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Distributed Energy Supply System for Residential Buildings with Renewable Energy

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Abstract: CCHP is developed on the basis of cogeneration system, which belongs to the category of distributed energy system and the main direction and form of distributed energy development. In this paper, a distributed combined supply system combined with renewable energy is provided to target buildings. The work done mainly consists of the structure and material of the building are analyzed, the cold, heat and electric loads are calculated by using the software; three different system flow schemes and equipment selection are proposed. The thermodynamic, economic, environmental and comprehensive evaluation of the three schemes was carried out according to the gray relational degree. The results show that the indexes of heat, economy and environment are considered comprehensively, the CCHP system of the small gas turbine and the integrated flue gas machine is most suitable for the distributed energy demand of the residential area. Its primary energy utilization rate is 0.582, the investment recovery period is 7.5 years, and the environmental and comprehensive evaluation also has obvious advantages.
Keywords: Cooling and heating combined power supply system, Natural gas, solar energy, Wind energy, Performance analysis.

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1. INTRODUCTION

In the past 20 years, the annual average growth rate of building energy consumption in China has remained above 10%. Heating and cooling are the most energy consuming, accounting for about 65% of the total energy consumption of the building. Due to poor thermal insulation building envelope and inefficient heating system, the energy consumption per unit area in China is often 1~3 times higher than that in Nordic and other developed countries[1]. In addition to the heating system, the air conditioning system is also the main source of building energy consumption. In some cities in China, the load of air conditioning equipment in summer can even reach about 40% of the peak load of the day.
Combined Cooling Heating and Power (CCHP) has the characteristics of energy saving, environmental protection, economy, reliability and flexible intelligence. In CCHP, high temperature heat released from fuel combustion (900 to 1200° C) by advanced micro and small power generation equipment, temperature in the exhaust heat power (300 to 500° C) and low temperature exhaust heat (100 to 300° C) can use absorption refrigeration (heat pump)

way of further conversion and utilization. The remainder of the low temperature heat, which is difficult to convert, is used for heating and living hot water to achieve the cascade utilization.

2. LOAD CALCULATION AND SYSTEM DESIGN SCHEMES

2.1 Residential building’s cold and heat load

The Hinge calculation software uses the harmonic response method to calculate the cold and heat load, which can meet the requirements of the heating and air conditioning load calculation for different types of envelop enclosure.

The condition of load calculation is shown in table 1.

Table 1. Condition of load calculation

Floor area of each floor(m^2)	Floor height(m)	Average diurnal temperature in summer(° C)	Outdoor mean wind speed in summer(m/s)	Average diurnal temperature in winter(° C)	Outdoor mean wind speed in winter(m/s)
642	3	31.2	2.8	-3.6	2.7

The total cold load of the whole building in summer is 266710.39×3=800kW, and the total heat load of the whole building in winter is 164634.04×3=494kW.

2.2 Residential building’s electric load

Standard of electric load design in new residential areas in China is shown in table 2.

Table 2. Standard of electric load design for residents in new residential areas in China

Area size(m^2)	<50	51~60	61~100	101~120	121~160
Electric loads(kW)	4	5	6	7	8

The electrical load is about 72×7=504 kW.

2.3 Residential building’s domestic hot water load

The residential building’s domestic hot water load can be calculated according to formula [2]:

$$Q'_{r\cdot p}=\frac{cm\rho v(t_r-t_l)}{T}=0.001163\frac{mv(t_r-t_l)}{T}$$

The calculation result is 0.001163*71*3*(60-10)/24=129.7 kW.

3. PERFORMANCE EVALUATION OF THE SYSTEM

3.1 Selection of system equipment

Get the residential building’s cold and heat load by load calculation software. Through the formula to get residential building’s electric load and domestic hot water load. Due to the complex working conditions of the combined supply system throughout the year, three solutions are proposed in terms of system flow and equipment selection in order to achieve a reasonable match of the heat and electric load. Different operation modes are set according to the characteristics of different seasons.

Equipment selection of system scheme 1 is shown in table 3.

Table 3. Equipment selection of system scheme 1

Gas turbine	Integrated flue gas machine	Plate heat exchanger	Solar photovoltaic module	Wind driven generator
475kW	872kW	---	34kW	1kW

Equipment selection of system scheme 2 is shown in table 4.

Table 4. Equipment selection of system scheme 2

Gas turbine	Waste heat steam boiler	Absorption refrigerator	Solar photovoltaic module	Wind driven generator
475kW	1t/h	800kW	34kW	1kW

The first one and the second plan are combined supply system and the third plan is a separate supply system, all of which are complete energy supply systems that can be applied practically. But the three thermal power, the economy and the environment have their own advantages and disadvantages. It's necessary to carry out specific quantitative analysis and get the best solution.

3.2 Performance evaluation of the system

A reasonable evaluation standard is essential for comprehensively and objectively evaluating the performance characteristics of the energy supply system. It is a benchmark for system simulation analysis and design operation optimization.

Primary Energy Rate (PER) is used in thermal performance evaluation [3]. It is also known as the system thermal efficiency or total energy utilization efficiency. It is defined as the ratio of output energy to input energy and the same as work, heat and cold. The higher the first energy utilization rate of the system, the better the thermodynamic performance of the system. The economic evaluation adopts the period of static investment recovery. The period of investment recovery refers to the time required to repay the total amount of investment by the cumulative value of the net income of the project, that is, the total amount of the initial investment of the system is divided by the net income per year. The environmental performance evaluation index of the system is Carbon dioxide emissions (CDE), a widely used and important environmental performance evaluation index.

The comprehensive evaluation of the system is based on Mixed Grey Relation Analytical Hierarchy Comprehensive Evaluation Process (MG-AHP) [4]. Under the framework of the layered model, the method is evaluated by the grey relation, and the qualitative index is quantified by fuzzy mathematics.

Evaluation result is shown in table 5.

Table 5. Evaluation result

Schemes Score Evaluation project	Initial investment	Investment recovery period	NO_X	CO_2	Primary energy consumption rate	Comprehensive evaluation
Scheme 1	0.562	0.445	0.217	0.764	0.525	0.505
Scheme 2	0.478	0.750	1	1	0.582	0.690
Scheme 3	1	1	0.439	0.445	1	0.483

It can be seen that the energy saving effect of the first energy of scheme two is obviously better than that of the project one from PER. From the period of investment recovery, it can be seen that when the gas price is higher than 2.5 RMB/m3, the system will not be able to pay for tithe separate supply system will take only 1.4 years to recover the initial investment, while the combined supply system has a high energy saving effect, but the initial investment is high, so the investment recovery period is longer. For a long time, the economy depends to some extent on the life of the system.

4. CONCLUSION

The results show that the indexes of heat, economy and environment are considered comprehensively, the CCHP system of the small gas turbine and the integrated flue gas machine is most suitable for the distributed energy demand of the residential area. Its primary energy utilization rate is 0.582, the investment recovery period is 7.5 years, and the environmental and comprehensive evaluation also has obvious advantages.

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