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Modeling and Simulation Research of Wind Energy Heat Pump Direct Heating System Based on Geographic Information System

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Abstract: In order to ensure the normal heating of residents during the heating season in my country, with the increase of the air extraction volume of the cogeneration unit, the power generation also exceeds the use demand, so that the poor quality wind power will be forced to give up during the peak shaving of the power grid. The aggravation of coal-fired pollution also leads to a waste of energy. The use of wind-driven compression heat pumps to run heating reduces energy and capital waste. Taking into account the volatility and instability of wind energy itself, the heating technology of WEHPDHS is one of the effective ways to achieve renewable clean energy heating in severe cold regions. In this paper, a simulation model of the wind energy heat pump direct heating system(WEHPDHS) is established, and the simulation experiment is carried out on the use of the model. The geographic information system is used to collect the wind speed data under the working condition, and the variation characteristics of the system energy parameters and the energy efficiency coefficient of the mechanical energy of the wind turbine are analyzed under the variable wind speed condition. COP, and then compared the performance coefficients of different heating methods to verify the high heating efficiency of the system in this paper and the high benefits in environmental protection.

1. Introduction

My country has abundant wind energy resources, and the number of new wind farms and the total installed capacity of wind power are increasing every year. As a clean energy, wind energy has the potential for large-scale promotion. Due to the long-distance transmission of wind power from wind farms, the instability of wind power, and the heating mode of cogeneration, the phenomenon of "abandoning wind and limiting power" occurs in my country's power supply industry during peak regulation of the power grid [1]. One of the effective solutions to this problem is to use wind energy for heating. On the one hand, the adoption of this technology is expected to improve the ability to absorb wind power in low valleys, and on the other hand, it opens up new forms of wind energy utilization and increases the market utilization rate of wind energy. Promoting the adjustment of energy structure is of great significance to my country's economic construction and environmental protection.

At present, heat pump technology using clean energy for heating and heating has received extensive attention. For example, some scholars believe that the unit-type independent heat pump will constitute a major power demand in the future wind power energy system. They applied an investment and operation-optimized energy system model to analyze how the heat pump system affects the integrated wind power system and covered a variety of different heat storage options. The results show that even without flexibly operating heat pump installations, wind power investment can be greatly promoted and system costs, fuel consumption and CO2 emissions can be reduced [2]. A scholar established an energy system model for a large-scale unitary heat pump driven by wind power. The results show that the operation of a large-scale unitary heat pump driven by wind power can effectively reduce the investment cost and operating cost of wind power, and can greatly improve the effective utilization of wind power [3]. Some researchers have studied the floor radiant heating system. The system uses solar energy and heat pump as heat sources. They mainly analyze and discuss the different composition and operation modes of the two heat sources. Numerical studies have been carried out, and the simulation results show the feasibility of this mode of operation [4]. Although the effectiveness of wind energy heat pump heating system in improving wind energy consumption and solving environmental pollution has been generally recognized by scholars at home and abroad. However, most of the existing research work focuses on the economic evaluation of wind power heat pump heating systems. No scholars have established a complete and reliable system simulation model, let alone reveal the energy conversion and operation integration characteristics of complex coupled systems.

This paper first introduces the composition and structure of GIS, then builds the simulation model of the direct heating system of the wind energy heat pump, and then simulates the system through the experimental simulation platform and the wind speed model, and simulates the kinetic energy of the system wind, the mechanical energy of the wind turbine, The changes of energy parameters such as compressor shaft power and system heat load, and by comparing the performance coefficients of the system in this paper with other heating methods, it shows that the system in this paper has higher heating efficiency and environmental benefits.

2. Related Systems

2.1. Geographic Information System (GIS)

GIS is an emerging discipline, which includes many disciplines such as information science, computer science, and geography. Geographical information system is a database system, information science theory, scientific management and comprehensive analysis of spatial data and attribute data under the support of computer software and hardware. Management, planning and engineering decisions provide complete and concise spatial and attribute information [5-6].

The complete GIS is mainly divided into five parts, as shown in Figure 1:

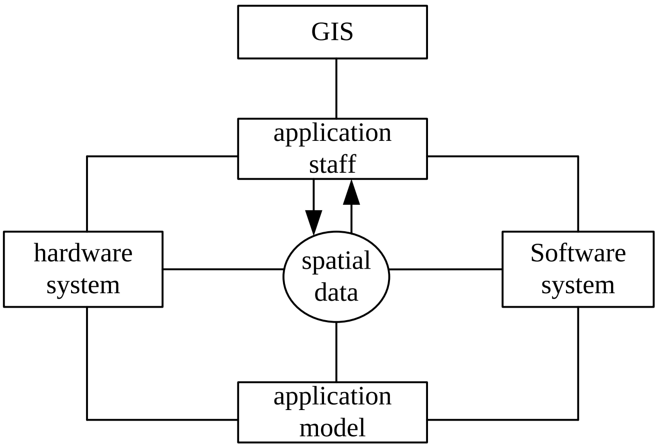

Figure 1. GIS composition

(1) Hardware system

The computer hardware system is the hardware environment of the GIS formed by the connection between the computer and the peripheral equipment, and it is the guarantee for the operation of the GIS. The size, speed, form, precision, function, operation method and operation of the software of the system all need the great support of the hardware, and these have a great relationship with the indicators of the hardware [7]. GIS is a very complex and special system, which requires strong support from computers.

(2) Software system

Software system is the core component of GIS system, mainly used to run various functional operations of GIS, such as data input, output, storage, data management and analysis, spatial analysis, etc. [8].

(3) Spatial database system

As the carrier spatial database of geographic information, it is the function object of geographic information system. Spatial data is used to define the spatial characteristics, attribute characteristics and temporal status of geographic spatial entities. Spatial characteristics are used to indicate the location characteristics of geospatial entities; attribute characteristics are used to indicate the type, name, quantity and other states of geospatial entities; temporal states usually refer to changes in spatial entities over time [9-10] .

(4) Application personnel

The application of GIS requires GIS development personnel and system users. These personnel need to have professional qualities and knowledge systems, so that GIS engineering can be used in practical applications. The development of GIS is a complex project. The application of GIS development is based on the premise of being convenient for people. Therefore, in the early stage of development, it is necessary to investigate and study the situation of its users, determine the goals of system development, and conduct feasibility analysis. , select an appropriate development plan, and formulate a complete design guide [11]. Developers should be able to grasp the demand information of GIS users in time, so that the development of the system can meet the needs of users, avoid the occurrence of high input and low output, and ensure the quality of GIS development [12].

(5) Application model

Applying geographic information system to solve practical problems is the purpose of establishing geographic information system. When solving a specific application purpose, we need to solve these problems by establishing a special model.

2.2. Simulation Modeling of WEHPDHS

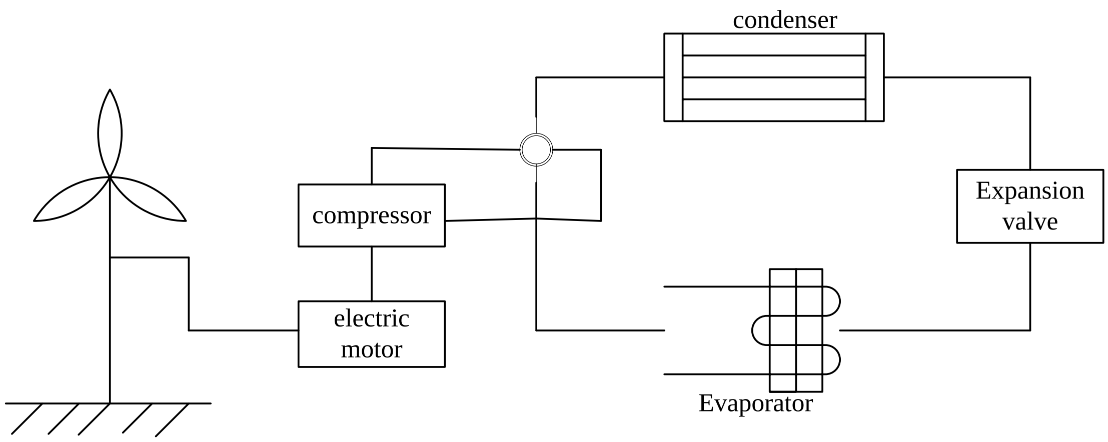

Figure 2. System Simulation Model

Figure 2 shows the simulation model of the WEHPDHS. The compressor of the heat pump unit is powered directly by the wind, and a four-way reversing valve is used to connect the compressor to the entire heat pump unit to form a complete heat pump circulation system, and finally realize the heating of heat users [13]. Because of the intermittent and fluctuating characteristics of wind energy, when the power of the heat pump compressor is completely supplied by the wind turbine, it is faced with the situation that the heat pump unit cannot operate normally under the condition of low wind speed or no wind, that is, the direct heating system of the wind energy heat pump. There are certain limitations in operation. Therefore, in order to make the system more perfect and ensure that the heat pump can operate normally under the condition of insufficient wind, it is necessary to install a hot water storage tank after the condenser to ensure that the heat pump can operate normally for heating throughout the day [14]. When the system is used to heat the heat users, the heat energy output by the system is first stored in the hot water storage tank, and then the heat is exchanged with the indoor circulating water system through the hot water storage tank to achieve heating for the heat users. It is ensured that the thermal users can heat normally without insufficient wind [15].

3. Experimental Simulation Platform

3.1. Experimental Equipment

The experimental device of the test bench is mainly composed of three parts: wind speed and wind turbine simulation and control system, mainly including servo motor, dSPACE dynamic simulation hardware and software; data measurement and acquisition system, mainly data acquisition by GIS, such as wind speed acquisition; heat pump cycle unit , mainly including electromagnetic expansion valve, low temperature water tank, high temperature water storage tank [16-17].

3.2. Wind Speed Model Modeling

The wind speed has the characteristics of fluctuation and intermittent, and the direct heating system of the wind energy heat pump will operate under the actual fluctuating wind conditions.

Therefore, the relatively accurate simulation of the actual wind speed is the basis for the simulation of the direct heating system of the wind energy heat pump. The composite wind speed model can accurately describe the variation characteristics of wind speed in a short time scale, which is suitable for laboratory dynamic simulation research [18-19]. Therefore, this paper uses MATLAB/Simulink to establish a composite wind speed model to simulate the actual wind speed.

The definition of the composite wind speed model is:

$$v = v1 + v2 + v3 + v4 \tag{1}$$

v1 is the basic wind speed, v2 is the gust wind, v3 is the gradual wind, and v4 is the random wind. Various actual wind conditions can be simulated by the superposition and combination of these four different types of wind.

$$f(v) = \frac{u}{T}\left(\frac{v}{T}\right)^{u-1} e^{-\left(\frac{v}{T}\right)^{u}} \tag{2}$$

where f(v) represents the probability density, and both u and T are parameters.

The random wind is generated using the random function function in Simulink. Basic wind and random wind always exist, gust and gradual wind need to consider the effect of action time, and the superposition of four simple wind conditions is the final composite wind speed that is used to simulate the actual wind field [20].

4. Simulation Results Analysis of WEHPDHS

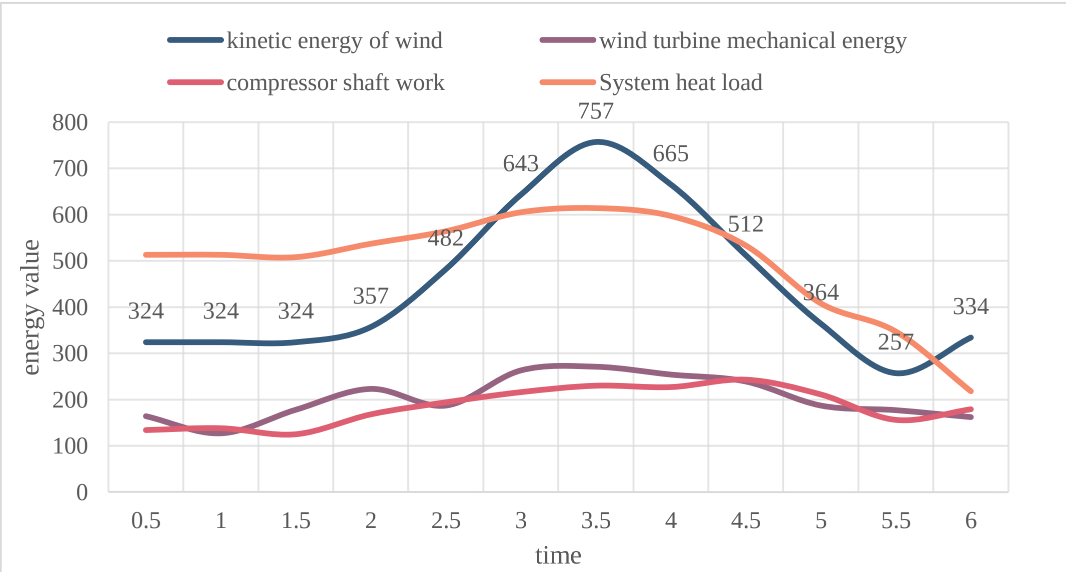

Figure 3. Energy parameter variation characteristics of the system under variable wind speed conditions (kW)

Taking the WEHPDHS to experience a 6s variable wind speed condition as an example, the wind speed variation range is 8-15m/s, and the energy conversion characteristics of the system under the actual fluctuating wind speed are studied. It can be seen from Figure 3 that the fluctuation of wind speed has a great influence on the stable operation of the system. From the 2nd s, with the increase of wind speed, the energy value of the whole system basically becomes larger, and reaches the extreme value at 3.5s; as the wind speed decreases, the energy value of the whole system also shows a decreasing trend; At the 5.5s, the kinetic energy of the wind fluctuated greatly, because the gradual wind completely disappeared, and only the gust was acting at this time and it was decreasing; the change trend of the energy value of each part of the energy-consuming unit in the system and the change trend of the wind speed consistent.

Table 1. Energy efficiency coefficient COP of wind turbine mechanical energy at different wind speeds

	5	5.5	6	6.5	7	7.5	8.	8.5	9	9.5	10
Calculated	2.8	3.0	3.4	3.2	3.1	2.9	2.5	2.1	1.7	1.4	1.2
Experimental value	1.9	2.3	2.8	2.6	2.5	2.3	2.0	1.8	1.5	1.3	1.1

As shown in Table 1, when the wind speed varies in the range of 5-7m/s, the energy efficiency coefficient COP of the system increases first and then decreases with the increase of the wind speed, and reaches the extreme point at 6m/s. The maximum value is 3.48; when the wind speed changes in the range of 7-10m/s, the energy efficiency coefficient COP of the system decreases with the increase of the wind speed. In addition, when the wind speed is low, the energy efficiency coefficient COP of the system is large, and when the wind speed is high, the energy efficiency coefficient COP of the integrated system is small. This is because the mechanical energy of the wind turbine has a cubic relationship with the wind speed, and the heating capacity of the system is basically proportional to the wind speed. Therefore, when the wind speed increases, the mechanical energy of the wind turbine grows faster, and the heating capacity of the system grows slower. The overall energy efficiency coefficient COP of the system shows a downward trend.

Table 2. Comparison of different heating methods

Heating method	Performance	Energy
Coal-fired boiler	36%	Coal
Natural gas boiler	57%	Natural gas
Electric boiler	65%	Coal
Electric heat pump	94%	Coal
This article system	172%	Wind energy, ambient heat

The COP value of the system refers to the coefficient of performance of the entire heating system, which is the ratio of the heat obtained by the user to the mechanical energy converted into wind energy. Table 2 compares the performance of different heating methods such as coal-fired boilers, natural gas boilers, electric boilers, electric heat pumps, and the wind energy heat pump system in this paper. It can be seen from the table that the COP value of the system proposed in this paper is higher than 172%>100%, which is because the heat pump absorbs the heat from the sun and the atmosphere. Therefore, the system has a high COP value and does not use fossil fuels, which is of great significance for solving the current energy problems and haze problems. In addition, the efficiency of the system in this paper is the highest, and the coefficient of performance of the system in this paper is 4.78 times that of the coal-fired boiler for heating. The system in this paper does not require fossil fuels such as coal, oil, and natural gas, and has good environmental benefits.

5. Conclusion

Energy and environmental issues are two global issues facing society today. Energy is an important factor to promote the survival and development of human society, the driving force of economic development, and the necessary material basis for the sustained, stable and rapid development of the national economy. The problems of energy crisis, environmental pollution and global warming have become increasingly prominent. Governments around the world are actively promoting the energy revolution and vigorously developing new and renewable energy. In terms of heating technology, many areas use electric heating, but there will be power cuts. In order to improve the current situation of the waste of wind resources and low utilization rate, this paper proposes that the wind can be used to drive the heat pump unit for heating. Simulation experiments show that this method can effectively reduce the consumption of non-renewable resources such as coal and improve heating efficiency.

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Data Availability

Data sharing is not applicable to this article as no new data were created or analysed in this study.

Conflict of Interest

The author states that this article has no conflict of interest.

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