Energy fan power consumption comparison of subway station HVAC system

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Abstract: Subway thermal environment control system is a mass energy consumed system. The fan operation is the key of energy saving. Some feasible fan operation modes are proposed and compared in this paper from the view of energy and operation cost saving. It is concluded that VAV is the optimal operation mode for metro system with highest energy saving.

Keywords: subway; HAVC; fan power consumption

1. Introduction

In subway station Heating, Ventilation and Air Conditioning (HVAC) system, Air Handle Unit (AHU) is widely used. Because of the mass load of the subway station, the capacity and the energy consumption of HVAC system are fairly large. The energy consumption of fans is the main part of the whole HVAC system energy consumption. it is important to reduce the energy consumption of fans. Variable Air Volume (VAV) system is a good choice to achieve this target. In this paper, some feasible fan operation modes include VAV are proposed and compared from the view of energy and operation cost saving.

2. System description

As shown in Fig. 1, a typical subway station HVAC system is symmetrically located in the both ends of the subway station. In each HVAC equipment room, two AHU send handled air to the station and two exhaust fans return air to AHU or discharge air to outdoors.

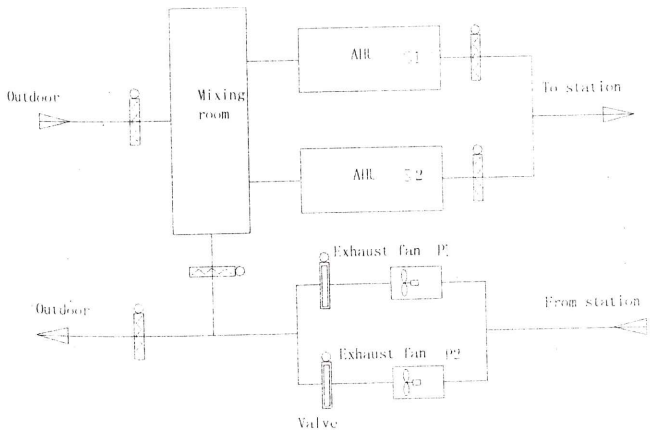

Fig. 1. HVAC system of subway station

3. Load analysis

3.1. Design load

The following data is based on a subway station located in the city near Yangtse River. It is a non Platform Screen Door (PSD) station with 4 passageways. According to the prediction, long-dated passenger flow is about 25 000 during the morning rush hour 7:00-8:00. The afternoon rush hour is from 17:00-18:00 with 90% passengers of that in the morning rush hour. There run 30 and 24 pairs of trains in the morning rush hour and in the afternoon rush hour, and 10-15 pairs in common hours. There is about 190kW heat emitted by lamps, elevator and other equipment in the station.

The design cooling load of this station is 2130 kW. Fresh air volume must be more than 10% of total air volume 31 800 m^3/h. The model and quantity of HVAC equipment are shown in Table 1.

Table 1. Fan data and quantity

Equipment	Air flow rate /(m^3/h)	Pressure /Pa	Fan efficiency	Motor efficiency	Rating power /kW	Quantity
AHU	90000	1200	0.75	0.9	44.4	4
Exhaust fan	80000	600	0.75	0.9	19.8	4

3.2. Typical Day Load in summer

Load of the subway station comes from the station equipment, trains, passengers and fresh air. Station equipment includes all kinds of equipment such as lamps, elevator, and automatic seller machine and so on. Equipment load is steady because all equipment keep working during subway running period.

Trains and passengers emit heat and moisture. Passengers' load fluctuates according to the quantity of passenger. The quantity of passengers also decides how many pairs of trains needed. Because of the big range

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of passenger flow from morning to night, the load of trains and passengers fluctuates obviously.

In the subway system, a train is like a piston running in tunnel and causes the piston wind flow through tunnel and passageway. Tens cube meter per second of fresh air enter the station through passageway because of the piston effect. Fresh air can cool the station when outdoors is cool. But it also increases the cooling load when the outdoor temperature is high in summer.

Considering the entire factor, the simulation result of summer cooling load of this subway station is shown in Figure 2. The curve of cooling load is similar to the curve of passenger flow. At 7:00 and 18:00, there are two peaks on the curve. it is in the morning rush hour and in the afternoon rush hour. The peak value is about 50% more than the whole day average value, and about 2.6 times of the lowest value at 5:00. Because the temperature outside is higher in the afternoon rush hour, though the passenger flow is lower than the morning rush hour, the load is higher than that in the morning rush hour.

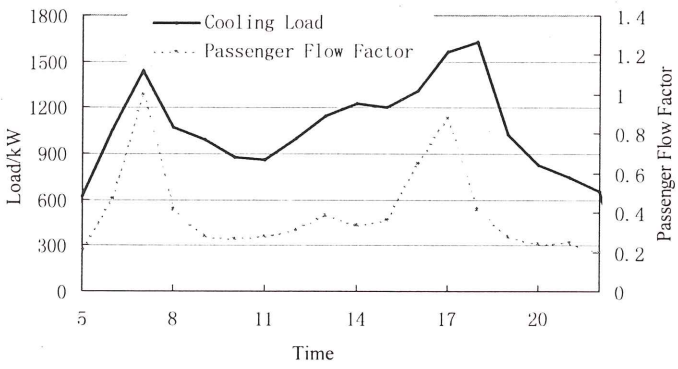

Fig. 2. Station load curve of typical summer day

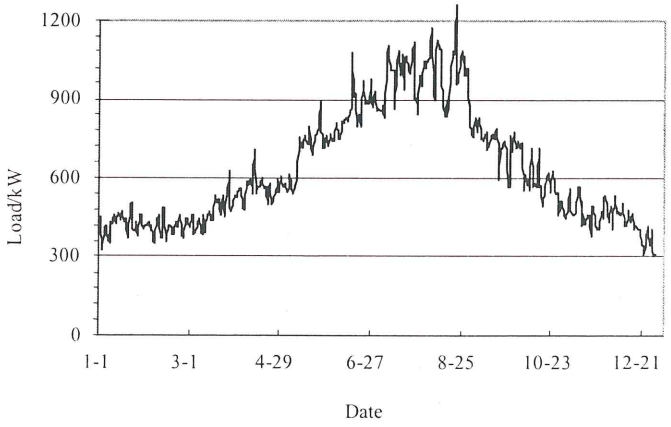

Fig. 3. Station day-average load curve of whole year

3.3. Load curve of whole year

The station day-average load curve of whole year is shown in Figure 3. There is still cooling load even though it is in winter. Of course, the cooling load in summer is about 3 times higher than in winter because of the difference in fresh air load. The fact that must be pointed out is that the set point of the station temperature is not the same value in different seasons. Because the heat resistance of the passenger's cloth is different in different seasons, the set temperature of temperature in summer is higher than that in winter.

4. Operation Modes and Energy Consumption Compare

Based on the HVAC system and the load curve as above, some feasible fan operation modes are proposed and compared below.

4.1. On-Off Control

It is the simplest operation mode. All fans running from morning to night until every train stopped.

4.2. Season Control

There are 4 or more passageways in each station. Each passageway's area is about 12 m^2. Passageways are good ducts because there have not muffler, filter and other components with high air flow resistance. If using passageways as ducts, part of fans can be stopped to save energy consumption.

Summer: All fans running. Water cooler running.

Spring and autumn: Exhaust fans running, AHU stop. Air outdoor going into the station through passageways.

Winter: AHU running but water cooler stopped. Exhaust fans stop, air exhausting through passageways.

In season control, the quantity of running fans will not be changed although cooling load fluctuates.

The power of fans in different seasons is shown in Figure 4. In spring and autumn, the fan power is about 1/3 of that in summer. In winter, air outdoor is colder than that in the station. Air exhausting through passageways is more comfort for passengers. So the fan power in winter is higher than that in spring and autumn, but still less than that in summer. Because spring, autumn and winter occupy about 3/4 of a whole year, the energy saving is considerable in season control.

4.3. VAV Control

Because of the notable fluctuation of the station load, VAV is suitable to be used in subway station. It not only gives better control to thermal environment but also minifies the energy consumption of fans.

Based on the season control, the following two techniques can be used to realize VAV control.

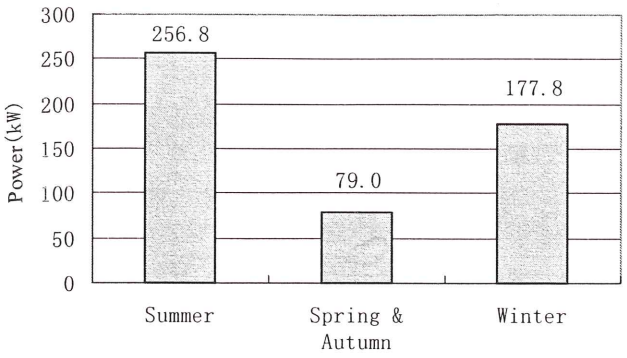

Fig. 4. Fan power in different seasons

4.3.1 Fans Quantity Control

If the station load is lower than 1/2 of design load, half of fans can be shut down. It means that the air volume and energy consumption of fans is just a little more than half of design value. It is easy and cheap to realize this technique but the effect of this technique is not as good as VF control.

4.3.2 Variable Frequency (VF) Control

Fan rotate speed and air volume can be continuously changed by power frequency transducer. The power consumption of fans decreases very fast with the decrease of fan rotate speed and air volume. When the load is 1/2 of the design load, the power consumption of fans is 1/8 of the design value. It is the best technique to save energy.

The fan power curves in summer of the two VAV techniques are shown in Figure 5. In the two curves, the max power equals to the design value. But VF control is far better than quantity control in mostly period of the time.

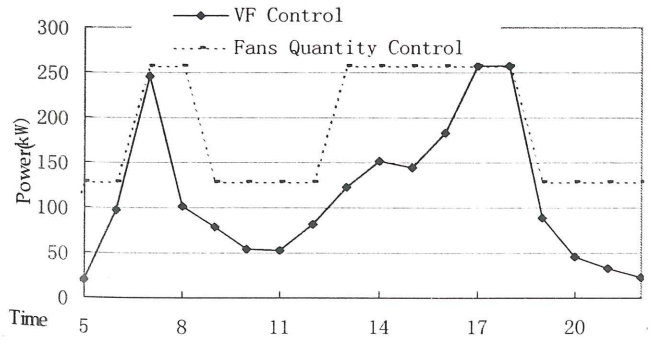

Fig. 5 Fan power curve of VAV in summer

4.4 Energy Consumption Compare

Year-round energy consumption and cost of fans in different operation modes are shown in Figure 6. VF control has the lowest energy consumption. It can save energy consumption more than 1 150 000 kW·h a^{-1} than On-Off control in this station. It means that the cost is saved about RMB ¥ 700 000/a (power price is ¥ 0.6/kW·h). The investment of frequency transducer about ¥300 000 can be called back in one year.

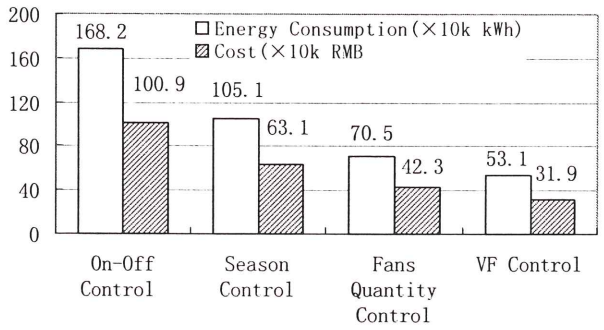

Fig. 6. Fans energy consumption and cost of whole year

5. Conclusions

1. For existing subway station HVAC system, energy saving of fans is considerable if proper operation mode is adopted.

2. During spring, autumn, and winter, take the passageways as ducts is doable and can save energy consumption obviously.

3. Because of the notable fluctuation of the station load, VAV is suitable to be adopted in the subway station.

4. VF control is recommended. It gives the best environment control and lowest energy consumption. Fans quantity control can be the substitute if there is no frequency transducer.

5. All the analysis above is based on the design data. That is a prediction to the long-dated passenger flow and train flow. In fact, the passenger flow in the near future is much less than the long-dated passengers flow. The error of prediction can not be avoided too. VF VAV system is the best choice in such situation.

6. For the subway station with Platform Screen Door (PSD), the load of station is much less than the station without PSD, but the passenger flow is still the key factor to influence the load. The load curves of the station with or without PSD are similar. The conclusion above is the same with the station with PSD.

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