Analysis of energy load characteristics of five typical users

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Abstract. Based on the investigation and analysis of typical users in Beijing and Guangzhou, a comparative analysis of the load characteristics of different types of users is carried out, and the basic characteristics of the load characteristics of various types of users are summarized. In the calculation example, the hourly load of the typical buildings in Beijing and Guangzhou is simulated and analyzed for the whole year. The load stability of the hotel and hospital buildings is poor and the continuity is strong. The load stability of shopping malls, residential and office buildings Stronger and weaker in persistence; the imbalance rate of the cumulative cooling and heating load in the summer hot winter and warm winter area and the cumulative cooling and heating load in the air conditioning season is higher, while the unbalance rate in the cold area is lower.

1. Introduction

In recent years, with the continuous development of China's economy and society, as well as the continuous improvement of the living standards of urban and rural residents, China's energy demand continues to grow. Due to the lack of accurate basic data, the load characteristic indexes in distribution network planning in many areas of China mainly rely on empirical estimation, and the accuracy of load forecasting results is usually not high. This also affects the planning and construction of energy network. Mastering the load characteristics and changing rules of power consumption load and cooling and heating load can increase the accuracy of load forecasting, effectively improve the effective utilization rate of energy supply equipment, plan the construction of energy grid more reasonably, and control the investment cost of energy system.

The load of energy supply system has the characteristics of continuity and periodicity, so it is necessary to fully understand the load characteristics of different levels and deeply study the load characteristics of different users. Based on the statistics of economy, energy consumption load and energy supply status, this paper studies the load characteristics of different types of typical users, compares and analyzes the load characteristics of different types of users, and clarifies the energy consumption characteristics of different types of typical users. On this basis, further studies the load calculation method, discusses the impact of load characteristics on energy network planning, and makes a scientific comprehensive plan It provides scheme and basis for the coordinated development of energy, and provides reference for the formulation of typical power supply scheme for users.
2. Typical user load characteristic analysis method

2.1. Classification Criteria for Typical Users

The division of typical user types is the basis of typical user load characteristics analysis. This article refers to the load classification method in the "Urban Power Planning Code" (GB50293-1999), and divides typical users into three categories: industrial users, public facilities users, and residential users. Among them, public facilities users are divided into hospitals, office and commercial, financial, and service categories; resident users have many points and wide areas, and the load data is scattered, and the load data of individual resident users is currently not available, so this article of residential users refer to residential areas or residential functional areas. Following the above classification method, Beijing and Guangzhou were selected as the key research objects for the following reasons. There are three reasons:

- Beijing and Guangzhou are economically developed. In the ranking of China's urban GDP in 2019, Beijing and Guangzhou rank in the top five, reaching 15.2125 and 11.755 billion yuan respectively. Therefore, the load characteristic index of the second place can reflect the highest level in the country and the future development trend.
- The variety of loads in Beijing and Guangzhou is rich, which is conducive to ensuring the wide range of research objects. The survey found that the tertiary industry in Beijing and Guangzhou is well-developed, with a complete range of industries including commercial finance, cultural entertainment, education and scientific research, catering services, and medical and health services. Guangzhou has a good industrial foundation, a wide range of industrial users, and is very representative.
- Energy management companies in Beijing and Guangzhou have high management level, and it is relatively easy to obtain continuous and real load characteristic data, which is conducive to improving the reliability and scientificity of the analysis conclusions.

2.2. Typical User Load Characteristic Analysis Index System

A scientific and standardized load characteristic index system is the basis of load characteristic research. The load characteristic index system can be generally divided into three categories: description, comparison and curve. Among them, the description class is only used to describe the load level status of each region, which is an absolute physical quantity index; the comparative class index is mainly used for regional and international comparison, and is a relative physical quantity index; the curve type index includes various load curves, is Intuitive reflection of load characteristics. Generally, the index method is used to quantitatively analyzing the average value and distribution range of the corresponding indicators of various typical users. The curve method is used to simultaneously analyzing the changes and characteristics of the annual and typical daily load curves of different users. The typical user load characteristic analysis index system includes several types of indicators:

2.2.1. Load characteristic index

The load characteristic index is an important basis for carrying out load analysis, summarizing the load change law and its characteristics, and mainly includes the following data.

(1) The average daily load rate $\gamma$ is calculated as follows:

$$\gamma = \frac{\sum_{i=1}^{N} \gamma_i}{N} \tag{1}$$

In the formula, $\gamma_i$ is the average daily load rate of the i user; N is the number of users.

(2) The average daily minimum load rate $\beta$, its calculation formula is as follows:

$$\beta = \frac{\sum_{i=1}^{N} \beta_i}{N} \tag{2}$$
In the formula, $\beta_i$ is the daily minimum load rate of the $i$ user.

(3) Seasonal unbalance coefficient $\rho$, its calculation formula is as follows:

$$\rho = \sum_{i=1}^{N} \frac{\rho_i}{N}$$  \hspace{1cm} (3)

In the formula, $\rho_i$ is the seasonal unbalance coefficient of the $i$ user.

(4) The average daily peak-valley difference $\varepsilon$, the calculation formula is as follows:

$$\varepsilon = \sum_{i=1}^{N} \frac{\varepsilon_i}{N}$$  \hspace{1cm} (4)

In the formula, $\varepsilon_i$ is the average daily peak-to-valley difference of the $i$ user.

2.2.2. Load characteristic curve

The load curve includes the annual maximum load curve, the annual continuous load curve and the daily load curve. The annual maximum load curve can reflect the change of the load throughout the year. The maximum load of each month is connected to form a curve, and its fluctuation degree will not be affected by individual loads. The continuous load curve reflects the proportion of the load level in the whole year, which is usually integrated using the arithmetic average method. The daily load will have a greater impact on the load curve due to the fluctuation of individual loads, and the weighted average method is usually used for integration. The calculation formula of each load curve is as follows:

(1) Calculation formula of annual load curve:

$$L_k = \sum_{i=1}^{N} L_{ik} \frac{k}{N}$$  \hspace{1cm} (5)

In the formula, $L_k$ is the load of the month after the integration, $k_1=1,2,\ldots,12$, and $L_{ik}$ is the load of the $i$ user in the month.

(2) Calculation formula of continuous load curve:

$$L_k = \sum_{i=1}^{N} L_{ik} \frac{k}{N}$$  \hspace{1cm} (6)

Where $L_k$ is the load at the hour $k_2$ after integration, $k_2=1,2,\ldots,8760$; and $L_{ik}$ is the load at the $i$ user at the hour $k_2$.

(3) Calculation formula of daily load curve:

$$L_k = \sum_{i=1}^{N} L_{ik} \frac{k}{N}$$  \hspace{1cm} (7)

Where $L_k$ is the load at the first moment after integration, $k_3=1,2,\ldots,24$; $L_{ik}$ is the load at the $i$ user at the $k_3$ moment.

2.2.3. Load density

The load density is used to characterize the intensity of the load distribution. The clustering method is usually used for analysis. The steps are as follows:

First, select the maximum load for several years according to the land type, and calculate the typical load density of the land type. The calculation formula is as follows:
\[
\sigma = \frac{L_{\text{max}}}{S_{\text{max}}} 
\]  

(8)

In the formula, \( L_{\text{max}} \) is the annual maximum load; \( S_{\text{max}} \) is the land area.

Then draw each sample into a scatterplot, find out the distribution of the data set, and remove the data with excessive differences. Then use clustering method to perform cluster analysis on the load density samples of different regions, and determine the grade range of each region from the classification results.

3. Case study

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3.1. Hourly load simulation results of buildings in typical industries throughout the year

Carry out the hourly load simulation of the five typical buildings in Beijing and Guangzhou in the whole year. In view of the different areas of the five typical buildings, the annual load peak indicators and the annual cumulative load indicators of the five typical buildings are shown in Table 1:

| Architecture Climate zone type | Region     | Cooling load peak index (w/ m²) | Heating load peak index (w/ m²) | Cumulative cooling load index (KW H/ m²) | Cumulative heating load index (KW H/ m²) |
|-------------------------------|------------|---------------------------------|--------------------------------|------------------------------------------|------------------------------------------|
| Hotel                         | Beijing    | 189.37                          | 167.34                         | 72.15                                    | 138.66                                    |
|                               | Guangzhou  | 202.74                          | 43.73                          | 297.65                                   | 7.77                                     |
| Market                        | Beijing    | 202.64                          | 145.32                         | 99.83                                    | 54.63                                    |
|                               | Guangzhou  | 254.38                          | 20.65                          | 439.22                                   | 0.40                                     |
| Office                        | Beijing    | 137.46                          | 84.67                          | 71.95                                    | 46.03                                    |
|                               | Guangzhou  | 139.87                          | 16.43                          | 236.53                                   | 1.13                                     |
| Residence                     | Beijing    | 71.28                           | 43.14                          | 56.28                                    | 18.23                                    |
|                               | Guangzhou  | 69.40                           | 3.95                           | 117.53                                   | 0.18                                     |
| Hospital                      | Beijing    | 125.88                          | 79.05                          | 69.91                                    | 95.22                                    |
|                               | Guangzhou  | 127.98                          | 21.90                          | 228.31                                   | 3.11                                     |

The length of the cooling and heating days of the building air-conditioning system and the determination of specific dates have a great influence on the peak and cold load of the building air-conditioning season and the cumulative amount of cold and heat loads. According to the outdoor dry bulb temperature, this paper formulates a typical climate zone representing the cooling and heating season of the city. The specific regulations are as follows:

- The start and end dates with an average daily temperature higher than 25°C are specified as the cooling season;
- The start and end dates with an average daily temperature of less than 5°C are specified as the heating season;
- The rest of the time is the transition season.

According to the above regulations, the specific time for the cooling season and heating season in Beijing and Guangzhou is shown in Table 2. It can be seen from Table 2 that there are differences in
the number of cooling days and heating days in Beijing and Guangzhou; there is only a cooling season in Guangzhou and no heating season in winter. In view of this, the buried tube ground source heat pump has no application in hot summer and warm winter regions (Guangzhou), so this article will not discuss the load characteristics of five typical buildings in hot summer and warm winter regions and mild regions. According to the division of cooling season and heating season of representative cities, the distribution of cooling load and heating load of five typical buildings in Beijing and Guangzhou can be obtained. The peak load indicators and cumulative load indicators for the five types of typical buildings in Beijing and Guangzhou are shown in Table 3.

### Table 2. Typical building air-conditioning season load simulation results.

| Representative city | Cooling season       | Heating season       |
|---------------------|----------------------|----------------------|
| Beijing             | June 12th to September 2nd | November 12th to March 14th |
| Guangzhou           | May 6th to October 10nd  | -                     |

### Table 3. Typical building air-conditioning season load simulation results.

| Architecture Climate zone type | Region  | Cooling load peak index (w/m²) | Heating load peak index (w/m²) | Cumulative cooling load index (KW H/ m²) | Cumulative heating load index (KW H/ m²) |
|--------------------------------|---------|--------------------------------|--------------------------------|------------------------------------------|------------------------------------------|
| Hotel                          | Beijing | 189.37                         | 167.34                         | 58.76                                    | 107.73                                   |
|                                 | Guangzhou | 202.74                         | -                              | 187.50                                   | -                                       |
| Market                         | Beijing | 202.64                         | 145.32                         | 116.66                                   | 71.09                                    |
|                                 | Guangzhou | 195.97                         | -                              | 343.21                                   | -                                       |
| Office                         | Beijing | 137.46                         | 84.67                          | 35.39                                    | 27.44                                    |
|                                 | Guangzhou | 139.73                         | -                              | 97.41                                    | -                                       |
| Residence                      | Beijing | 71.28                          | 43.14                          | 21.63                                    | 11.58                                    |
|                                 | Guangzhou | 60.85                          | -                              | 46.09                                    | -                                       |
| Hospital                       | Beijing | 125.88                         | 79.05                          | 33.89                                    | 44.35                                    |
|                                 | Guangzhou | 127.98                         | -                              | 103.75                                   | -                                       |

#### 3.2. Results analysis

In terms of the influence of building types on load characteristics, the room functions of hotels and hospitals are more diverse, their loads are larger during the day and smaller at night, and their sustainability is stronger; the room functions of shopping malls and office buildings are relatively single, and their loads are mainly concentrated in the daytime and almost zero at night. It is less persistent and intermittent throughout the day. The load of residential buildings is affected by people's daily life. The load is generally small during the day and large at night, and the continuity is weak. It can be seen from the distribution of the five types of typical buildings in the annual peak load index and season air-conditioning peak load index of five representative cities. Overall, the change trend of the building's peak load index is shopping mall> hotel> hospital> office> residential.

In the influence of climate area on load characteristics, due to the influence of meteorological parameters in the climate area, there are four distinct seasons in the cold area (Beijing). In this area, the cooling load is too large or the heating load is too large. On the whole, the imbalance rate of the accumulated cooling and heating load in the whole year and the accumulated cooling and heating load in the air conditioning season is relatively low. In the hot summer and warm winter area (Wuhan), the cooling time in summer is long, and there is no heating in winter. The cooling load in this area is relatively large. On the whole, the annual accumulated cooling and heating load of buildings and the accumulated cooling and heating load imbalance rate in air conditioning season are relatively high.
4. Conclusions
This paper summarizes the basic characteristics of various types of user load characteristics, and simulates the annual dynamic hourly load of five representative buildings in five representative cities in the calculation example. The following conclusions can be drawn:

- Hotel and hospital buildings, the room functions are more diverse, the load is larger during the day, the night is smaller, and the continuity is stronger; the room functions of shopping malls and office buildings are relatively single, and the load is mainly concentrated in the daytime. Intermittent within a day. The load of residential buildings is affected by people's daily life. The load is generally small during the day and large at night, and the continuity is weak.
- Through the analysis of the annual peak load of the five types of buildings and the seasonal peak load of the air conditioning, the peak load change trend of the building is mall> hotel> hospital> office> residential.
- Through the analysis of the imbalance rate of the cumulative cooling and heating load of the five types of buildings and the cumulative cooling and heating load of the air-conditioning season, the thermal load of the five typical buildings in severe cold areas (Harbin) is too large. The cumulative cooling and heating load imbalance rate in the air-conditioning season is high; the cooling load of the five typical buildings in the hot summer and cold winter area (Wuhan) is relatively large. The annual cumulative cooling and heating load of the five typical buildings in the region (Beijing) and the unbalance rate of the cumulative cooling and heating load of the air conditioning season are relatively low.

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