The Study of Distributed Energy System Optimization in Low Carbon Park–an Application in Shenzhen

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Abstract
The low carbon economy is proposed in China, and the national supportive policy for low carbon industrial park is also provided. Distributed energy system applies cascade utilization of energy technique with very high primary energy utilization efficiency. This system can meet users' requirements immediately. Therefore, distributed energy system has become an important technical method to achieve energy conservation, emission reduction and efficiency improvement due to these advantages. In this paper, the power (cool, heat, electricity) load characteristics in a promoter region of low carbon industrial park in Shenzhen are predicted and analyzed. Then the generating set configuration is optimized. The comprehensive energy efficiency of the whole energy system takes priority over others. Finally the generating set form of a distributed energy system is determined.
Key words: DISTRIBUTED ENERGY SYSTEM, COMPREHENSIVE ENERGY EFFICIENCY, LOW CARBON PARKS

1. Introduction

Industrial park characterized by industry cluster has become an important form and the main force of economic development in China. However, the development model is excessively dependent on the input of energy, resource and material. This extensive development model focusing on enlarging scale needs to be changed. Therefore, it is urgent to develop low carbon parks. In order to plan and design low carbon parks, the consumption, pollution and emission in the park should be controlled. At the same time, ecological sustainable construction and development including environmental protection and harmony with nature should be emphasized from the aspects of energy, water, landscape, traffic, etc. It should be in accordance with the principles of being easy for practice, implementation and evaluation. To maximize the efficiency of the energy system in the park, the demand should be lowered and the efficiency should be improved [1]. Non-renewable resources should be replaced by renewable resources by cascade utilization of energy technique. A clear development goal will be obtained. Eighty pilot national low carbon industrial parks with distinctive characteristic and strong demonstration significance will be created before 2015. In addition, a batch of low carbon enterprises which master low carbon core technology and have advanced management experience on low carbon will be built [2]. Then a group of industrial parks with low carbon development model can be formed. The low carbon economy is proposed in China, and the national supportive policy for low carbon industrial park is also provided. Distributed energy system applies cascade utilization of energy technique with very high primary energy utilization efficiency [3]. This system can meet users' requirements immediately. Therefore, distributed energy system has become an important technical method to achieve energy conservation, emission reduction and efficiency improvement due to these advantages. Natural gas distributed energy system is a heat and power cogeneration system. For this system, natural gas is used as the main fuel. It can drive the power generation equipment such as gas turbine or gas engine. Electricity produced by the electric power can meet the demands of internal users. The waste heat generated by the system can be used to supply heat and cool for terminal users through recycling equipment [4]. Its main advantage is that the power can be produced and used onsite. The energy efficiency per unit can reach more than 70%. And it has dual peak cutting effect on the power grid and natural gas pipe network. Distributed energy system will be popularized in cities above national scale by 2020, and the installed capacity is fifty million kilowatts [5]. The "gas utilization policy" and "energy development in the Twelfth Five-Year Plan" promulgated in 2012 and 2013 by the national development and reform commission and state council explicitly encourage the development of natural gas distributed energy. In addition, supportive policies of encouraging the development of natural gas distributed energy have been issued recently in Beijing, Shanghai, Guangzhou and other places. The file of "gas distributed energy system development supportive measures for air conditioning in Shanghai" was issued in Shanghai in 2008. The equipment investment subsidies can be offered for the company using distributed power system and gas air conditioning. Natural gas will be supplied for priority. Among them, the distributed power system has 1000 yuan/KW subsidies, and gas air conditioning has 100 yuan/KW subsidies per refrigeration capacity. The file "development plan of cogeneration and distributed energy station in Guangzhou" published in 2012 also puts forward that 16 area type distributed energy stations, 33 commerce and building distributed energy stations will be constructed in the future in Guangzhou city. And about 10 distributed energy demonstration stations will be built during the "Twelfth Five-Year".

2. General situation of the project

This project is located in Shenzhen city with the planning area of about 53 square kilometers. Among them, the promoter region, including public buildings such as office buildings, shopping malls, school buildings and libraries, covers an area of about 1.3 square kilometers. The total construction area is about 2 million square meters. The project is aimed for the international first-class low carbon industrial park with its integrated energy efficiency more than 70%. By predicting and analysing power (cool, heat, electricity) load characteristic in the promoter region, configuration of generating set is optimized. The comprehensive energy efficiency of the whole energy system has priority over other things. Finally the generating set form of a distributed energy system is determined. This will be a model for other cities.

3. Power load analysis in park

3.1. Electric load prediction and analysis

Shenzhen belongs to the region with hot summer and warm winter. The power load in this area is given priority to cooling load of air conditioning, and time of supplying cool may be up to 6-8 months. Electricity is mostly used in architectural lighting, refrigeration by air conditioning and other office auxiliary equipment in promoter region. Electricity consumption by refrigeration with air conditioning is consisted of cold source side (chiller, pumps, cooling towers, etc.) electricity consumption and end side (fan coil units, air cooling tank, etc.) electricity consumption. Only the electric load at the end of the air conditioning system needs to be considered, because heat and power cogeneration distributed energy system is adopted in this project.

This project is mainly about power load in office. The electric load with time (hour) is closely related to the use frequency of construction and personnel schedule. Therefore, the analysis of electric load is carried out on design day including working days and rest days. And the results are shown in Fig. 1 respectively.

3.2. Cooling load prediction and analysis

In order to grasp the characteristics of cooling load changes throughout the year of air conditioning more accurately in the promoter region, and provide basis for the cooling capacity selection and cold water pipe diameter design in subsequent regions, the following steps should be followed. According to files "civil building heating ventilation and air conditioning design specification", "public building energy efficiency design standards", "energy efficiency design standards of residential building in area with hot summer and warm winter" and other relevant local energy-saving design standards, air conditioning load simulation calculation software (Energyplus, E +) should be used for air conditioning load simulation analysis hourly throughout the year. And the simulation results are shown in Fig. 2

3.3. Hot water load prediction and analysis

Living hot water load is associated with the required temperature, the tap water temperature and the

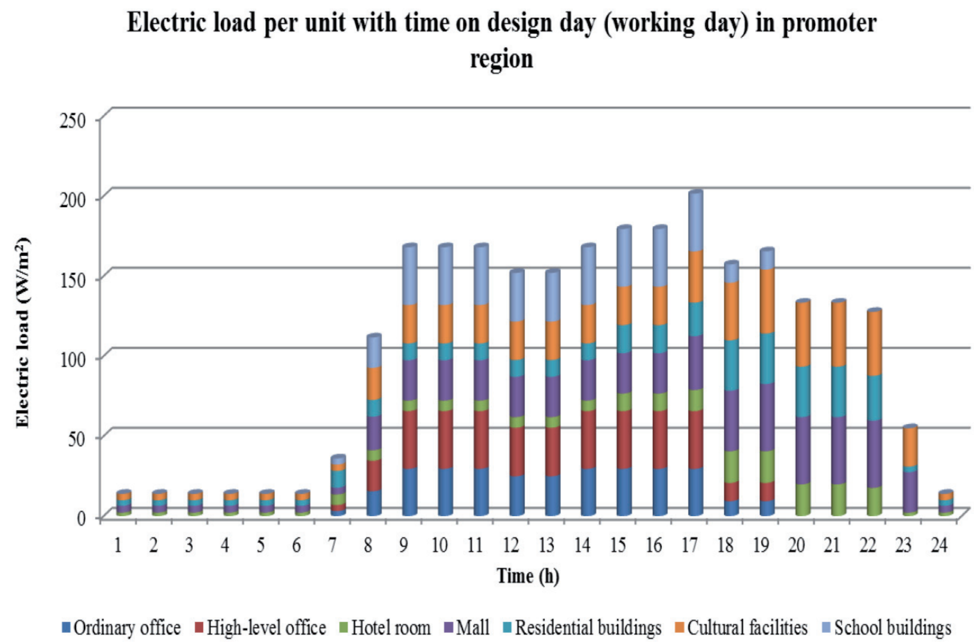

Figure 1. Electric load per unit with time on design day (working day) in promoter region

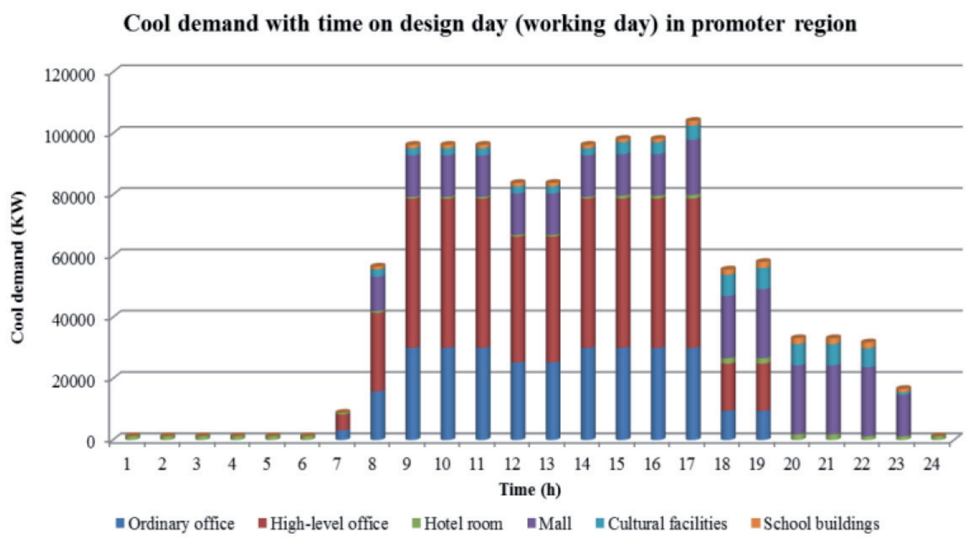

Figure 2. Cool demand with time on design day (working day) in promoter region

supplying living hot water temperature. The hot water temperature is 60 °C for all users in this plan. According to the existing planning data combined with the size and position distribution characteristics of hotels and residential buildings in the promoter region, a population of 1.5×10^4 who use hot water is determined in the promoter region. When considering the population flow factor, population number is multiplied by the coefficient of 0.95 for calculating hot water load. It is estimated that the supplied hot water (60 °C) is 1710 t/d in winter, 570 t/d in summer, and 1140 t/d in spring and autumn in average in the promoter region. And the hot water load of each season in promoter region is shown in Table 1.

4. Selected schemes of generating set configuration and analysis for a distributed energy system

According to electricity generated at end and cooling load curves, different generating sets and configuration methods can be chosen. The selected schemes are shown as Fig.3- Fig. 5.

Table 1. Load generated by hot water demand in promoter region of each season

Season		Spring	Summer	Autumn	Winter
Month		3-4	5-9	10-11	12-2
Population that hot water supplied for (1.5×104)	Hot water demand per day (t)	1140	570	1140	1710
	Load generated by hot water (t/h)	71.3	35.7	71.3	106.8

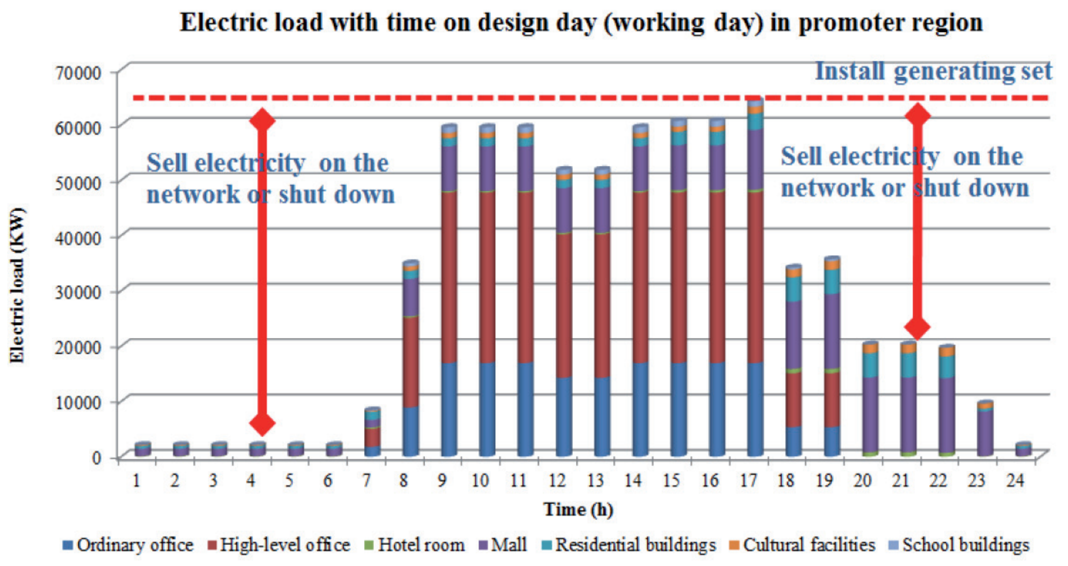

Figure 3. Selected scheme one: installed capacity of each generating set

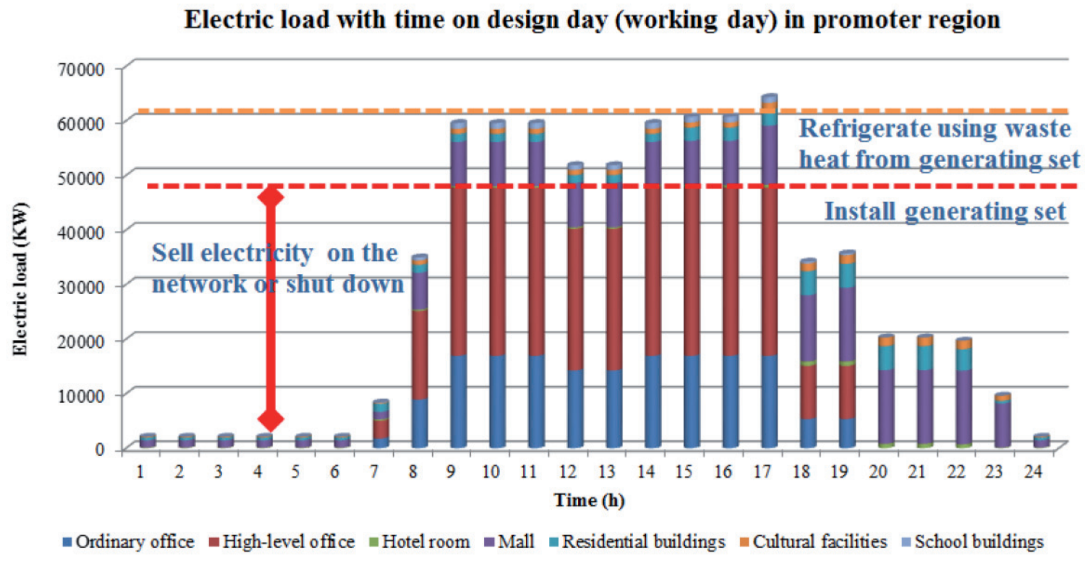

Figure 4. Selected scheme two: installed capacity of each generating set

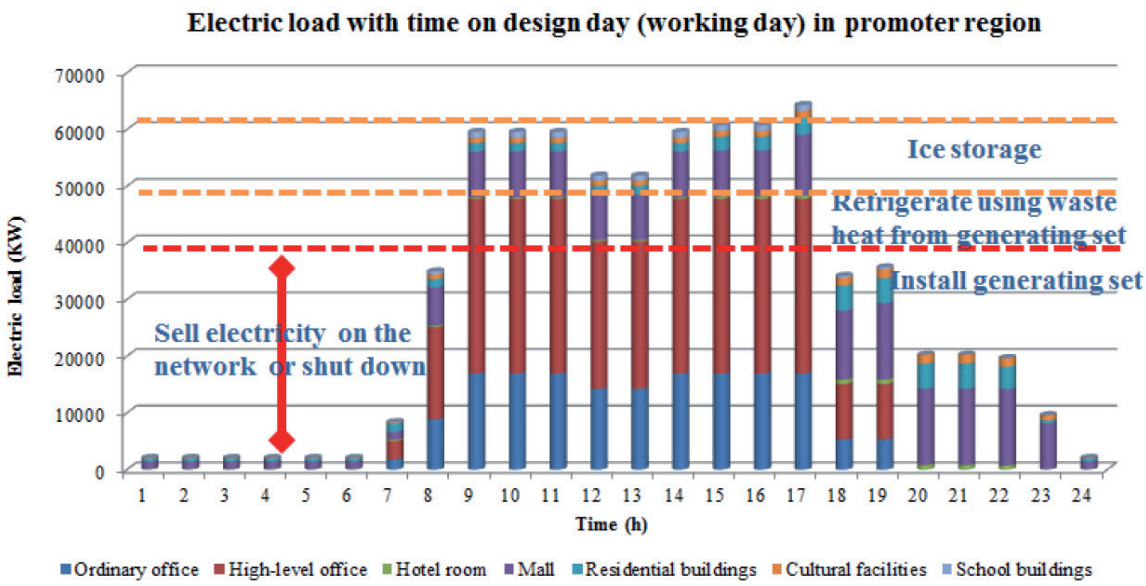

Figure 5. Selected scheme three: installed capacity of each generating set

Selected scheme one: Generator capacity can satisfy the electric demand, without needing to buy electricity on the network (Fig. 3).

In this scheme, installed capacity of generating set is defined by the maximum electric load in this region, and the waste heat is not used for refrigeration. Electivity generated by energy station can meet the demand of electricity in the whole region. In the rest time beyond the peak period, electricity should be sold on the network or shutdown. Since the waste heat is not used for refrigeration, system efficiency of 70% is difficult to achieve as the national development and reform commission requires. So scheme one is not recommended.

Selected scheme two: Waste heat generated by generating set is used for refrigeration. Part of electricity at end can be shared (Fig. 4). In scheme two, generating waste heat refrigeration technique is applied. The electric demand for air conditioning cold source at the end is reduced, and installed capacity of generating set is also reduced. At the same time, the time of generating electricity is effectively extended, and the time of selling electricity or shutdown is reduced. The system efficiency is less than 70% without using waste heat for refrigeration.

Selected scheme three: In addition to generating heat refrigeration technique, ice storage technique is also used in cool rush hour to further reduce electricity demand of the cold source at end (Fig. 5).

Through the ice storage technique, which is refrigeration using low electricity at night and cancellation the cooling load peak during the day, the generator installed capacity can be further compressed, and the time of selling electricity on the network or shutdown is more reduced. However, in the period without refrigeration using waste heat, the system efficiency of 70% is still can’t be obtained.

5. Comparison and determination of schemes

As it is discussed above, selected scheme four is used for the selection of equipment type. According to different types of airborne generator, the following two kinds of schemes are proposed and analyzed in detail respectively.

Power generator systems: gas-steam combined cycle units: one 41.63MW gas turbine and gas engine, five 4.3MW gas engines.

Gas turbine is chosen to share airborne electric supply (lighting inside the region, electricity used by equipment). Then gas engine is chosen to share peak electric supply and refrigerate using flue gas. Gas-steam combined cycle units can supply domestic hot water using waste heat with running mode of 12 h/d.

Cooling supply systems in the region: A series model of the absorption chiller and electric refrigeration units is used with part of ice storage. Electricity generated by heat and power cogeneration system is used during the day, while low net electricity is used at night.

Domestic hot water is heated by using waste heat of boiler flue gas. The hot water is heated to 65 °C via extracting a moderate amount of salt-free water from waste heat boiler. Then the hot water is transported to the end user through the network. The user owns hot water storage facilities.

Gas turbine combined cycle power generation system based on airborne units can supply sufficient electricity to be used during 8:00-20:00 (12 h) on working days. When the quantity of electric load is less than that of the system capacity, the electricity generated by the system needs to be sold on the network. When the quantity of electric load is more than that of the system capacity, the skimpy electricity can be complemented by gas engine + waste heat utilization system or the network. During 20:00-8:00, electricity demand per unit of the buildings in promoter region is reduced, and electricity can be bought directly from the network for application.

Gas engine + waste heat usage system includes gas engine and gas steam absorption refrigeration machine. They can supplement electricity shortage as the gas turbine on working days, and generate power on rest days with refrigeration based on this system.

6. Summary

In this paper, the power (cool, heat, electricity) load characteristics in a promoter region of low carbon industrial park in Shenzhen are predicted and analyzed. Then the generating set configuration is optimized. The comprehensive energy efficiency of the whole energy system has priority over other things. Finally the generating set form of a distributed energy system is determined.

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References

1. Thomas Bruckner, Robbie Morrison and Tobias Wittmann. Public policy modeling of distributed energy technologies: strategies, attri-

butes, and challenges, Energy Conversion and Management, 13 (4), pp.100-107, 2005.

2. Mercourios Papamarcou and Soteris Kalogirou. Financial appraisal of a combined heat and power system for a hotel in cypus, Energy Conversion and Management, 42, pp.689-708, 2001.
3. Claudio Arbib and Fabrizo Rossi. Optimal resource assignment through negotiation in a multi-agent manufacturing system, IIE Transactions/Institute of Industrial Engineers, 32 (10), pp.963-974, 2000.
4. Kari Alanne and Arto Saari, Distributed energy generation and sustainable development, Renewable and Sustainable Energy Reviews, 10, pp.541-542, 2006.
5. Andreas Poullikkas. Implementation of distributed generation technologies in isolated power systems, Electricity Authority of Cyprus, 23 (7), pp.158-160, 2006.