs, but this defect is inevitable. However, geothermal energy is basically unaffected by other factors, and its temperature can remain stable throughout the year. Therefore, the combination of solar energy and geothermal energy can achieve the complementary advantages of the two. At the theoretical level, the combined use of solar heat pump and ground source heat pump technology can be achieved. An example of the combined system scheme is as follows : (1) Summer refrigeration : on the side of the evaporator, the circulation of refrigerant water can be realized by valve control, and the refrigerant water can be cooled to the indoor fan coil air conditioning system. For the condenser, the heat released during the condensation process can be transferred to the soil through the underground heat exchange coil. (2) Winter heating : the heat storage device is used to store solar energy or geothermal energy, and the refrigerant water circulation system is directly connected to the energy storage device. The temperature of the refrigerant water flow through the energy storage device increases, and then the hot water is used for heating. The energy storage device stores water and continuously exchanges heat with the soil and solar collectors through the pump. (3) Hot water for life : The solar collector can heat the water, and then store the hot water into the buffer accumulator. In this way, the solar energy can be used to preheat the water. When the user needs to use hot water, the preheated water can be further heated to the required temperature through the gas. Taking an independent building in Xining City as an example, Reference [7] introduced a solar-air source heat pump combined heating system with air source heat pump as the core. Through the system model simulation and actual heating effect test, the average COP of the air source heat pump heating system is 2.4, and the average indoor temperature is maintained at about 21.9°C, which meets the heating demand. The economic and CO_2 emissions of the combined heating system and the air source heat pump water heater are compared. The results show that the average annual cost of the combined heating system is 24.4% lower than that of the pure

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air source heat pump water heater unit, and the CO emission of the combined heating system is 41.62% lower than that of the pure air source heat pump water heater unit in a heating season. The effect of carbon emission reduction is particularly significant.

3.2. Application of Heat Pump in the Field of Heating and Cooling

Literature takes the heating and refrigeration project of sewage source heat pump system in a county sewage treatment plant in Dongying City as an example, and introduces the principle, design and investment of sewage source heat pump technology. In order to make full use of the existing sewage resources, the sewage plant intends to build a sewage source heat pump system with a heating scale of 100,000m^2 to provide heating and refrigeration to the residential, office, commercial buildings in the surrounding 5km area. The project includes equipment, civil engineering, pipe network supporting and other projects. The sewage source heat pump system includes sewage water intake and drainage system, sewage and medium heat exchange system and terminal circulation system. It is concluded that the sewage source heat pump technology has the advantages of energy saving and environmental protection, remarkable benefit, low operation cost, mature technology and reliable operation. It is very suitable for popularization and application in conditional sewage treatment plants. Taking the heating system of two 300 MW units as an example, Reference [8] discussed and analyzed the influence of heating extraction pressure, back pressure and primary network temperature on the heating capacity of heat source and heating energy consumption. The results show that the use of absorption heat pump heat transfer technology to reduce the return water temperature of the primary network and increase the back pressure is an effective way to reduce the energy consumption of heat source heating. In addition, reducing the primary return water temperature also has a significant effect on increasing the transmission capacity of the existing pipeline network.

3.3. Application of Heat Pump in Agricultural Industry

In order to ensure the storage quality of agricultural products, drying has become a common unit operation in the processing of agricultural products, and the drying energy consumption of agricultural products is second only to the drying energy consumption of papermaking. Therefore, on the premise of ensuring the drying quality of agricultural products, it is necessary to find ways to reduce the energy consumption of the drying process [9]. Heat pump drying is developed with the rise of heat pump technology. Compared with traditional drying methods, it has the effect of realizing the synergistic emission reduction of air pollutants and greenhouse gases. In recent years, with the promotion and implementation of the policy of coal to electricity and coal to gas in China, the application of heat pump drying technology in agriculture has become a hot topic in the field of drying, including the drying of tobacco leaves, roses and wolfberry. In reference [10], a coupling scheme of air treatment process and quasi-two-stage compression heat pump system was established for the semi-enclosed heat pump dryer. The performance of two heat pump system processes of subcooler and flasher based on quasi-two-stage compression was modeled and analyzed. The results show that compared with the traditional heat pump system, the two quasi-two-stage compression heat pump systems can reduce the discharge temperature of the compressor. When the condensing temperature is 50°C and the evaporation temperature is-25°C~0°C, the heating COP of the subcooler system is increased by 5.0 % -7.1 %, and the heating COP of the flasher system is increased by 2.3%~6.6%, which provides a basis for the development of new heat pump dryers.

4. Conclusion

In order to achieve the goal of carbon peak and carbon neutralization, carbon emissions should be greatly reduced in civil and industrial industries. In this paper, through the research and analysis of the application of heat pump in different industries, it is found that heat pump has

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been widely used in various industries with its excellent energy saving and emission reduction effect, and has produced significant carbon reduction effect. The future development trend of heat pump technology will still be in the rising stage of rapid development.

As a technology of energy saving and emission reduction, heat pump technology has a broad prospect. More and more countries, governments and enterprises will realize the energy saving and environmental protection benefits that heat pump can bring. Market data also show that the future development trend is good. In summary, heat pump technology will be widely used in the future to achieve carbon peak, carbon neutralization target process, in order to produce significant energy saving and carbon reduction effect.

References

[1] Jinxiang Yu,Xiaoyu Zhang,Yibo Wang,Jianhong Guo:Experimental Study on Air Source Heat Pump Heating System Based on Phase Change Heat Storage.IEEE Access, Vol.11(2023),p.1.

[2] Chen, Fu;Bian, Zhengfu;Yin, Dengyu:How to Handle the Crisis of Coal Industry in China Under the Vision of Carbon Neutrality. Journal of the China Coal Society, Vol.46(2021), No.6 p.1808-1820.

[3] Ge Zhu:The Current Status and Development Prospect of Ground Source Heat Pump Technology.AIP Conference Proceedings, Vol.2036(2018), No.1 p.030035.

[4] Qiong Chen;Nan Li:Energy, Emissions, Economic Analysis of Air-Source Heat Pump with Radiant Heating System in Hot-Summer and Cold-Winter Zone in China.Energy for Sustainable Development, Vol.70(2022), No.6 p.10-22.

[5] Ning Luo;Wei Liu;Yanglong Duan:The Combined Application Technology of Solar Heat Utilization and Ground Source Heat Pump.Journal of Physics: Conference Series, Vol.2683(2024),p.012003.

[6] Shuailing Liu;Guoyuan Ma;Yaya Lv;Shuxue Xu:Review on Heat Pump Energy Recovery Technologies and Their Integrated Systems for Building Ventilation.Building and Environment, Vol.248(2024), p.111067.

[7] Tianhu Zhang:Optimization of a Solar-Air Source Heat Pump System in the High-Cold and High-Altitude Area of China.Energy, Vol.268(2023), No.0 p.126653.

[8] Zhibin Liu; Liangdong Ma; Zhang; Jili Zhang:Application of a Heat Pump System Using Untreated Urban Sewage as a Heat Source.Applied Thermal Engineering, Vol.62(2014), No.2 p.747-757.

[9] Erbay, Zafer;Hepbasli, Arif:Application of Conventional and Advanced Exergy Analyses to Evaluate the Performance of a Ground-Source Heat Pump (GSHP) Dryer Used in Food Drying.Energy Conversion & Management, Vol.78(2014), No.13 p. 499-507.

[10] Cui, Mengdi;Cheng, Zuo;Wang, Baolong;Wei, Falin;Shi, Wenxing:Experimental Investigation on an Auto-Cascade Quasi Two-Stage Compression Heat Pump System.Applied Thermal Engineering , Vol. 219 (2023),p.1359-4311.