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Case analysis of energy consumption of the existing office building in the severe cold region

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Abstract

With the relevant requirements of energy-saving and green buildings put forward by our country, carrying out the building energy consumption analysis is the premise and foundation of implementing energy-saving improvement of the existing buildings. Nowadays, modern office buildings, whose energy consumption structure and proportion are relatively stable, are widely used. The energy review work of an existing office building in severe cold region is carried out. Investigation and statistics on the general situation of buildings, the general situation of energy consumption and water system consumption and the total energy consumption are implemented. Based on the audit, the energy consumption situation and characteristics in a certain year are analysed. According to the characteristics of energy-using structure, the energy-saving potential of buildings is analysed, and the reasonable energy-saving opinions and suggestions are proposed to provide theoretical support for the energy-saving management of office buildings in severe cold areas.

Keywords: existing office buildings; energy consumption; energy-saving potential; energy utilisation structure

1 Introduction

In the context of global energy conservation and emission reduction, building energy conservation, as the most effective and efficient way to save energy, has developed rapidly in recent years. By reducing energy consumption and improving energy efficiency, various countries have gradually researched different construction forms such as ultra-low-energy consumption, zero energy consumption and prefabricated buildings [1]. Since the 11th Five-Year Plan has listed the energy issue as the key issue concerning whether China will maintain sustainable development. China is a country with a large population and energy consumption, in which the

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building energy consumption is more than 20% of the total energy, and it is going up [2]. The building energy consumption has attracted attention from all sides [3,4]. In 2007, the former Ministry of Construction (now the Ministry of Housing and Urban-Rural Development) issued the Implementation Opinions on Strengthening the Energy Saving Management of Office Buildings and Large Public Buildings of State Organs, which required to gradually establish a nationwide networked monitoring platform for energy consumption of office buildings and large public buildings of state organs to monitor the energy consumption of key cities and buildings in real time [5].

Local construction departments have carried out energy consumption assessment for different types of buildings such as office buildings and public buildings. The assessment contents mainly include comprehensive energy consumption, building thermal insulation, energy consumption of building internal equipment and so on [6,7]. He selects an office building in Jinan area, uses DeST software to simulate its energy consumption, compares it with the reference building to obtain the practical law of reducing energy consumption in office buildings in Jinan and provides energy reduction and energy saving for office buildings in the future reference [8]. Several reference suggestions are proposed through the collection and analysis of data on the operation of the air-conditioning system and transformers in an office building in Changsha as well as the analysis and summarisation of the energy consumption features of the office building [9]. The office buildings and large-scale public buildings of Qingdao as the objects of energy consumption statistics are based on the energy consumption data provided by energy supply companies and the data obtained from the Qingdao energy consumption monitoring platform. It identified 195 buildings, with a total construction area of more than 6.63 million m², as research objects to get the overall energy consumption status of the sample. Then the buildings are divided into different categories according to the function of analysis. Electricity and total energy consumption per unit area are regarded as the main analysis indicators to study each category. Finally, the total energy consumption distribution and energy consumption structure of different types of buildings can be obtained [10]. Large office parks are densely populated, have concentrated energy-consuming equipment and require high office comfort. They are one of the key areas for building energy-saving renovation. By investigating the energy consumption of buildings in a large office park, the factors leading to high energy consumption were discussed from the aspects of design implementation and management use. The energy consumption level of the park was reduced through the transformation of the lighting system and air-conditioning system [11–13]. Based on the annual energy consumption monitoring and analysis report of Shanghai government office buildings and large public buildings as an entry point, Feng analysed the content and function changes of energy consumption analysis reports over the years, introduced the development and application process of energy consumption monitoring platform of government office building and large public building in Shanghai, revealed the present problems and predicted the future development trend by problems [14].

This article takes an office building in Daqing as a research object, evaluates, analyses the main energy consumption according to its energy consumption in a certain year and puts forward reasonable energy-saving suggestions.

2 General situation of architecture

The building is located in Daqing City, which was originally built in 1997. It has 9 floors and the highest office area is 8 floors. The total height of the building is 35.1 m; the total building area is 4368.09 m²; the air-conditioned area covers an area of 542.5 m²; there are 80 permanent residents in the building. The building structure is brick concrete, the external wall material is a solid clay brick and white wall brick, and there are blue glass curtain walls in the middle of the wall and on the east-west wall; the external window is a common transparent glass double-layer steel window without any decoration and shading measures, and the roof is a flat roof.

3 General situation of building energy system

The building energy system includes building power supply and distribution system, air conditioning and ventilation system, heating system, lighting system, indoor equipment system, energy consumption of integrated service system, water supply and drainage system.

3.1 Building power supply and distribution system

The building is powered by Daqing Oilfield Electric Power Group Company and led to the distribution room on the first floor of the building via outdoor cables. There is one power distribution cabinet in the power distribution room, which provides electricity for socket, lighting, boiled water, elevator and so on; they are led out from the low-voltage distribution cabinet. According to the nature and scale of the building, it is required that the electricity consumption for elevators and fire fighting is Class II load, and the rest is Class III load.

3.2 Air-conditioning and ventilation system

There is no fan coil and centralised air-conditioning system in the building but only 10 split air conditioners. Air conditioning is only used when the indoor temperature is high in summer; there are no other auxiliary pumps and fans. The usage details of air conditioner are seen in table 1.

Table 1 Parameters of a separate unit or VRV unit.

Separated unit	
Type	Heat pump type landed air conditioner
Number of units (please indicated if there are standby units)	10
Manufacturer and models	KFR-60L
Refrigerating capacity/kW	6
Heating capacity/kW	6
Motor power/kW	2.95
Power supply/Ph/V/Hz	1/220/50
Every day running time/h	2
Whole year running time/h	140

3.3 Heating system

The heat source of the building heating system is 95/70°C municipal heating hot water, and the heating equipment is mainly made of cast iron radiator; heating system adopts upper supply and lower return type. Heating and thermal inlet is at the back of the building, and the heating pipe network specification is DN65.

3.4 Lighting system

According to the character of the building, 188 thin-tube fluorescent lamps of 32W are used in the office area. Two 80W fluorescent lamps are used in the hall. The corridor uses 32W annular fluorescent lamps; other areas use 36 incandescent lamps of 40W; outdoor lighting adopt high-pressure mercury lamp; when the light is dim, the building lights are turned on and the office lights are controlled by the users themselves; the corridor and stair lights on floors 2–7 are controlled by sound and light, while the rest are controlled by the security guards. One switch controls one to two lamps; the outdoor lighting is generally turned off.

Table 2 Indoor office equipment and household appliances.

Serial number	Equipment name	Number	Rated power/kW	Amounted power/kW	Every day running time/h	Year running time/h	Subordinate to the zone
1	Desktop	75	0.08	1.2	8	2000	Office
2	Printer	75	0.35	26.25	8	2000	Office
3	Duplicator	4	1.8	135	1	250	Office
4	Fax Machine	10	2	8	1	250	Office
5	Laptop	15	0.05	0.5	1	250	Office

3.5 Indoor equipment system

Indoor office equipment includes desktop computers, printers, copiers, fax machines and notebook computers, etc. The specific usage details are seen in Table 2.

3.6 Energy consumption of integrated service system

The building is equipped with a passenger elevator, which can stop by each of the floors, each with a power of 9.5 kW and an annual operation of about 750 h. There are no domestic water pumps, sewage pumps and other equipment inside the building.

3.7 Water supply and drainage system

The water supply of the building is mainly divided into domestic water and firewater, both of which are taken from the municipal pipe network and supplied by the water company. Water from the external network is directly supplied to the building, and the water pressure meets the demand without auxiliary equipment such as pumps; the water pressure of firewater comes from the water pressure of pipe network and adopts the automatic sprinkler system. Because the water pressure meets the requirements, so it would not use the firewater pump; the main water-using equipment are hand washing basin, urinal and fire-fighting water. There are 8 hand-washing sinks with manual drainage, 24 manual flushing urinals, 32-time delay valve flushing urinals and 10 manually controlled mop pools.

4 Energy consumption analysis

4.1 Analysis of total daily energy consumption of building

This building is an office building, mainly for office space, without canteen, and its conventional energy consumptions are mainly electric power consumption and water consumption. The total conventional energy consumption of the building in a certain year is obtained through the energy statistical analysis. Annual electricity consumption is shown in Figure 1, while water consumption is shown in Figure 2.

The electricity load of the building is relatively stable every month, and the electricity consumption from November to January of the following year is relatively large. There may be two reasons through the analysis: First, the 3 months are the lowest temperature months in the whole year, and some of the staff members may choose air conditioners and electric heaters to supplement heating; second, at the end of the year and the beginning of the year, workers working overtime that will lead to a significant increase in office electricity consumption. From June to October, due to the longer sunshine time, the illumination time will become shorter, and the temperature is relatively high; there is no need of additional electric heating supplement, so the electricity consumption is relatively small.

The building staff is stable, and the monthly water consumption is relatively average. In May, due to the

Fig. 1 The building's annual electricity consumption chart.

Fig. 2 The water consumption of the building in a given year.

relatively longer time of holidays, water consumption is the lowest. In August, due to the severe hot weather, domestic water consumption will be increased.

4.2 Proportion of itemised energy consumption

The energy consumption of building electricity sub-items (i.e. air conditioning, ventilation, heating, lighting, indoor equipment and integrated service system, etc.) and their percentage of energy consumption are shown in Figure 3.

Daqing City is located in the severe cold region, and its climate is characterised by cold winter and cool summer, so the heating energy consumption accounts for 69% and air-conditioning energy consumption only accounts for 1% of the total energy consumption the whole year. This is an office building, and the energy consumption of equipment is relatively large, which accounting for 20% of the total annual energy consumption [2]. The energy consumption of comprehensive service system accounts for 2%. Since the working hours are all spent during the day, the energy consumption of lighting equipment is low, which accounting for only 1% of the annual energy consumption; others were not audited energy consumption accounts for 7% of the annual energy consumption.

Fig. 3 Energy consumption component structure scale. *Note:* The National Bureau of Statistics of 0.404 kg of standard coal per kilowatt-hour is used as the coefficient of power conversion.

5 Energy-saving potential analysis and suggestions

Combined with the structural characteristics, using functions and energy consumption sub-proportion, carry out the energy saving potential analysis and put forward suggestions for the heating energy consumption and indoor equipment system energy consumption.

(1) This article conducts a long-term survey on seven office buildings using the multi-split air-conditioning systems in different climatic regions of China. It finds that the energy consumption of multi-split air-conditioning system in heating season of cold zone accounts for about 60% of the total annual energy consumption and about 50% and 29%–40% for those in cooling and heating season of hot summer and cold winter zones, respectively. The energy intensity is closely related to the occupancy rate and outdoor temperature. Combined with the available literatures, 19 office buildings using the multi-split air-conditioning systems have been analysed. The results show that the energy consumption intensity ranges from 20 to 50 kW·h/(m²·a), equivalent to 6.5–16.4 kg/(m²·a) of standard coal. For the buildings with an area over 20000 m², relative to other types of central air-conditioning systems, the multi-split air-conditioning system shows the advantage of energy efficiency [2, 15].

(2) According to the breakdown ratio of energy consumption, due to the building is an early building and is not designed according to the requirements of energy-saving buildings, the heating energy consumption is relatively large. Therefore, it could carry out the energy-saving renovation of enclosure structure and add the thermal insulation layer to exterior wall and roof; the external window can be changed into double-glass plastic-steel window, which is to reduce the cold and hot air penetrating into the building through the external window and to reduce the building energy consumption; the external doors shall be insulated, and the doors shall be closed instantly when entering or leaving buildings so as to reduce the intrusion of cold and hot air. At the same time, it is suggested to do well about the job for pipeline leakage prevention and pipeline insulation to prevent the phenomenon of running, emerging, dripping and leakage or the rupture of pipeline insulation layer; and do the well job of heat metering at the hot port of the building heating network. If conditions permit, it is recommended to set the temperature control valve in each room so as to keep the minimum heating capacity when no person is working at night and to reduce the heat loss when no one is in the room.

(3) The lighting fixtures in this building mainly use incandescent and fluorescent incandescent lamps. It is suggested to install the energy-efficiency lights (the illuminance of 13W energy-efficiency lights is the same as that of 40W thin-tube fluorescent lamps) and as far as possible use sound control switches in the corridors, and the lamps should be turned off automatically when no person is in corridors. At the same time, as far as possible,

it should use the natural light.

(4) For indoor equipment, it is recommended to shut the operation down or switch it to standby mode during the lunch break time and when there is no work. Make sure that all power should be cut off after work. At the same time, the water dispenser and computer can be set as a timing switch; the water heater can be turned only on when it is used, which can reduce unnecessary waste.

(5) On the premise of not reducing the normal water demand of the staff in the building, it is suggested that the staff should improve the water-saving consciousness, turn off the tap in time after using water and put an end to the phenomenon of long-term water flow if the economic conditions permit, the faucet should be changed to the induction type.

6 Concluding remarks

(1) The building is located in the severe cold area, and its energy consumption is determined by analysis as heating energy consumption, which accounts for nearly 70%; therefore, improving the enclosure structure, reducing the heat load of the building and improving the operation and management level of the heating system are main means to save energy and reduce the consumption.

(2) Due to the main function of the building is for office use, its working hours are relatively fixed, and the energy consumption of the office equipment is relatively large, so promoting the energy-saving office is also one of the measures to reduce the building energy consumption.

(3) For office buildings in severe cold areas, due to the adoption of the additional electric heating equipment such as air conditioners, the peak power consumption appears in the coldest month, and the electric power consumption in other months is relatively unstable.

Through the analysis of building energy-saving potential, this article puts forward reasonable energy-saving opinions and suggestions to provide theoretical support for the energy-saving management of office buildings in severe cold areas.

References

- [1] Zheng Xu. The analysis of energy efficiency in chinese and foreign buildings. *Sichuan Building Materials*, 2020, 46(9), pp.18-19+36.
- [2] Wang Z, Zhu Y, Wang F, et al. Proceedings of the 11th International Symposium on Heating, Ventilation and Air Conditioning (ISHVAC 2019) Volume III: Buildings and Energy: Volume III: Buildings and Energy[J]. 2020.
- [3] Han guang, Ma liangdong, Chen Yongpan. Statistical analysis of energy consumption of typical office buildings in Dalian. *Refrigeration. Air conditioning and electric machinery*, 2009(4), pp.77-80+84.
- [4] Chen Shuqin, Li Nianping, Fu Xiangzhao, etc al. Study on statistical methods of residential building energy consumption. *HVAC*, 2007(3), pp.44-48+95.
- [5] Code for Construction, Acceptance and Operation Management of Energy Consumption Monitoring System for Office Buildings and Large Public Buildings of State Organs. 2008.
- [6] Liang Zhen, Zhao Jianing, Guo Jun. Investigation of energy consumption and analysis of energy saving potential of high-rise office buildings. *Energy Saving Technology*, 2001, 19(1), pp.19-22.
- [7] Li Xiaoqing, Liu Xiaoyan, Ma Chuan. Energy Audit and Case Analysis of a Large Public Building. *Low Temperature Building Technology*, 2014, 36(1), pp.131-133.
- [8] He Song, Chen Si, etc al. Research on energy consumption simulation and energy saving of an office building in Jinan area. *District Heating*, 2020, 000(002), pp.127-131.
- [9] Liang Zhichao. Analysis on Energy Consumption Data of an Office Building. *Building Electricity*, 2020, v.39;No.270(05), pp.82-85.
- [10] Xie Zexi, Ruan Yingjun, etc al. Study on energy consumption of public building in Qingdao based on statistical data. *Architecture Technology*, 2020, 51(6), pp.662-665.
- [11] Qiu Zheng, Ni Wenhui. Statistical Analysis of Energy Consumption of Public Buildings in Wuxi City. *Building Energy Efficiency*, 2020, 48(6), pp.84-88.
- [12] Zhou Hao, Tian Xin, etc al. Discussion on Application and Service Plans of Energy Consumption Data of Public

- Buildings in Beijing. *Construction Science and Technology*, 2020, 413(16), pp.22-31.
- [13] Wang Zhaoqi, Guo Huijie, Analysis of building energy consumption and discussion on energy-saving reform in an office park. *Architecture Technology*, 2020, 51(6), pp.670-672.
- [14] Feng Jun, Xu Wenxian, Analysis of Development and Future of Building Energy Consumption Monitoring Platform in Shanghai. *Construction Science and Technology*, 2020, 413(16), pp.36-38.
- [15] Zhang Guohui, Liu Wanlong. Energy consumption of multi split air conditioning system for office buildings in China. *HVAC*, 2018, 048(008), pp.17-21+34.