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Optimal strategy for VAC system in metro station of small and medium size city

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Abstract

Metro construction grows fast in China, the energy consumption increases in the same time. The ventilating and air conditioning (VAC) system of metro stations takes a big part of the energy consumption. The operating state of the system plays an important role, so it's necessary to optimize the strategy of the VAC system. There're studies of optimizing the VAC operation system in big cities, but related study lacks in small and medium size cities. In this paper, several field measurements have been conduct. Based on the data measured, the optimal ventilation strategy has been put forward.

Introduction

With the quick economy development and civilization trend in China, the metro lines grow fast in China. Data shows that up to the year of 2016, there are 29 cities have already established or are currently constructing metros, the total number of the metro stations is 2630, and the total length is 3849 kilometres[3].

What's more, there're not only big cities like Beijing, Shanghai, Guangzhou, Shenzhen expanding metro lines, but also small and medium size cities like Wuxi in Jiangsu Province, Luoyang in Henan Province and Huhehaote in Inner Mongolia Province start to construct metro lines.

Research shows that the ventilation and air conditioning (VAC) system of the metro station consumes most of the energy in metro station[5], even exceeds the energy consumption of the traction system of trains. More than 30% of the total energy is used in VAC system. The huge energy consumption restricts the development of metro system, so, the VAC system has the potential of energy saving[6].

The newly built metro traffic lines, especially that in small and medium size cities, the passenger flow recently is much smaller than designed level, so as the cooling load and fresh air demand. That's much different from the situation in big cities, in which the equipment fits well for the operating state. So, the optimal strategy should be come up for the VAC system in metro stations of small and medium size cities.

Common form of VAC system in metro stations

The form of metro station VAC systems differs in China. Generally speaking, north part of China needs ventilation only; middle part using non-platform screen door-system; and south part of China widely applied PSD system[1]**错误!未找到引用源。**. In consideration of passenger's safety and comfort, increasing numbers of the newly built metro stations apply the Platform Screen Doors(PSD) system. The PSDs divide the tunnel and platform, so air form tunnel wouldn't affect the thermal environment of the platform.

The target of the VAC system of the metro station is to deal with the cooling load of the station hall and platform, and to provide enough fresh air for the passengers. The cooling load includes heat from the fresh air, tunnel air, light, equipment, people and so on. The fresh air demand is more than 12.6m3/h according to the standards in China[2].

Figure1 is the general view of the VAC system of the metro station. There're fresh air duct and exhaust air duct connecting the station underground and the outside. There are three fans in a VAC system, including a supply fan inside the AHU (air handling unit, shows in Figure 2, a back fan inside the back duct and a fresh air fan. The back air divides into the exhaust air and mix air in the back-air chamber. The fresh air mixes with mix air in the mixed-air chamber, then to be handled in AHU to become the supply air been delivered to station hall and platform. The fresh air fan and the big fresh-air valve are in the fresh air duct, as showed in Figure 3.

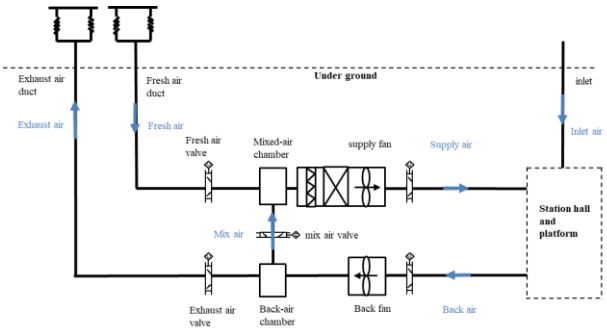

Figure 1. General view of the VAC system of the metro station

Figure 2. Air handling unit of the VAC system

Figure 3. Fresh air fan and whole-fresh air valve

In order to achieve the comfort goal, and save energy in the same time, the operation strategy of the VAC system in the metro station changes according to the weather condition. The operation mode can be divided into four types: minimum fresh air cooling mode, whole fresh air cooling mode, mechanic ventilation mode and natural ventilation mode.

When the enthalpy of the outdoor air is higher than that of the indoor air, minimum fresh air cooling mode should be adopted. So that the fresh air cooling load can be reduced to the lowest level. When the enthalpy of the outdoor air is lower than that of the indoor air, but still need the chiller operating to deal with the cooling load, whole fresh air cooling mode should be taken. In this mode, all of the supply air is made up with the fresh air outdoor. When the outdoor air is cool enough, the chiller can stop working, only fans keeps operating to cool down the station hall and platform in metro stations. When it is winter, no more mechanic ventilation is needed, the fans can stop, only the natural ventilation from the inlet is enough.

Case study

Wuxi is a city in Jiangsu Province, south of China. The passenger flow and the cooling load remain far below the designed level, so it is selected as a case in this paper to be present of the small and medium size cities.

To study the VAC system in Wuxi-Metro station, the characteristic of the cooling load, the fans and ducts should be studied. The composition of the cooling load and its proportion is showed in figure 4. The field measurement includes the air flow volume in the supply air duct, back air duct and fresh air duct; the pressure difference between the supply fan and back fan. So the lift-volume curve of the fans and resistance curve of the ducts has been drawn according to the measured data.

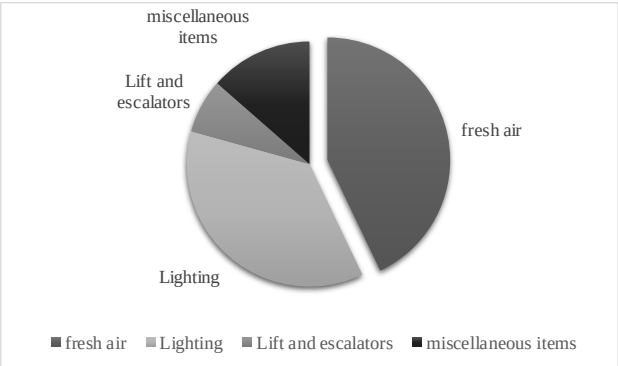

Figure 4. Composition of the cooling load in metro station.

By adjusting the opening degree of the valve, the resistance of the duct changes, so the lift-volume curve can be obtained. The measurements have been done under two circumstances: the operating frequency of the fans is 50Hz or 30Hz. The performance curves of the supply fan and that of the back fan are showed in Figure 5 and 6.

By adjusting the frequency of the fan, and keep the valve fully open, the resistance curve of the duct can be obtained. The resistance curves of the supply duct and that of the back duct are showed in Figure 7 and 8.

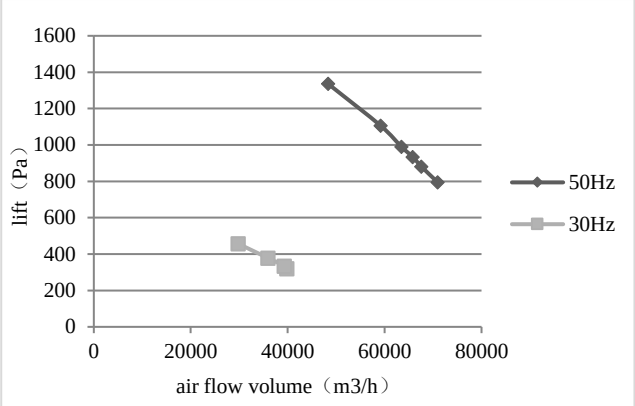

Figure 5. Performance curves of the supply fan

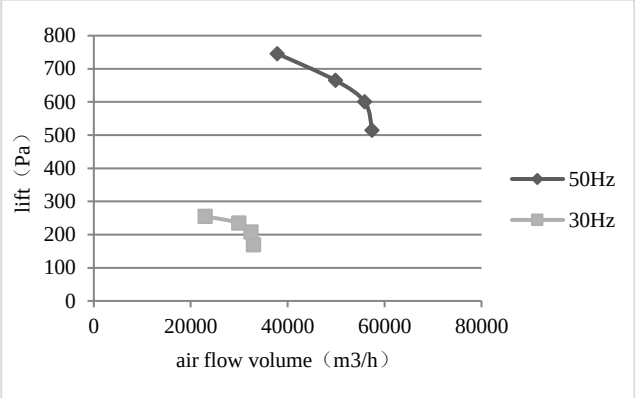

Figure 6. Performance curves of the back fan

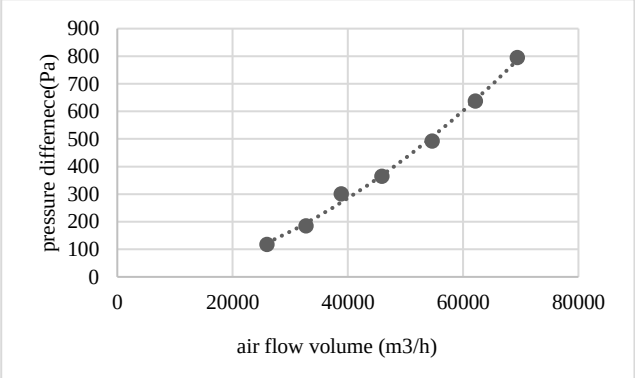

Figure 7. Resistance curve of the supply duct

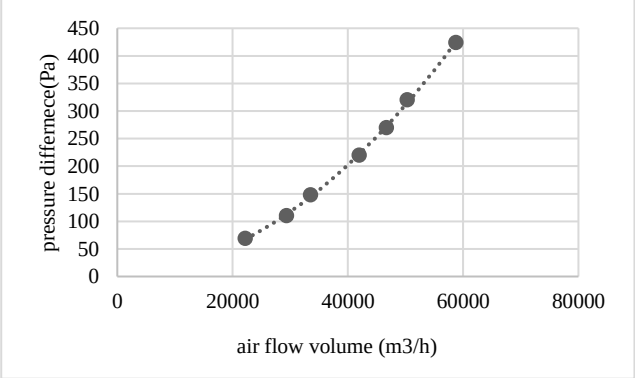

Figure 8. Resistance curve of the back duct

In the minimum fresh air cooling mode, all of the three fans keep working, the building automation system adjusts the frequency of the supply fan according to the temperature of the station hall and platform. By investigation, the frequency of supply fan is about 30Hz, which means about the volume of 38000m^3/h is enough for air conditioning of the station hall and platform in Wuxi-Metro.

The other mission of the VAC system in the metro station is to provide enough fresh air for the passengers in the station hall and platform. In this metro station, the total fresh air demand is about 6000 m3/h. The current operation mode is to keep the fresh air fan working. But the operating state of back fan's influence is neglect usually.

In this case study, the fresh air volume is measured under different situations when the frequency of the Supply fan, the frequency of the back fan and the open state of the fresh air fan change. Setting the frequency of the back fan at 30Hz, and changing the frequency of the Supply fan from 25Hz to 35Hz, then measuring the fresh air volume. The relationship between the fresh air volume and frequency of the Supply fan is showed in Figure 9. In the same way, the relationship between the fresh air volume and frequency of the back fan when the AHU is showed in Figure 10.

From the results in Figure 9, the fresh air volume increases with the increasing frequency of the supply fan whether with the fresh air fan on or off. So, to increase the operating frequency of the supply fan is one of the approaches to introduce more fresh air. What's more, even with the fresh air fan turned off, there's also a lot of fresh air coming inside. So, an optimal approach is to turn off the fresh air fan, and adjust the frequency of the back fan to meet the fresh air demand.

According to the results in Figure 10, when the fresh air fan is working, the fresh air volume decreases with the frequency of back fan increases. So, to increase the fresh air volume, the frequency of the back fan should be set at lower level. But when fresh air fan is turned off, the results are different. When the frequency of the supply fan keeps at 30Hz, and the frequency of the back fan is 25Hz, the fresh air volume is less than that the frequency of the back fan is 30Hz. The reason is that when the supply air less than the back air, the air from the fresh air duct decrease. By research, in the same time, some of the outdoor air comes from the exhaust air duct because the pressure of the back air chamber is below the barometric pressure under this situation.

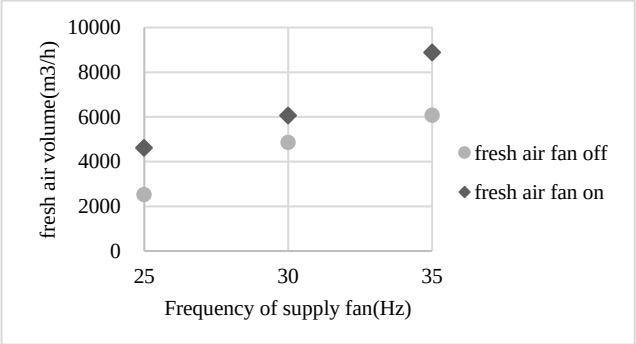

Figure 9. Fresh air volume of different supply fan frequency

The results of the case study are also helpful to determine the proper operating state of the fans. When the supply fan is adjusted to 30Hz according to the building automation system (BAS), and if there's fresh air demand about 5000 m3/h, the back fan should be adjusted to 30Hz, too.

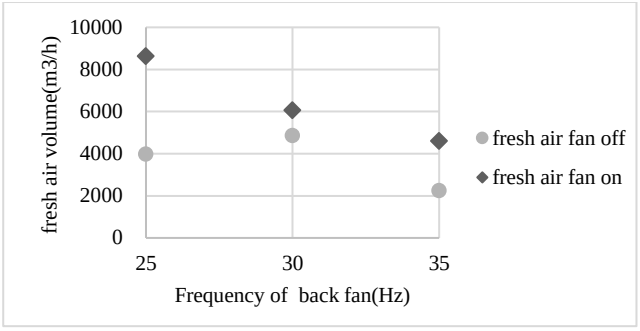

Figure 10. Fresh air volume of different supply fan frequency

Conclusion

The VAC system of metro station in small and medium size city has energy saving potential because of the equipment and cooling as well as the fresh air demand don't match. So in these systems, frequency conversion strategy should be adopted.

There're four operating modes including minimum fresh air cooling mode, whole fresh air cooling mode, mechanic ventilation and natural ventilation, the switch points depend on outdoor situations. The optimal strategy for the VAC system in metro stations can be summed as following:

1) In the minimum fresh air cooling mode, the frequency of the supply fan should be adjusted according to the indoor temperature. The optimal strategy is to turn off the fresh air fan, and adjust the frequency of the back fan to meet the fresh air demand.

2) In the whole fresh air cooling mode, only the supply fan should keep working, the frequency of the supply fan should be adjusted according to the indoor temperature in the same way.

3) In the mechanic ventilation mode, only the back fan keeps on, and the cool outdoor air is introduced from the inlet. The frequency of the back fan is adjusted according to the cooling load.

4) When weather is cool enough, all the fans can stop working, the air conditioning of the station hall and platform only depends on natural ventilation.

References

[1] Guoqing Li. Research on a New Multi-Function Integrated Ventilation and Air Conditioning System for City Rail Transit[D]. Tianjin university,2009.

[2] Hygienic standard for waiting room of public transit means (GB9672-1996).

[3] LIU, Y. et al., 2017. China's urban rail transit operation statistics and analysis in 2016. Urban Rapid Rail Transit, 01(CN 11-5144/U), pp. 4-6. Cooley, J.W. & Tukey, J.W., An Algorithm for the Machine Computation of Complex Fourier Series, *Math. Comp.*,**19**, 1965, 297-301.

[4] Metro Design Code (GB50157)

[5] Ming-TsunKe, Tsung-Che Cheng, Wen-Por Wang. Numerical simulation for optimizing the design of subway environmental control system[J]. Building and Environment,2002,37(11):1139-1152.

[6] Yongcai Wanga, Haoran Fengb,Xiangyu Xib. Monitoring and autonomous control of Beijing Subway HVAC system for energy sustainability[J], Energy for Sustainable Development, 2016.12.004