Cooling load analysis in Hubei with Global Warming

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Abstract: Meteorological factors such as temperature play a key role in electric power load during summer. Variation in climate pattern and micro-climate of metropolitan changes temperature distribution over season and day and night, and affect electric power load as a consequence. Since power load are affect by enhanced temperature induced by both climate change and heat island of city, in order to find out the contribution of these two coexist factors, variation of temperature and cooling load of a small city B with 50 kilometer people and metropolitan A with 8 million people are investigated in the paper. The observed temperatures from 1982 are analyzed. the cooling day, cooling degree day, heat wave with temperature over 33℃, and hot days in day and all night are investigated to compare contribution of variation of climate patter and micro-climate of cities.

1. Introduction
The meteorological condition is an important factor affecting the power supply load during summer high temperature. In hot summer, the peak load caused by residents and commercial refrigeration load will have obvious influence on the safety operation of power grid and power transmission equipment, which is the focus of urban power grid planning and construction and dispatching operation.

Since the new century, the living standard and housing condition of the urban and rural residents have been improved obviously, and the air conditioning load in summer high temperature period is increasing rapidly. A is an important industrial base in China, the traditional power supply load is mainly industrial users. Influenced by the concentration of urbanized population, the proportion of electricity consumption in A power grid has increased obviously in recent years. Since 2010, A in the summer more than 35℃ of continuous hot weather, high temperature period residents air conditioning refrigeration load soaring. Since 2016, when the first electricity load of A power grid was over 10 million kw, the peak load in summer has hit new highs, while the air conditioning refrigeration load has accounted for 38% of the total load. The medium-term load forecasting is an important basis for the arrangement and operation of power grid operation, while the peak load of air conditioning refrigeration with short load in summer brings great challenge to power load forecasting.

Ambient temperature is the key factor to determine the cooling load of air-conditioning in summer. In the long time scale, the environmental temperature is mainly affected by the change of climate and the microclimate conditions caused by the urban development. Domestic and foreign studies show that the average temperature of the world is rising. According to statistics, the annual average temperature of our country has risen about 0.209℃\(^{11}\)in the past 40 years. In contrast, the performance of microclimate conditions such as urban heat island effect is more obvious, and it is generally believed that heat island effect can cause 0.5℃~1.5℃ temperature rise in urban areas.

In order to understand the long-term change of climate model and the influence of the change of urban microclimate conditions caused by the heat island on air conditioning load, to deepen the...
understanding of the meteorological elements directly affecting the electric load during the summer high temperature period, this paper chooses the B of A and the urban population less than 50,000 to carry on the comparative study, combined with the interannual variation of the monthly maximum temperature, the refrigeration day, The change trend of refrigeration and the high temperature monthly distribution and diurnal temperature difference are discussed, and the contribution of climate change and microclimate condition of urban heat island to the influence of the change climate model under the long time scale is studied.

2. Cooling Energy Consumption index

According to the building energy consumption design code, the number of days in the refrigeration period should be higher than or equal to the refrigeration critical temperature of 28℃ The total number of days determined [4]. In the absence of high-density reliable meteorological observation data, the length of the refrigeration period can be used as a rough measure of refrigeration energy consumption, the longer the refrigeration period, the more energy consumption, otherwise [2,3].

The actual refrigeration energy consumption intensity is related to the ambient temperature, the refrigeration energy demand is much higher than the general high temperature condition, and the refrigeration days can only reflect the duration of the high temperature period and cannot accurately characterize the intensity of the energy consumption of refrigeration under the continuous high temperature of 35℃. In order to make up for refrigeration day cannot effectively reflect the refrigeration energy intensity of the defects, but also to reflect the heat wave high temperature on the refrigeration effect of refrigeration live. Refrigeration is the sum of the daily average temperature of the time period greater than the given critical temperature, which is often used to reflect the energy demand[4].

The daily temperature of refrigeration is more than that of the given critical temperature, and can be calculated according to the (1) formula. If the daily temperature is below the critical temperature, take Rd is 0, the day of refrigeration is zero, conversely take rd for 1.

\[ CDD = \sum_{i=1}^{n} r_d(T_i - T_0) \]  

When calculating refrigeration, 28℃ is generally selected as the critical temperature. Refrigeration is a description of the temperature of the summer six months, can also be used to quantify the demand for refrigeration, refrigeration, the greater the number of days, the corresponding refrigeration period longer, the higher the temperature, the corresponding refrigeration energy intensity greater. According to the analysis of historical temperature and electricity data, there is a strong correlation between refrigeration living and power supply load, and the refrigeration living can effectively characterize the energy growth and decline of refrigeration in summer [6-8].

3. Trend analysis of temperature variation in long time scale

The change of the climate model itself and the change of the microclimate conditions may cause the variation of the urban climate model. This section selects A and adjacent B from 1982 to 2014 to analyze hourly meteorological observations and extract the maximum daily temperature, minimum temperature and average temperature.

B and A are the same place in Jianghan Plain, the two spacing is only 160 kilometers, and the latitude is similar, both in the temperature of the common change of the law as a result of the impact of climate change [5]. A and B in the urban development level and the number of people in contrast, the former urban resident population of more than 10 million, completed area of 552km2, while the latter Shang total population of only 40,000 people, can basically eliminate urban microclimate effect caused by the city. Therefore, the variation of the climate pattern between the two can be regarded as the result of microclimate conditions such as urban heat island effect.
According to the average temperature of each day in A and B, the temperature growth trend is drawn as Figure 1. From the figure visible, because of the distance between two sites, A and B of the year’s average temperature of 17.17℃ and 17.02℃, small difference. Both the temperature of A and B are increasing, but there are obvious differences in the growth rate. The least squares linear fitting of annual temperature growth trend shows that A grew 0.306 ℃ per 10, while B grew 0.233℃ per 10, significantly lower than the former [6]. This difference is particularly evident in the difference between the average annual temperature of two sites, where the average annual temperature of the two places is not far or even nearly identical in most years, and the average annual temperature difference between the two places has widened markedly over the past 2004 years.

The average annual temperature change is only the overall response to the trend of temperature.
growth, and the temperature changes during the summer high temperature will have a direct effect on the refrigeration load. With 1980-1990, 1991-2000 and 2001-2014 as the boundary, statistics of three hours per month of the highest monthly temperature, A and B monthly average maximum temperature receipts, such as Fig 2 and 3. It is shown that there are significant differences in the growth regularity of the average monthly maximum temperature in A and B:

- The average maximum temperature warming in B was mainly in March, while A from March to Nov. had obvious warming;
- In the 80’s climate model, the June monthly maximum temperature is 28.6 ℃, the refrigeration load is relatively limited; After entering the new century, the average maximum temperature in June reached 30.3 ℃, and the probability of peak cooling load increased significantly under the condition of the temperature.
- Compared with B, A has a significant temperature increase during the summer from June to September during the cooling load concentration, which may be caused by the microclimate conditions of urban heat island.

4. Trend analysis of refrigeration energy consumption demand change

According to the outdoor 28 ℃ threshold to calculate the number of refrigeration days and refrigeration in the past years in A and B, the growth trend can be drawn as shown in Figures 4 and 5, as well as the growth rate of refrigeration days and refrigeration in the two places as shown in table 1.
Table 1  Incremental of cooling day & cool degree day

|                         | A       | B       |
|-------------------------|---------|---------|
| Increase speed of cool date(d/10a) | 7.803   | 4.470   |
| Increase speed of cool degree date (d·℃/10a) | 25.877  | 14.161  |

It can be observed that:

- The average refrigeration day in A is 105.2d, while refrigeration is 337.6℃D, and the average refrigeration day and refrigeration days in B are 98.5d and 311.7℃D respectively, which are slightly lower than that in A.

- In the early days, the refrigeration days of A and B were not far off. Starting from around 2005, A Refrigeration day and refrigeration began to start with B distance. After the new century began to get popular application of air-conditioning, it may begin to aggravate the large urban heat island microclimate conditions, which quickly opened up large cities and small towns refrigeration load demand difference.

- Affected by the urban heat island microclimate conditions, A in 2005 years after the refrigeration day and the refrigeration daily rise rapidly, every 10 years refrigeration day growth of 7.803 days, and refrigeration daily growth every 10 25.877d ℃, almost is the B corresponding growth of twice times.

Besides the annual refrigeration intensity, the temperature difference between 30 ℃ and 30 ℃ at high temperature has certain influence on the power grid load. The statistical chronology of the monthly average of 30 ℃ days and the corresponding diurnal temperature difference, it is drawn as Figure 6 to 8.

Fig. 6 The Interdecadal monthly distribution of high temperature days in A Super 30 ℃
Fig. 7 Interdecadal Monthly distribution of the high temperature day of the B super 30 ℃

Figure 8. Average annual temperature difference of 30 ℃ high Temperature Day

It can be seen:

- In the hottest August, A and B exceed 30 ℃ days not only see growth but a slight decline.
- Both A and B in July, the number of high temperature of 30 ℃ increased significantly, so the power grid has entered the peak of the summer state, over 30 ℃ high temperature increase in the impact of the power grid is not outstanding.
- Traditionally, the weather was pleasant in June and the refrigeration load was less activated. So the power grid is still arranging spring inspection. has not been closed to the net summer, at this time the Super 30 ℃ high temperature day increases greatly, may have the adverse effect to the power grid operation.
- There are many obvious peaks and valleys in the daily curve of power load in production. Fig. 8, the temperature difference between A and B at high temperature is reduced. If the night is still high temperature weather, air-conditioning refrigeration load will always remain high, to the residential area transformer operation caused adverse effects.

In addition to the above analysis, due to the hot and high temperatures above 35 ℃, the power grid may enter the peak load period, will be to power grid power supply and transmission equipment challenges [7-9]. The statistics of the Super 35℃ in the two places are plotted in Fig. 9. From the figure, the number of hot days in B is basically unchanged. The number of hot and hot days in A is obviously higher than that of B, 2005 years after the hot and high temperature days more than 30 days, and every 10 years the hot and high temperature increased 4.1 days, showing a rapid growth trend.
5. Conclusion

According to the historical temperature data of A and B, this paper analyses the indexes and their changing trends of refrigeration day, refrigeration daily, ultra high temperature and diurnal temperature difference, and draws the following conclusions:

- In the long run, the average annual temperature, refrigeration day and refrigeration in A and B have increased markedly compared to the 80s. Under the dual influence of climate change and urban heat island, the growth rate of A is faster than that of the weak heat island effect.

- Under the background of general temperature increase in different months, the influence of temperature in A 5 Jun on power grid operation is more prominent, and the number of above 30℃ is obviously increasing. Due to the 5 June grid is still in spring inspection period, such as high temperature caused by peak load, will likely cause some regional power rationing.

- July, Aug into the network closure of the network to meet the peak of the summer, the continuous occurrence of 35℃ of hot weather or day and night temperature reduction, will be the power grid load, the power grid security of the summer has adverse effects.

- Super 35℃ hot weather, the power grid air-conditioning load close to full, and the temperature difference between day and night will further uplift the night load level, the power grid and transmission equipment safety has a prominent impact. From the comparison between A and B, the effect of urban heat island effect on the two kinds of power grid operation is more obvious than that of climate change.

It should be pointed out that, in addition to the climate model changes, residents in the summer, the use of air-conditioning and fan refrigeration mode of change in summer electricity load and power grid safe and reliable operation of the impact more prominent. In the follow-up work, the paper will combine the summer load data of different types of community to study the change and evolution of the temperature and the usage of night air conditioner, and further deepen the understanding of the law of electricity consumption in summer.

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