Operation Analysis of the Natural Gas Distributed Energy System

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Abstract: This paper analyzes the cold, heat and electric loads of a hospital in China’s severe cold area, and determines the equipment scheme of the natural gas distributed energy system. Based on the lowest cost, the operation principle of the energy supply system is determined, and the annual balance of cold, heat and electric loads in the hospital is analyzed.

1. Introduction
The natural gas distributed energy system is suitable to be built in the area or building users with the relatively stable power, cooling and heating load demand, which is conducive to the long-term stable operation of the system. A hospital is such a typical building. China has built a number of natural gas distributed energy station projects, but there are few actual projects in the cold area of Northeast China. This paper takes a hospital in the cold area of Northeast China as the research object and focuses on the analysis of operation of the natural gas distributed energy system.

2. Analysis of the cold, heat and electric loads of a building
The project is the relocation of a hospital, with the total construction area of about 135987m². The outpatient department and inpatient department have 22 floors on the ground and 2 floors under the ground; the office and laboratory building has 12 floors on the ground and 1 floor under the ground. The operation time of air conditioning in summer is about 3 months, and the cooling time of air conditioning in the whole year is 93 days (2232h); the operation time of heating in winter is about 5 months, and the heating time in the whole year is 151 days (3624h). The domestic hot water is supplied 24 hours a day throughout the year.

The three-dimensional model of the new building is built, and the simulation computation of the cold and heat loads of the new building is carried out by the DEST software for 8760h in the whole year. When the air conditioning and heating loads are computed, the maintenance structure, indoor and outdoor meteorological parameters, personnel, equipment, functions and other factors are considered. According to the analysis of the energy consumption of the original buildings in the hospital, there is little change in the energy consumption of holidays and working days, so there is no need to analyze the energy consumption of holidays and working days, respectively. On this basis, the configuration scheme of the natural gas distributed energy system is determined and its operation is analyzed.

3. Equipment of the natural gas distributed energy system

3.1. Natural gas generator unit
The energy station of the project is mainly used to meet the needs of cold, heat and electric loads of the hospital. In terms of its construction scale, the gas turbine or gas internal combustion engine can be used. The power generation efficiency of the gas internal combustion engine is higher than that of the gas turbine, about 35% - 48%, generally more than 40%. However, the waste heat recovery method of the gas internal combustion engine is complex, so it is necessary to recover the waste heat of flue gas and hot water at the same time. The gas pressure requirements for the internal combustion engine are low, and it can be directly connected with the municipal gas pipe network. The energy station of the project is located on the second floor underground, and the gas pipeline pressure is not suitable for the gas turbine, so the gas internal combustion engine is adopted.

According to the annual power consumption statistics of the original buildings from 2012 to 2013 provided by the hospital, the hourly change curve of the annual power consumption per unit building area (as shown in Figure 1) and the delay change curve of the power load per unit building area (as shown in Figure 2) are drawn.

![Figure 1: Hourly Change Curve of the Power Consumption Per Unit Building Area of the Hospital](image1)

Analyzed from Figure 1, it is concluded that the average hourly power consumption per unit area in the heating season in 2012 and 2013 is 8.01W/m² and 8.39W/m², respectively. The average hourly power consumption per unit area in the cooling season is 11.04W/m² and 12.78W/m², respectively. The average hourly power consumption per unit area in the transition season is 7.42W/m² and 7.96W/m², respectively.

![Figure 2: Delay Change Curve of the Power Load Per Unit Building Area of the Hospital](image2)
Analyzed from Figure 2, it can be known that, in 2012 and 2013, the hours of the hourly power consumption per unit building area of the hospital more than 15W/m² are 305h and 355h, respectively; the hours of that more than 12W/m² are 825h and 1152h, respectively; the hours of that more than 10W/m² are 1744h and 2429h, respectively, and the hours of that more than 8W/m² are 3412h and 4028h, respectively. Most of the time, the hourly power consumption per unit building area of the hospital is more than 6W/m².

In order to ensure the high efficiency of the generator unit, the full utilization hours of the whole year should not be less than 2000h, so the economic installation range of the generator is 6-12W/m². The total building area of the hospital after reconstruction and expansion is 135987m², so the generator scale suitable for this project is 815-1600kW. After the economic comparison, the 1189kW gas internal combustion generator unit is finally selected.

3.2. Other equipment

The waste heat recovery device should be matched with the generator unit, and the flue gas hot water LiBr unit corresponding to the waste heat parameters of the gas internal combustion engine should be selected, with the heating capacity of 497KW and the cooling capacity of 1231KW.

Using waste heat of flue gas to obtain domestic hot water is a common way of using waste heat of flue gas, which can be realized by adding a heat exchanger at the tail of the main exhaust pipe of the LiBr unit, and the system is relatively simple.

The natural gas direct fired turbine is adopted for the peak shaving equipment, which is easier to be combined with the distributed energy system. The investment in the peak shaving system with the gas boiler combined with the electric air conditioner is slightly lower than that in the direct fired unit, and the operation cost depends on the price of the local energy. Calculated according to the local electricity price and natural gas price, the operation cost of the direct burning natural gas refrigeration is higher than that of the electric air conditioning refrigeration. Therefore, the gas-fired boiler heating and electric air conditioning refrigeration is adopted for the peak shaving equipment of this project.

4. Operation analysis of the natural gas distributed energy system

According to the actual situation in China, the surplus power generated by the generator cannot enter the power grid, so the power generated by the generator unit is given priority to meet the power consumption of the equipment in the energy station, and the surplus power is supplied to the hospital buildings. When the power generated by the generating unit is insufficient, it shall be supplemented by purchasing power from the municipal power grid. Considering the economy of operation, the generator unit in the energy station operates continuously all day, and the equipment is overhauled in the transitional season.

4.1. Analysis of load balance in the refrigeration season

The typical daily cooling capacity balance of the generator unit under the 100% working condition in the cooling season is shown in Figure 3.
Figure 3  Typical Daily Cooling Capacity Balance Chart under the 100% Working Condition in the Cooling Season

Analyzed from Figure 3, under the 100% working condition of the cooling generator in the refrigeration season, the proportion of power generation waste heat in cooling capacity of the whole day is low, accounting for only 24.35%.

The power load balance of the typical daily energy station in the refrigeration season under the 100% working condition of generator unit is shown in Figure 4.

Figure 4  Power Load Balance Chart of the Typical Daily Energy Station under the 100% Working Condition in the Refrigeration Season

The gas internal combustion engine runs continuously for 24h, and the power generated by the gas generator is preferentially used for the power self-consumption of the energy station, and the surplus power is used for the hospital buildings. In the maximum cold load under the 100% working condition of the generator, the power self-consumption of the energy station is about 1949kW. At this time, the power output of the generator in the energy station cannot meet the power demand in the station, so it is necessary to introduce the municipal power to supplement it.

4.2. Load balance analysis in the heating season

The typical daily heat load balance in the heating season under the 100% working condition of the generator unit is shown in Figure 5.
Figure 5  Typical Daily Heat Balance Chart under the 100% Working Condition in the Heating Season

It can be known from the analysis in Figure 6 that under the 100% working condition of the generator, the proportion of waste heat of power generation in the heat supply of the whole day is low, accounting for only 19.28%.

The power load balance of the typical daily energy station in the heating season under 100% working condition of the generator unit is shown in Figure 6.

4.3. Load balance analysis in other working conditions

The same method is used to analyze the 75% working condition of the generator unit:

In the refrigeration season, the waste heat of the typical daily power generation accounts for 34.18% of the cooling capacity of the whole day; the power self-consumption of the energy station is about 1434kW, and the generator cannot meet the power demand in the station, so it needs to introduce a small amount of municipal power to supplement it. In the heating season, the waste heat of the typical daily power generation accounts for 20.57% of the heat supply of the whole day; in winter, the power generated by the generator can meet all the power load demand of the hospital.
50% working condition of the generator unit:
In the refrigeration season, the waste heat of the typical daily power generation accounts for 49.12% of the cooling capacity of the whole day; the power self-consumption of the energy station is about 859kW, the generator in the energy station can meet the power demand in the station, and there is surplus power for the hospital buildings. In the heating season, the waste heat of the typical daily power generation accounts for 26.64% of the heat supply of the whole day. In winter, the power generated by the generator can meet all the power load demand of the hospital.

5. Conclusion
The natural gas distributed energy system can supply cold, heat and power at the same time. Compared with the conventional mode of municipal heating in winter and electric air conditioners for cooling in summer, the annual operation cost is significantly reduced, and the comprehensive utilization efficiency of energy is increased to more than 80%. However, due to the fact that the surplus electricity could not enter the power grid and the limited scale of the generator unit, the hospital purchased more municipal electricity in the whole year and the peak shaving equipment ran for a long time.

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