CCHP System with Interconnecting Cooling and Heating Network

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Abstract: The consistency between building heating load, cooling load and power load are analyzed in this paper. The problem of energy waste and low equipment usage in a traditional CCHP (combined cooling, heating and power) system with generated electricity not supplied to the grid is analyzed in detail. Further, the new concept of CCHP system with cooling and heating network interconnecting is developed. Then, the Olympic Park energy system is presented to illustrate the advantage and improvement both in economy performance and energy efficiency.

Key words: consistency CCHP cooling and heating network interconnecting

1. INTRODUCTION

Combined cooling, heating and power (CCHP) can supply electricity, heating and cooling as its name implies. In most researches and applications of CCHP cases, more attention are paid to the relationship of electricity generation and grid, which is on grid, parallel in grid or operated independently[1]~[4]. So the cool and heat capacity, which just generated to meet the demand of its own consumer, haven't been considered to connect the other heat consumers openly in the heat (cool) network.

The main profit for CCHP with connecting or paralleling in grid is that the dynamic variation of heating, cooling and power load would be well balanced among heat consumers, which lead to well operational economy performance and high energy efficiency. While the electricity generated by traditional CCHP policy is served for its own consumer, which called as 'parallel in grid, not connect in grid'. In this case, the optimum running condition is that the power generated by CCHP meets the demand of consumer, and in the meanwhile, the heat quantity is used up by consumer. Otherwise the 'heating restricts electricity' phenomena will emerge, which lead to reduce electricity generation capacity of unit and its utilization hour. And the surplus heat (cool) quantity is wasted for nothing, thus the energy efficiency of the whole system is depressed. In sum, asynchronous variation between heat (cool) load and power load will lead to unreasonable unit output and bad economy because of heat energy-wasting and equipment low-usage, even that it's inferior to conventional heating and air conditioning system.

2. ISSUE ON CONSISTENCY BETWEEN BUILDING HEAT (COOL) LOAD AND ELECTRICITY LOAD

The key to a successful building gas CCHP exists in that the detailed building heat, cool and power load status and appropriate unit capacity to ensure high operation hourage and waste heat recovery. It's shown as figure 1 the hourly heat and power load between one office building (about 0.1 million square meters) and one hotel building in a typical climate day of Beijing. The hourly heat load is simulated by load simulation software DeST and the hourly power load is calculated according the literature [5]~[7]. It can see that the hotel load variation is relatively smooth contrary to the quite great wave of office building. And the hourly heat and power load ratio of those building is shown as figure 2, which can evaluate the consistency of load distinctly. Because of the intermittent using characteristic of office building, the value of ratio is greatly fluctuant especially when it need huge pre-heat load to reach the comfortable temperature level from 7:00 PM to 9:00AM.

Conversely, the load of hotel building is relatively stable. Suppose that CCHP in those two buildings are operated independently and set the heat and power load ratio equaling to 1, we can conclude that the most generated waste heat would be discharged in vain in order to satisfy power load in office building from 6:00PM to 8:00AM. In the meanwhile, in the hotel building, the generated waste heat may not meet the demand of heat peak load in night. Thus, if we connect the heat (cool) network of the adjacent CCHP system such as hotel and office building, the heat load are complementary and reciprocal, which decrease remarkably the energy consumption and increase equipment utilization hour thus to improve system economic performance. Similarly, there exists inconsistency between cool load and power load in those two buildings.

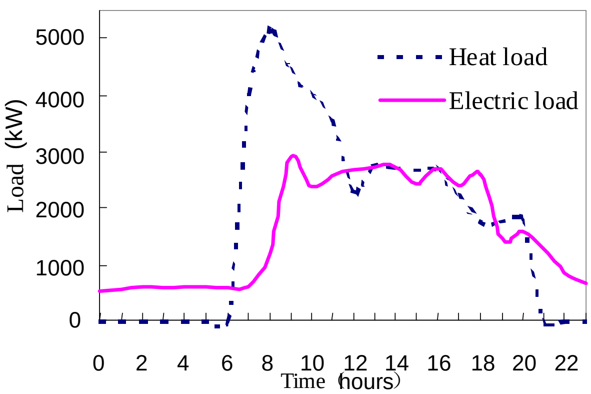

Fig.1 (a)Typical day load of office building in winter

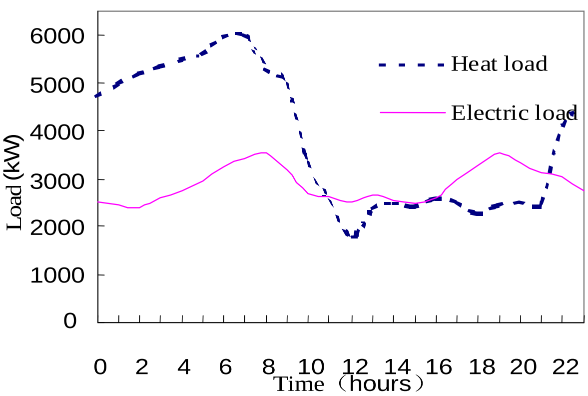

Fig.1 (b)Typical day load of hotel building in winter

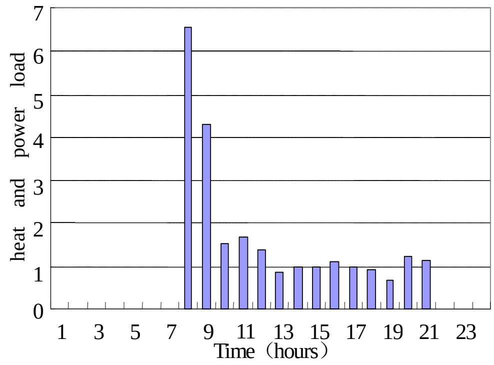

Fig.2 (a)Typical day ratio of office building heat and power load in winter

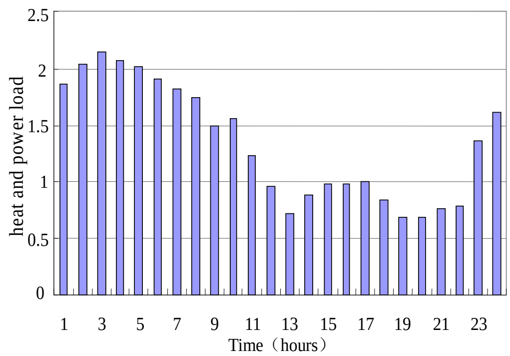

Fig.2 (b)Typical day ratio of hotel building heat and power load in winter

3. CCHP SYSTEM WITH COOLING AND HEATING NETWORK INTERCONNECTING

It's difficult to sale the surplus electricity to grid because the electricity generated by traditional CCHP policy is served for its own consumer. And the CCHP distributed electrical source is prohibited to interconnect the grid according the electric law in China. But if the CCHP heat (cool) network are connected with the external CCHP according above stated, the system would be operated more openly and the restriction of heat (cool) load are weaken, which improve greatly the energy efficiency and the economic performance.

There are basically three types of CCHP system with cooling and heating network interconnecting. (1) Two or more CCHP system with complementary heat (cool) load, as the above hotel and office building type. (2) CCHP system connecting with some other heat consumers, which bear complementary heat (cool) load without CCHP. And for further load balance, stored energy device would be set on network, as following the Olympic Park case. (3) CCHP system connecting parallel with adjacent network, which supply the surplus heat (cool) quantity to the adjacent network and get the absent quantity from it.

There are generally three advantage of this new concept of CCHP system. (1) Well economic performance. For the CCHP system designed separately in some buildings, the complement load increase the energy using efficiency and utilization hour. And the electricity generated parallel in grid with the same price of grid, which improve remarkably the total economic performance. While for one central CCHP system with different consumers, the electricity generated isn't allowed to supply to building and supply to grid with cheap price. Thus, it causes the poor economic performance. (2) High safety and reliability of energy supply. Power supply with individual system in buildings and heat (cool) with complementary heat (cool) quantity are safer than the central system. (3) Low capacity of storage device, peak-load chiller and peak-load boiler.

4. ANALYSIS OF CCHP NETWORK INTERCONNECTING SYSTEM IN THE OLYMPIC PARK CASE

The planning project of Olympic Park will occupy 28 block of land (B01~B28), shown as Fig.3, which cover 3 million square meter area. And the first-stage construction completed before 2007 will cover 2.5 million square meter area, including gym facilities located in the south, conference facilities located in the north, part of commercial buildings and athlete village (B28). The second-stage construction including some commercial buildings, Capital Juvenile Palace and Beijing City Development Exhibition Hall will be completed after 2008.

Considering that one central CCHP system with different consumers in the Olympic Park would cause poor economic performance, gas CCHP system was established individually in one big-scale building with independent management (B02~B26) or one block with area of above 50,000m^2 (B01, B28). And four-pipe system, that is, two heating (cooling) pipes and two living hot water pipes were adopted and connected to make use of the surplus heat (cool) quantity. In addition, gas heat pump system was established in the north of park where two wastewater treatment factories located. And the wastewater served as chilled water of heat pump evaporation. Those two systems are also connected with the heat (cool) network to share the load of the whole park. And the peak shaving units include the stored device in the terminal of network, gas boiler, electricity boiler and refrigerator inside the buildings, shown as table 1.

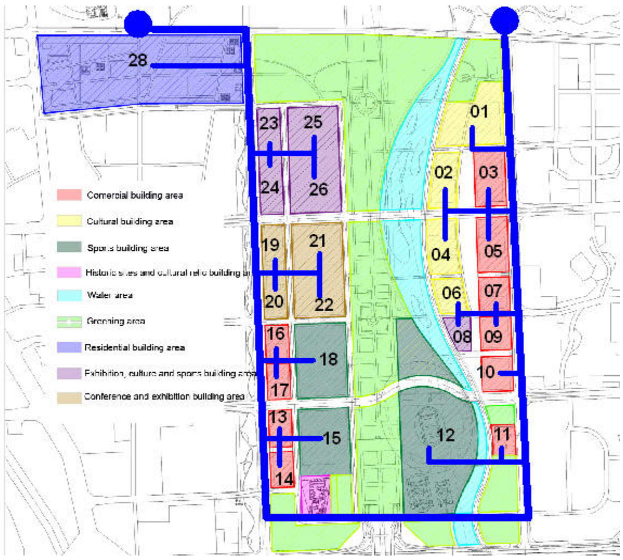

Fig.3 The network of CCHP system with cooling and heating network interconnecting

The operational condition of CCHP system with cooling and heating network interconnecting in one typical day in summer is illustrated as figure 4 and figure 5. It can see distinctly that commerce and office buildings share the most load supplied by the CCHP, which have certain electric load and almost zero cooling load at night. Consequently, the CCHP system will produce more cool quantity than be consumed when it operate in "electricity restrict heating" condition in this period of time. Meanwhile, some of this surplus cooling is supplied to Olympic Village dwelling and the remaining is stored in energy storage tank. And the energy storage tank will share the peak cool load of the buildings with CCHP system in daytime when CCHP system can't meet the demand of cool load of its own consumers.

Tab.1 The capacity of CCHP units

Units	Capacity
water source gas heat pump unit（×10^4kW）	3.18（heating） 3.45（cooling）
Gas engine（kW）	39686
Peak load gas boil（×10^4kW）	12
Electric boiler（×10^4kW）	1.7
Compress refrigerator（×10^4kW）	14.8
Absorption refrigerator（×10^4kW）	4.1
Stored energy tank（×10^4m^3）	3.9

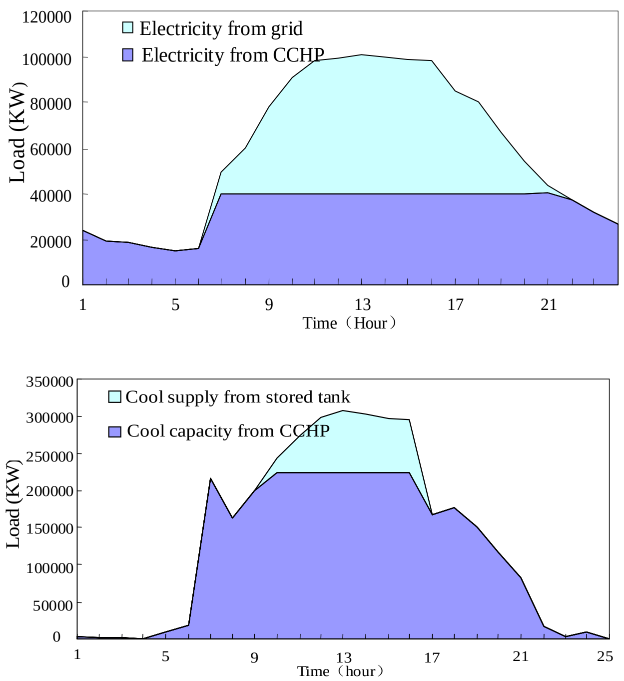

Fig.4 Operational condition of CCHP in one typical day in summer

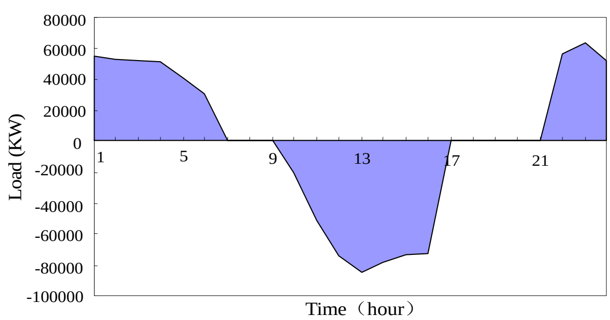

Fig. 5 The surplus cooling quantity curve in one typical day in summer

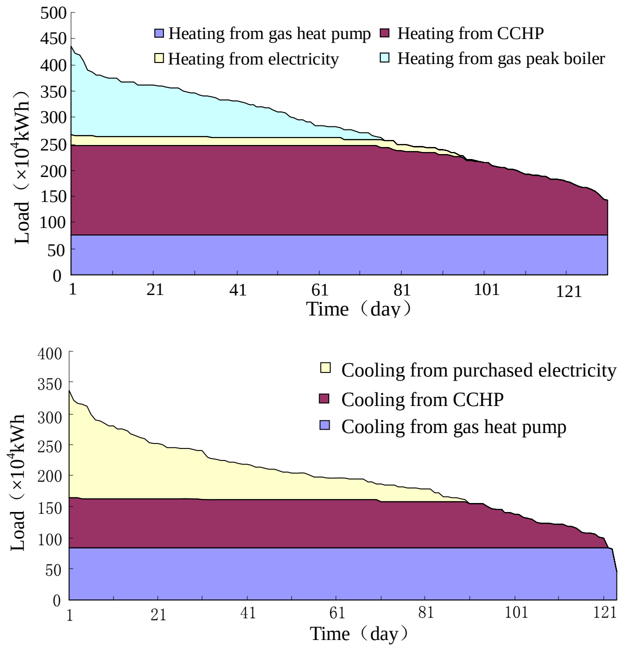

Fig.6 Operational load delaying curve of CCHP with cooling and heating network interconnecting

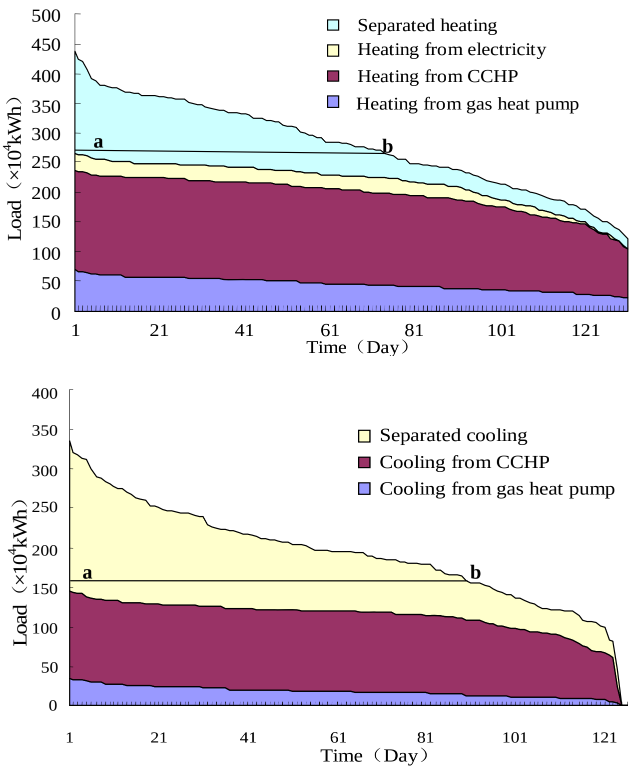

Fig.7 Operational load delaying curve of CCHP without network interconnecting

As we known that the cool load will decrease with drop of the air temperature in summer. However, the electric power load wouldn't change so much in those days, so CCHP system could supply more surplus cooling quantity to other consumers besides its own consumers. In the further, during the warm day in winter, CCHP system can supply heating quantity to the Olympic Village besides meeting the demand of heat load of its own consumers. It can see clearly from figure 6 that CCHP system with cooling and heating network interconnecting share the basic heat and cool load of Olympic Park together with gas wastewater heat pump. Therefore, the operation hour age of units will be ensured to show clearly the advantage of this new CCHP system with cooling and heating network interconnecting.

Tab.2 Compared analysis between CCHP system with cooling and heating network interconnecting and CCHP system without cooling and heating network interconnecting

Item	Interconnecting scheme	Disconnecting scheme	Reduced value
Total fuel consumption （$\times 10^8 m^3$）	0.7404	0.7244	0.016
Electric power quantity（$\times 10^8$kWh）	2.0023	1.7073	0.295
Heating quantity of CHP（$\times 10^4$GJ）	130	114	16
Other heating quantity（$\times 10^4$GJ）	19	35	-16
Cooling quantity of CHP（$\times 10^4$GJ）	58	51	7
Cooling quantity of electric refrigeration（$\times 10^4$GJ）	29	36	-7
Invest （$\times 10^4$yuan）	70398	69405	993
The operated hours yearly	5381	4689	692

In this paper, the CCHP system without cooling and heating network interconnecting is chosen as a compared scheme in order to evaluate the energy efficiency and economic of CCHP system with cooling and heating network interconnecting, so it’s necessary to research the operation system condition of the compared scheme firstly.

In this scheme, the gas wastewater heat pump supply the heat and cool load of commerce zone (B01) and Olympic Village(B28) whose electric power is supplied from electric network. And other buildings have their own independent CCHP systems.

Comparing from Figure 6 and Figure 7 above, some conclusions can be drawn that the surplus heating and cooling quantity produced by CCHP system and gas wastewater heat pump can’t be transmitted to other consumers through heating and cooling network when heat and cool load is decreased because of the independent operation between each CCHP system and gas wastewater heat pump. Therefore, the CCHP system and gas wastewater heat pump which operate independently produce less heating and cooling quantity than they operate with network interconnected. And the reduced heating and cooling quantity is respectively equal to the heating quantity from gas boiler and the cooling quantity from electric refrigeration, that is, the quantity beneath the line ‘ab’ as shown in Figure 7. Concretely speaking, 16×10^4GJ heating quantity and 7×10^4GJ cooling quantity is totally reduced as the table 2 shown[8].

Both system with network connecting and system without network connecting have the same heating and cooling load if all the heating and cooling supply systems in Olympic Park are treated as a integrated energy system. However, the system with cooling and heating network connecting can generate extra electricity amounting to 0.295×10^8kWh at the cost of more nature gas amounting to $0.016\times10^8 Nm^3$ is consumed. In the meanwhile, contrasted to the system without cooling and heating network interconnecting, peak load shaving units (energy storage device, boiler .etc) would be less or smaller in the network interconnecting system at the cost of more pipes should be invested. In sum, the system with cooling and heating network interconnecting increases extra 9.93million Yuan investment. According to the above data, the interconnecting system is equivalent to a power plant with high electric generation efficiency amounting to 185%. And the more sufficient using of waste heat from CCHP system and wastewater heat pump contributes to this high efficiency. In this point of view, suppose that investment depreciation cost will last 20 year and the price of natural gas equals to 1.8Yuan/Nm^3, the cost of generated electricity of this equivalent power plant with efficient 185% is only 0.12 Yuan/kWh comparing to the normal electricity price 0.6 Yuan/kWh. So the investment cycle life only amounts to 0.7 year and the high economic performance is achieved with the network interconnecting. Of course, there are still some problems in this system such as the determination of heating or cooling price, thermal metering and charge. But it is possible to solve these problems through the economic lever because of the wholly well economic performance of the system.

5. CONCLUSIONS

In this paper, through theoretical analysis of the CCHP system with cooling and heating network interconnecting and the practical analysis of the Olympic Park case, some conclusion can be drawn as follow.

(1)The interrelationship of dynamic characteristics of the heat, cool and electric load is different in different type of buildings. Besides, there are distinctly less consistency between heat and electric load or between cool and electric load.

(2)The electricity generated by traditional CCHP system is served for its own consumer and doesn't connect in grid. In this case, asynchronous variation between heat (cool) load and power load will lead to unreasonable energy output and bad economy.

(3)CCHP system with cooling and heating network interconnecting could increase the system operational hourage or reduce the discharging of surplus heat produced by devices. In the end, it optimizes the economic performance and improves the energy efficiency.

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