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Research on Airflow distribution in Internet Data Center

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Abstract—With the rapid growth of IDC (Internet Data Center) construction, the energy consumption is also increasing gradually. It is extremely important to design a reasonable air distribution to reduce the energy consumption of IDC. The research object is an IDC Plant in Beijing. Airpak software is used to conduct DeST (Building energy consumption analysis software) simulation of the air flow organization in IDC room. Under the same cooling load conditions, through the simulation of the three types of diffuse air supply, closed cold aisle and closed hot aisle in the IDC room, it is concluded that the air flow organization after the closed cold and hot aisle is excellent. The energy consumption analysis of the enclosure structure of the three air flow organizations of IDC room shows that the energy consumption of the closed cold aisle is lower than that of the closed hot aisle air-conditioning system.

1 Introduction

With the rise of Internet of Things, cloud computing, mobile Internet and other businesses, the construction of IDC has shown a trend of rapid growth in recent years[1]. At the same time, the proportion of energy consumption in IDC has increased significantly. The contradiction between the rapid development in the age of big data and the environment and energy situation is becoming increasingly serious, so the voice of green energy saving IDC is getting higher and higher.

Air conditioning energy consumption in IDC generally accounts for 20% - 45% of that in IDC, and even up to 60% in some old plants. Therefore, energy conservation in the air conditioning system is crucial to reducing the overall energy consumption of IDC plants. For the air conditioning system of the IDC, it is necessary to have enough refrigeration capacity under the condition of energy saving as much as possible. Therefore, it is necessary to design a reasonable air flow organization of the air conditioning system to ensure the energy saving effect[2].

2 Three different air distributions

At present, the air distribution form of air supply under the static pressure box under the static floor and air return above is widely used in IDC air conditioning system. The air supply mode of the air conditioning system in the IDC room can be divided into indoor diffuse air supply, closed cold aisle air supply and closed hot aisle air supply.

2.1 Diffuse air supply system

The principle of diffuse air supply system is to cool the server cabinet according to the thermal circulation of cold and hot air, as shown in Figure 1. The air conditioner supplies cold air from below and returns hot air from above. In the actual project, the front cold air and rear hot air of the cabinet are used to move the heat of the server in the cabinet to the heat aisle, and then return to the air conditioner through the ceiling air return grille. As the cold and hot aisle are not closed, there is no effective isolation of cold and hot airflow. Therefore, the cold supply air cannot cool the server cabinet effectively.

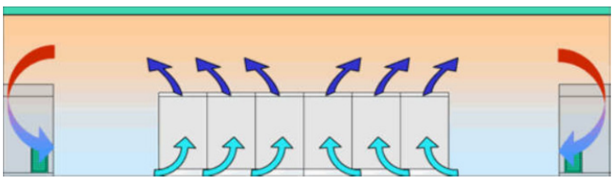

Figure 1. Diffuse air supply mode

2.2 Closed cold aisle air supply

The closed system of cold aisle is to evenly send cold air between the server cabinets. According to the layout of the cabinet, air supply outlets are set relevantly. The cold air is blown out of the raised floor and enters the closed cold aisle. The servers in the cabinet be cooled as inhale cold air. After cooling the servers, the hot air is exhausted from the back of the cabinet to achieve uniform air conditioning effect in the server room, as shown in Figure 2. After the cold aisle is closed, the cold

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and hot airflow is divided and the cold energy and energy consumption loss are all reduced[3].

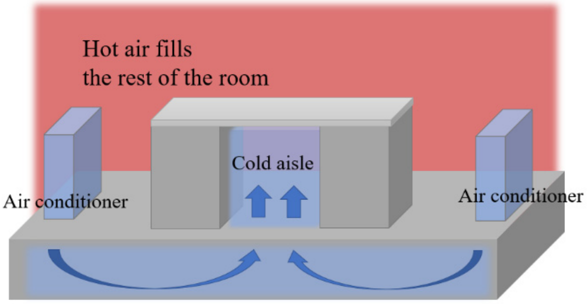

Figure 2. Simulation Diagram of Closed Cold Aisle

2.3 Closed hot aisle air supply

The closed hot aisle system is similar to the closed cold aisle system in that the server cabinets hot air outlet is connected to the air duct and directly return to the air conditioner, as shown in Figure 3.

Since the cold air flow from the air conditioner enters a relatively larger area, when the hot aisle is closed, the cold and hot airflow is divided, so the cold energy and energy consumption loss are all reduced.

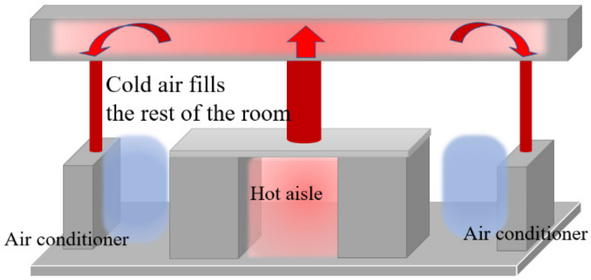

Figure 3. Simulation Diagram of Closed Hot Aisle

3 Comparison of energy consumption before and after cold aisle closure

This section mainly studies on the influence of whether the sever room has a closed cold aisle on the energy consumption of the sever room. Before the rebuild of the sever room, the air return outlet is installed in the ceiling for return air. The return air outlet in ceiling is 9.0m (L) ×0.6 m (W), and the size of the cold aisle is 9.0 m (L)× 3.5 m (W)× 2.2 m (H), the size of the cabinet is 1.2 m (L) ×0.6 m (W)×2.2 m (H). The severs room's area is 455.55 m^2, it has 220 cabinets, and two air conditioner rooms on both sides. Each air conditioner room has five precision air conditioners, four for use and one for standby. The cooling capacity of each air conditioner is 152 kW, the power is 8.4 kW, and the air volume is 39400 m^3/h. The sever room's air conditioning system is operating all year round, and the sever room is surrounded by thermal insulation cotton to reduce the heat loss of the sever room's enclosure wall[4].

After the rebuilt of the sever room' air conditioning system, the cold aisle is completely enclosed. The top of the cold aisle uses a flip sunroof. The sunroof is usually closed, open only for emergency. According to the actual energy consumption in the sever room, without closed cold aisle (i.e. diffuse air supply system) test data was recorded on June 21, 2021, and the test data under closed cold aisle was recorded on August 21, 2021. In order to improve the accuracy of the energy consumption of the entire IDC room's air conditioning system, the analysis was made by comparing the energy consumption of the air conditioner with diffuse air supply system and closed cold aisle system.

Under the condition that the supply air temperature, daily power consumption of the refrigeration system and power consumption of the precision air conditioner in the sever room remain unchanged, change with diffuse air supply system or closed cold aisle air supply, and record the daily energy consumption of the two-type airflow distribution, as shown in Table Ⅰ.

The power loss accounts for 10 % of the energy consumption. After the cold aisle is closed, the energy consumption factor CLF of the air conditioner in the sever room decreases from 0.074 to 0.051, a drop of 0.013. Although the data seems small, for the IDC plant, the daily power consumption of the air conditioner can be reduced from 11000 kWh to 9150 kWh, 1850 kWh can be saved, and 573544 kWh can be saved all year, The annual electricity charge for the air conditioner in the machine room can save 437858.5uan.

TABLE 1. ENERGY COMPOSITION WITH OR WITHOUT CLOSED COLD AISLE

Date	June 21	August 21
Whether the cold aisle is closed	No closure	close
supply air temperature ℃	24	24
Average temperature of cold aisle ℃	25.4	23.8
Total daily power consumption of air conditioner × 100kW·h	110.0	91.5
Total daily power consumption of IDC × 100kW·h	2111.5	2093.1
Daily power consumption × 100kW·h	1488.0	1499.0
Daily power consumption of refrigeration system × 100kW·h	354.8	354.8
PUE	1.419	1.407
PLF	0.100	0.100
CLF	0.319	0.307
CLF of precision air conditioner at the end of machine room	0.074	0.051

When the cold aisle of the sever room is not closed, the cold air flow directly mixes with the hot air flow which flow out from cabinets outlet, then return to the air conditioner's inlet. There is a short circuit between hot and cold air in the sever room. The effective refrigeration efficiency is low, which will cause unnecessary energy waste in the sever room's air conditioning system[5]. Therefore, this air supply mode can only be applied to small IDC with low number of sever cabinets.

After the cold aisle is closed, the problem of short circuit of cold and hot air flow in air conditioning system is effectively solved, the utilization efficiency of cold air flow in the air conditioning system is improved, and the air conditioning system's supply and return air temperature are optimize met[6]. In addition, the temperature distribution in the whole sever room is more uniform, and the return air temperature is closer to the set value, have advantages to improving the set temperature of supply air and reducing the energy consumption of the air conditioner.

4 Influence of different air distribution on energy saving in summer

The cooling load of the enclosure structure of sever room under different airflow distribution in the sever room is discussed in this part. The server in the sever room is needed for cooling all the year round, so the heating load of the sever is not discussed here. The cooling load mainly occurs in April to October. The air supply temperature of the air conditioner in the sever room is set at 22 ℃.

Under the three types of air flow distribution, according to the indoor air temperature is different by different airflow distribution, it can cause different cooling load with same enclosure structure[7]. Table II shows enclosure wall area under different type of air distribution in sever room is calculated. The overall area of the south enclosure wall is 1219.75 m^2, and the temperature of the diffuse air supply mode in sever room is relatively low, with the maximum temperature of 26 ℃. With closed cold supply system and closed hot supply system, and the maximum temperature can reach 32 ℃, the minimum temperature is 22 ℃.

TABLE 2. INDOOR AIR TEMPERATURE AND ENCLOSURE WALL AREA OF DIFFERENT TYPE OF AIR DISTRIBUTION

Supply air type	Air supply type Ambient temperature in sever room/℃	Exterior wall area/m^2
Diffuse air supply mode	22	195.16
	26	1024.59
Closed cold aisle	22	286.28
	32	1024.59
Closed hot aisle	22	286.28
	32	933.47

The DeST software is used to calculate the cooling load of the enclosure structure. Table III shows the cooling load of the exterior wall of the enclosure structure under three different air flow distributions in the sever room.

TABLE 3. DESIGN COOLING LOAD OF EXTERIOR WALL OF ENCLOSURE UNDER THREE DIFFERENT AIRFLOW ORGANIZATIONS IN THE MACHINE ROOM

Equipment name	Actual power/kW	Load rate
Precision air conditioner	928.00	6.62%
IT Server	9060.00	62.32%
refrigeration system	2788.00	19.18%
electrical system	916.00	6.30%
Maximum cooling load of enclosure under closed hot aisle	71.22	0.49%
Maximum cooling load of diffuse enclosure	204.23	1.40%
Maximum cooling load of enclosure under closed cold aisle	40.85	0.28%
Total load	14008.30	/

Figures 4, 5 and 6 are the daily cooling load curves of the exterior wall of the enclosure structure under the three-type airflow distribution in the sever room. From these figures, it can be seen that the maximum cooling load in summer is in July, and the cooling load is relatively smaller in April and October. Among the three-type airflow distribution, the daily cooling load curve of the exterior wall of the enclosure structure with closed cold aisle is the smallest between the three types of airflow distribution[8]. Figure 7 is shown the maximum cooling load of the exterior wall of the enclosure under the three-airflow distribution in sever room all year.

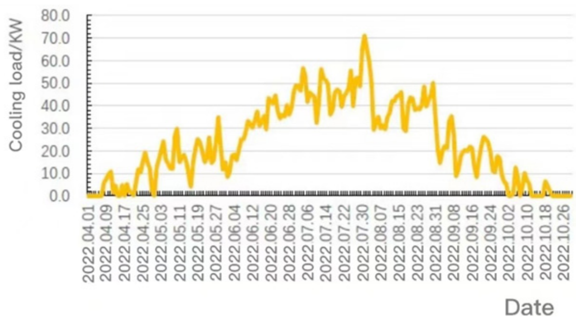

Figure 4. Daily Cooling Load Curve of Enclosure wall under Closed Hot Aisle in Sever Room

Figure 5. Daily Cooling Load Curve of Enclosure Wall under Diffuse Air supply system in Sever Room

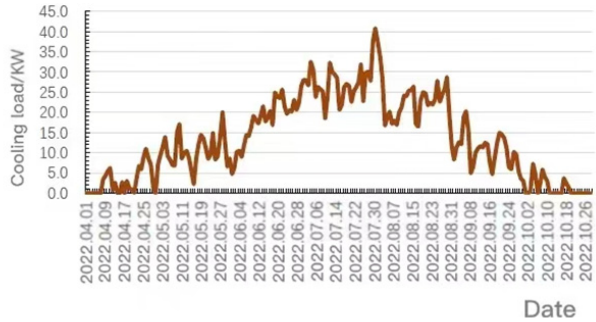

Figure 6. Daily Cooling Load Curve of Enclosure Wall under Closed Cold Aisle of Sever Room

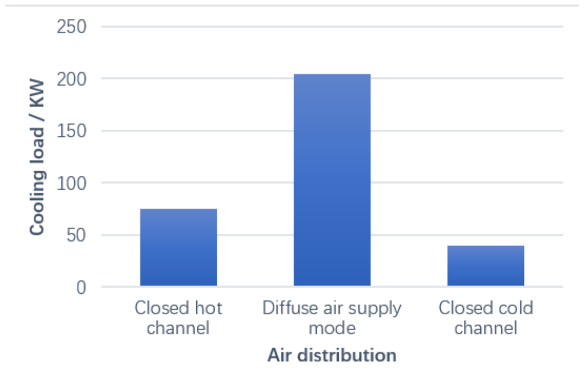

Figure 7. Maximum Cooling Load of Enclosure under Three Type of Airflow system in the Sever Room

From April to October, the energy consumption of the enclosure structure of the sever room is calculated, as shown in Figure 8. The energy consumption of the enclosure structure under the three types of airflow distribution of the sever room is shown. The energy consumption of the three-airflow distribution is the highest in July, the energy consumption of the enclosure structure of the diffuse airflow distribution is 4269 kWh, the energy consumption of the enclosure structure of the closed hot aisle is 1488.7 kWh, and the energy consumption of the enclosure structure of the closed cold aisle is 853.8 kWh. The energy consumption of exterior wall of enclosure structure can be reduced 634.9 kWh by adopting closed cold aisle system rather than closed hot aisle system.

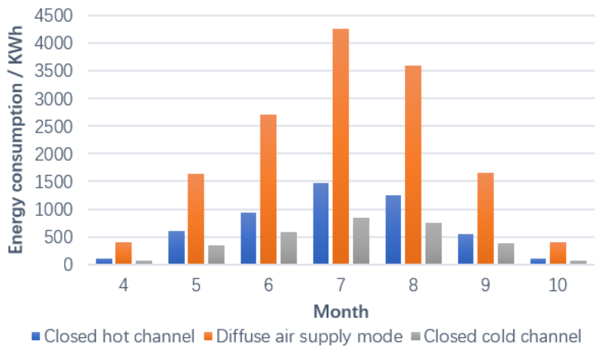

Figure 8. Energy consumption of exterior wall of enclosure structure under three type airflow distribution

By analyzing the energy consumption of the building envelope of the IDC, the following conclusion can be given that the cooling load of closed cold aisle in sever room is the minimum among the three types of airflow distribution.

5 Conclusion

In this article, DeST simulation was carried out for the cooling load of three type airflow distribution in the IDC room. By comparing the overall energy consumption among three type of airflow distribution, i.e., the diffuse air supply mode and the closed cold aisle system and the hot aisle system, it was concluded that the closed cold aisle system in the sever room would save more energy[9].

The energy consumption analysis of the enclosure structure of three air flow organizations in sever room shows that the energy consumption of the enclosure structure of closed cold aisle is the lowest in three type of airflow distribution.

To sum up, the closed cold aisle can optimize the air flow organization of air conditioner in the sever room, improve the refrigeration efficiency of air conditioner, achieve significant energy saving effect, and meet the construction requirements of a new generation of green IDC plant[10]. For the later construction of the air conditioning system of the IDC plant, the air flow organization can be designed according to the air flow organization form of the closed cold aisle and different projects to achieve the required energy-saving effect.

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