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Study on Configuration Optimization of Natural Gas Cooling, Heating and Power Systems Coupled with New Energy Sources

Jingru Liu [1,*], Yanlei Li [2], Yanfeng Li [3]

[1] Shandong Electric Power Engineering Consulting Institute Corp., Ltd., Jinan, China
[2] State Power Investment Group Beijing Electric Power Corp., Ltd., Beijing, China
[3] State Key Joint Laboratory of Environmental Simulation and Pollution Control, School of Environment, Beijing Normal University, Beijing, China

*** Corresponding author:** Jingru Liu (Email: liujingru@sdepci.com)

Abstract: The study on the configuration optimization of natural gas combined cooling, heating and power system coupled with new energy can provide reference for the planning, design and operation of this type of project. The optimal configuration problem is a multi-system coupling and multi-objective optimization problem. The optimal system configuration is obtained by establishing model, using algorithm and numerical simulation based on optimization software.

Keywords: New Energy; Natural Gas Cold; Heat and Power; Configuration Optimization.

1. Introduction

The situation of global coping with climate change is very serious, and the pressure of reducing greenhouse gas emission is increasing day by day. The shortage crisis of traditional energy and the environmental problems caused by it have become a major problem that restricts the development of human economy and society. The 14th five-year plan of modern energy system aims to improve the capacity of gas storage and natural gas supply, which will make natural gas-based clean energy popular in China. The utility model has the advantages of being close to the user side, realizing the energy cascade utilization, and having broad application prospects. It is helpful to improve the flexibility, economy and cleanness of the power system to construct a combined natural gas cooling-heating-power system coupled with new energy and realize multi-technology coupling and multi-energy synergy, it has important research value.

Gas-fired Combined Cooling, Heating and Power (CCHP) refers to the electricity demand of users, which is generated by the operation of Power generating equipment such as steam turbines and generators driven by natural gas as the main fuel, an energy supply system in which the waste heat discharged by the system after power generation is supplied to the users for heating and cooling by waste heat recovery equipment in order to meet the cold-heat-electricity demand, it usually consists of a gas electric generator, a waste heat recovery refrigeration unit, and a heat exchange unit. The triple supply makes the heat energy of natural gas be fully utilized, and greatly improves the efficiency of energy comprehensive utilization.

2. The Principle of Configuration Optimization

Because of the variability of building load, the equipment in CCHP system is in variable operating mode in most cases, that is, partial (hourly) load operating mode. Therefore, it is very important to study the thermodynamic characteristics of the equipment under variable operating conditions. In general, the performance of equipment in CCHP system under partial (hourly) operation will decrease, and the degree of decrease is related to the degree of partial load. The partial load power generation efficiency $\eta_{i,pgu,e}$ and the partial load thermal efficiency $\eta_{i,pgu,h}$ of gas-fired internal combustion engine are composed of heat dissipation efficiency$\eta_{i,pgu,h1}$ of high temperature flue gas and heat production efficiency $\eta_{i,pgu,h2}$ of cylinder liner hot water.

Considering that the multi-objective optimization research of multi-energy cooperative triple supply system belongs to a nonlinear, multi-variable and multi-constraint optimization problem, in this paper, the hybrid algorithm of hokchev-particle swarm optimization (HPSO) is used to solve the global problem with high accuracy, fast convergence and strong optimization. Based on the coupling platform of TRNSYS energy consumption software and GENOPT optimization software, the numerical simulation is carried out.

3. Instance of System Configuration Optimization

Taking a centralized energy supply system as an example, the building is a two-story underground and three-story above-ground building with a total floor area of 20607.5 m^2. The energy supply network adopts four-control system. Year-round cooling, heating in winter. It covers an area of 2.83 km^2 and needs to provide heating, cooling and domestic hot water for 2.17 million $m^2$of offices, businesses and hotels in the region. Natural gas distributed energy cogeneration, to heat fixed power, residual power grid (10kV high-voltage grid). Electric drive refrigerator in summer, heat pump in winter and energy storage system to balance production and marketing.

According to the data of energy supply area and the calculation method of load demand, the cooling load of air conditioning is designed to be 135109 KW, the index of cooling load per unit area is 62 W/m^2, the design heat load is 58408 KW, the index of heat load per unit area is 27 W/m^2. According to the annual load forecast, the regional planning annual cooling needs 136.22 million kWh, annual heating

needs 19.59 million kWh. The annual cooling and heating load of the energy center is shown in Figure 1 and figure 2. Figure 3 and figure 4 show the delay curves of the thermal and cold loads respectively. Hourly cooling load on summer design day and hourly heat load on winter design day are shown in Figure 5 and Figure 6.

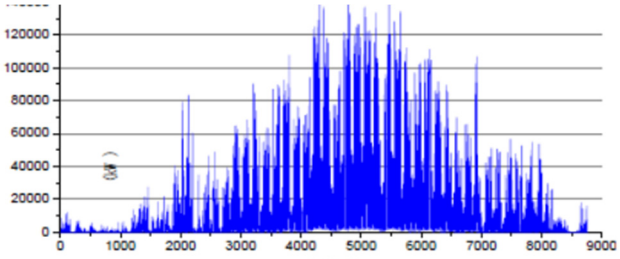


Figure 1. Energy center annual cooling load curve

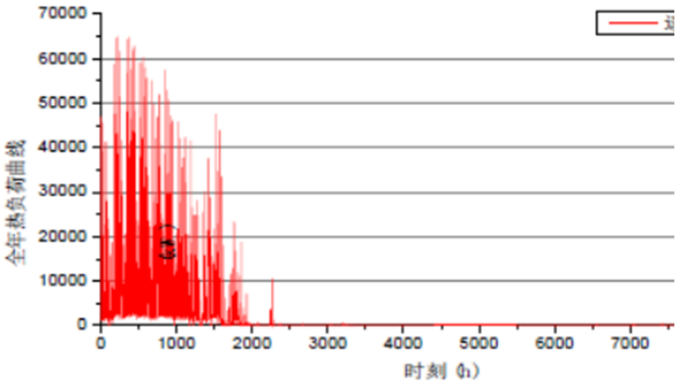


Figure 2. Energy Center annual heat load

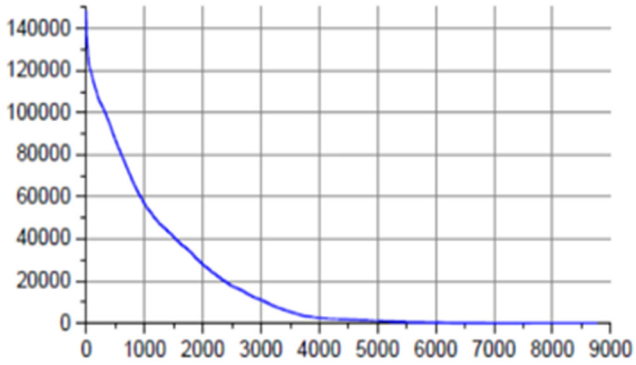


Figure 3. Energy center cooling load delay curve

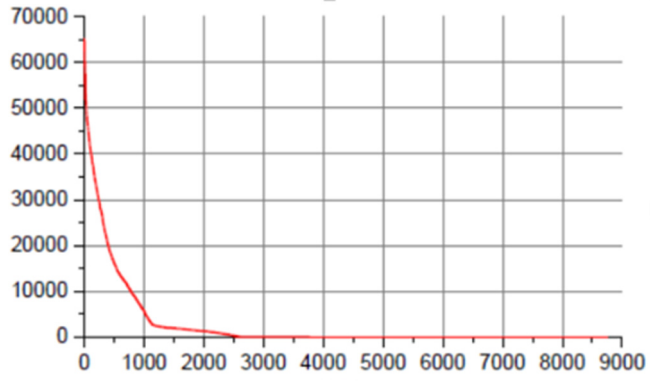


Figure 4. Energy Center annual thermal load delay curve

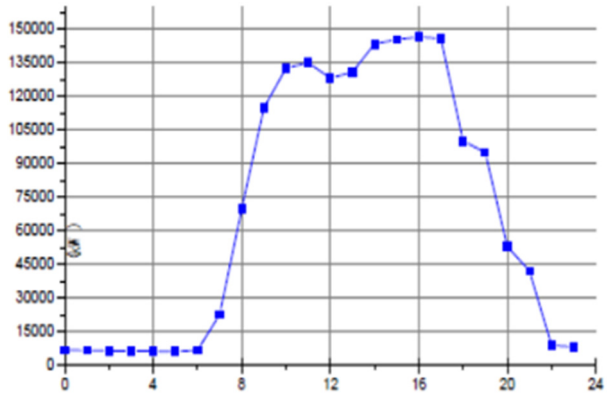


Figure 5. Energy Center summer heat load design

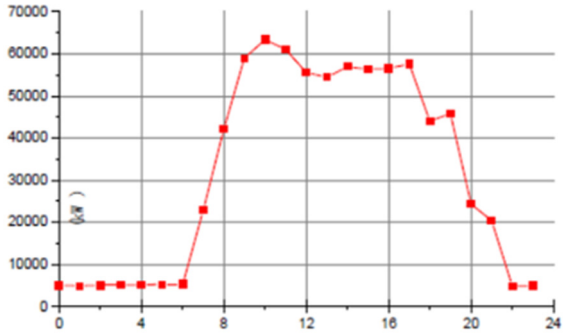


Figure 6. Energy center winter heat load design

4. Design Ideas

1) technical programmes, equipment energy efficiency and so on are in line with national and local energy policy guidance and energy conservation requirements, and the selection of energy programmes that meet the needs of the project is based on the available energy conditions at the project site.

2) according to the subsidy policy, the electricity price and the gas price and so on preferential measures, through the technical plan comparison, chooses the reasonable equipment disposition plan.

3) according to load forecasting, power grid policy, grid-connected mode, energy price and other factors, the actual operating parameters are predicted, and the economy of the project is evaluated.

The main design principles are as follows:

1) the distributed energy supply system can make full use of the waste heat of power generation, improve the comprehensive utilization rate of energy, and increase the running hours.

2) the distributed energy supply system takes on the basic load and adopts the measures of energy storage to ensure its stable operation.

3) make full use of peak and valley electricity price policy, use energy storage system to reduce project operating costs.

4) on the premise of meeting the needs of users, the temperature difference between supply and return water of pipe network should be improved as far as possible, and the energy consumption should be reduced.

5. Installation Options

1) 2×3203 KW gas internal combustion engine electric generator with 2 flue gas hot water type lithium bromide units installed in the B1F internal combustion engine room of the Energy Centre;

2) 1×1800 KW domestic gas turbine electric generator and 1 flue gas type lithium bromide unit installed in the 1f gas turbine room of the energy centre;

3) 6 ×York 2800 RT centrifugal chillers installed in the B2F HVAC plant room of the Energy Center;

4) 4 ×Kelley 1350 RT centrifugal heat pumps installed in the B2F HVAC plant room of the energy center;

5) 21 ×Kelley 1135 KW air source heat pump units installed in the Energy Center 4F, 5F;

6) Energy storage: an effective storage volume of 25,000 m3 of Asia's largest steel energy storage tank;

7) Equipped with two intelligent lighting system devices, with smart charging device, smart monitoring, public broadcasting, lighting, network and other smart functions;

8) Siemens PCS7-SMART410 DCS control system, to achieve the full station real-time automation functions;

9) remote centralized control system: Based on Big Data Analysis and cloud technology, control strategy automatic optimization online intelligent operation; Universal Complementary, collaborative optimization of intelligent control strategy, multi-station centralized control, Internet + control technology to build 3D visualization operation and monitoring cloud platform; mobile office, operation and maintenance and decision-making, to achieve the slave station “Unattended, less on-duty.”

6. Business Models

The establishment of the project company, making it clear that the project is the only source of air-conditioning heat and cold in the entire region, the users must use the energy centre for centralized energy supply and not allow the construction of backup air-conditioning systems. The price of energy supply adopts two-part system, which is composed of access fee and energy fee. The access fee is charged once when the user is connected, and the energy fee is charged monthly after the official power supply, including the fixed basic usage fee and the metering fee charged according to the actual usage. The price of energy supply will be adjusted according to the fluctuation of gas price, electricity price, water price and staff salary.

7. Benefit Analysis

The annual air-conditioning cooling capacity is 136.22 million kWh, the annual heat supply is 19.59 million kWh, and the annual power generation is 29.42 million kWh. The total return on investment was 5.36% , the net profit margin on capital was 19.38% , the internal rate of return was 7.24% , and the net present value was 27.57 million yuan. The payback period (after income tax) is 14.57 years, the internal rate of return (project capital) is 10.56% , the net present value (Project Capital) is 16.26 million yuan, and the payback period (Project Capital) is 16.19 years.

8. Conclusion

There are some problems such as high investment of gas turbine, high price of natural gas, high price of energy supply, and so on. Therefore, in the decision of the project installation program or to combine specific project specific analysis, strive for the optimal solution.

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