Research on Operation Optimization Strategy of Integrated Energy System Considering Ground Source Heat Pump

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Abstract. With the depletion of fossil energy and the popularity of renewable energy, a comprehensive energy system with the goal of improving system energy efficiency and consuming renewable energy is booming. Based on the combined heat, power, and heat generation, this paper builds a comprehensive energy system operation optimization model in conjunction with ground source heat pumps. It aims to find the optimal operation strategy based on the actual situation of the park's load, equipment capacity, and energy prices. Using the linear programming method, a mathematical model with the best economic efficiency of the integrated energy system is established, the optimal operation strategy for a typical day is analyzed, and the annual operation is simulated. Finally, it compares with conventional energy supply methods and analyzes the contribution to the consumption of renewable energy.

1 Introduction

Natural gas cold, heat and power triple supply system follows the "temperature pair. The principle of using the mouth and energy cascades. The utilization efficiency of the source is maximized [1]. Therefore, the triple supply system has developed very well in recent years because of its high energy efficiency and environmental friendliness.

With the increasing installed capacity of renewable energy power generation Plus, its power generation ratio has also increased year by year, wind power generation by the end of 2017 has reached 188.39GW. However, renewable energy generation is intermittent and random. Characteristics [2,3], installed with 200kW wind power¹. As an example of equipment, it can be seen that wind power fluctuates at night and during the day. Sexually large. Wind power generation in the first half of 2018 was 191.7 billion kWh, abandoned wind power of 18.2 billion kWh [4], abandoned wind peak. It is necessary to concentrate on the moment when the wind power output is large at night. Abandoned wind power. In the middle of the night, electricity consumption is about 60% [5].

In order to meet the heat load demand of the building, the traditional triple supply system operates in the "heat-set" mode, and the excess electricity brought about to ensure heating will not be absorbed. If the system is operated in the "heat setting" mode, the heating will not be satisfied due to insufficient heat [6]. Therefore, the thermos electrics are coupled to each other, resulting in a system that cannot be flexibly adjusted. In view of the

above problems, this paper constructs a three-in-one integrated energy system coupled with ground source heat pump. Through the optimal adjustment of the system, thermal electrolysis is realized, which provides enough space for renewable energy to access the Internet.

2 Introduction to integrated energy system

The integrated energy system studied in this paper is composed of gas internal combustion engine, flue gas driven absorption type hot and cold water unit, ground source heat pump, electric refrigerator, regenerator, gas boiler and so on. The flow chart of the system is shown in Figure 1.

Fig. 1. Integrated Energy System flow chart

In the winter, natural gas enters the generator set to generate electricity. The generated flue gas (458°C) and cylinder water (90°C/70°C) enter the absorption hot and cold water unit to obtain hot water (60°C/50°C). The electricity of the generator is used to drive the ground

source heat pump to heat, the insufficient electricity is purchased from the grid, and the insufficient heat is supplemented by the gas boiler. In summer, natural gas enters the generator set, and the flue gas and cylinder water after power generation enters the absorption chiller to drive the absorption refrigeration mechanism to take cold water (6°C/12°C). The electricity of the generator is used to drive the ground source heat pump. And electric refrigerator cooling, to meet the building's cooling load demand, not enough electricity purchased from the grid. How to adjust and control the coordinated operation between the various devices in the triple-supply system to minimize operating costs and maximize energy utilization efficiency has become the key to research. In the following, based on the performance characteristics of the various components of the integrated energy system, the mathematical model of each component is established to find the optimal operation strategy.

3 Integrated energy system optimization model

All the equipment in the integrated energy system is not isolated and should be coordinated with each other, so that the whole system can be in optimal operation [7]. The mathematical model will be built based on the role and characteristics of the various components in the system. The optimization analysis was carried out in one hour as the operating cycle and in steps of one hour ($i = 0, 1, 2, \dots, 22, 23$).

3.1 Objective function

According to the above analysis, the objective function is established, the operating cost of heating within one day is minimal:

$$f(x) = \sum_{i=0}^{23} (P_{gas} G_{ige} + P_{gas} G_{iboiler} + P_{ei} E_{ibuy}) \quad (1)$$

$$F = \sum_{j=1}^{365} f(x) \quad (2)$$

$$w = \frac{W}{N} \quad (3)$$

$$Z = F + w \quad (4)$$

$$z = \frac{Z}{Q} \quad (5)$$

In the above formula, $f(x)$ stands for objective function. F is annual operating costs. Z is equipment depreciation expense. z stands for energy supply cost. P_{gas} is the price of natural gas, yuan/Nm³. P_{ei} is time-sharing electricity price, yuan/kWh. W is the total investment of the project, N is the depreciation period. Q is the energy for the whole year, GJ.

3.2. System energy balance

The building's thermal and thermal loads are all provided by the system, so the building's thermal and thermal loads are guaranteed at each moment. For the power load, the triple supply system is a type that does not connect to the Internet, that is, the triple-connected unit can not generate electricity for power generation, the power generation meets the self-use of electricity in the energy station, and the insufficient power is purchased from the power grid. According to the output of the equipment and the load demand of the building. The following constraints are as follows:

$$Q_{iload}^h = Q_{icchp}^h + Q_{isehp}^h + Q_{itanK}^h + Q_{iboiler}^h \quad (6)$$

$$E_i + E_{ibuy} - E_{isehp}^h = 0 \quad (7)$$

$$Q_{iload}^c = Q_{icchp}^c + Q_{isehp}^c + Q_{itanK}^c + Q_{iboiler}^c \quad (8)$$

$$E_i + E_{ibuy} - E_{isehp}^c - E_{iec}^c = 0 \quad (9)$$

In the formula, Q_{iload}^c , Q_{iload}^h — the cold load and heat load of the building at the moment, kW; E_{ibuy} — the power purchased at the grid, kW.

4 Case analysis

4.1 Basic information of the project

The integrated energy system bears the cooling and heating load of the building area. The cooling load of the building is 40.56 MW in summer and hot in winter. The load is 18.84 MW according to the construction load, the specific equipment capacity and quantity allocation are shown in Table 1.

Table 1. Equipment Capacity Configuration

Device name	Capacity /kW		Number of tables
Alternator	800		3
Flue Gas Waste Heat Thermal Water Unit	876(heating)	1002 (refrigeration)	2
Ground source heat pump	1443(heating)	1417 (refrigeration)	5
Gas fired boiler	4200		2
Electric refrigerator	6680		3
Regenerative tank	16800(m) ³		1

The total investment of this project is 202 million yuan. The values of energy prices and key parameters are shown in tables 2and3.

Table 2. Values of important parameters

key parameter	Value
ETA	40%
Cophsehp	4.26
Copcehp	5.97
Copcec	4.98

ETA boiler	95%
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Table 3. Hourly Price Distribution

TOU price	Unit price (yuan/kWh)
23:00-7:00	0.4262
7:00-10:00/15:00-18:00/21:00-22:00	0.9138
10:00-15:00/18:00-20:00	1.2856

The price of natural gas is 2.39 yuan/Nm.³ According to the equipment parameters, building load and energy price, according to the constraints mentioned above, the operation mode of the system is simulated and analyzed by the built-in optimization toolbox and programming language of MATLAB software.[10]

4.2 Result analysis

4.2.1. Seasonally typical days

The typical daily load is shown in Fig. 2. After the above simulation and optimization, the specific operation strategy is shown in Fig. 3 and Fig. 5.

Fig. 2. Composition of Building Heat Load on Typical Days

Fig. 3. Typical Daily Energy Supply

Fig. 3 shows the output of each equipment in the optimized system. During the low power load period (23:00-6:00), the ground source heat pump (GSHP) driven by purchasing electricity from the power grid operates at full load. On the premise of meeting the building heat load, the excess heat of GSHP is stored in the storage tank. During peak load period (9:00-14:00).

From 18:00 to 20:00, the internal combustion engine generates electricity, drives the ground source heat pump to make heat, and flue gas drives the absorption chiller and water heater to make heat. At this time, the heat storage tank releases the stored heat, and the absorption chiller jointly bears the heat load of the building. Figure 3 shows the detailed storage state of the regenerator.

4.2.2. Annual operation energy consumption analysis

Heating operation as shown in Table 4. Using the integrated energy system and operating under the optimized strategy, the operating cost of the whole heating season is 3665,800 yuan, the equipment is depreciated according to its 30-year service life, and the heating cost is as follows: 62.15 Yuan/GJ is lower than the heating cost of natural gas boilers. Under this operation strategy, 1.64 million kWh is purchased to provide 1.64 million kWh of Internet space for renewable energy generation.

Table 4. Heating Season Operation

Natural gas consumption (10000 Nm)³	Air intake of triple supply	81.56
	Gas Boiler Intake Volume	40.5
Electricity statistics (10000 kWh)	Internal combustion engine power generation	300.78
	Power grid purchase	164.5
	Power Consumption of Ground Source Heat Pump	486.7
Heating statistics (10000 GJ)	Triple heating	1.3
	Ground Source Heat Pump Heating	6.5
	Gas-fired Boiler Heating	1.5
Annual operating cost (10,000 yuan)		366.58

5 Conclusion

In this paper, an integrated energy system coupled with ground source heat pump (GSHP) is proposed, and its operation is optimized. Under the optimized operation strategy, the integrated energy system embodies the unique dual advantages of economy and energy saving.

Under the premise of satisfying the energy supply, the optimized integrated energy system not only provides enough space for renewable energy to access the Internet, but also saves a lot of operating costs. The distributed cogeneration system with integrated energy utilization is an efficient and economical distributed energy system. It has good development potential in the consumption of renewable energy and thermal

decoupling of energy system.

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