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Research on frequency conversion technology of metro station's ventilation and air-conditioning system

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HIGHLIGHTS

- Use the FCT to reduce energy consumption of metro VAC is necessary and possible.
- Analyze the influence of running the chilled-water pumps with FCT.
- Results show that variable air volume of station public area is feasible.
- Calculations indicate that energy-saving effect of using the FCT is considerable.

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ABSTRACT

Ventilation and air-conditioning system (VAC) is the most energy-saving potential system in the metro. This paper analyzes the passenger traffic, air-conditioning load and station air supply on the initial, recent and long-term phase of metro station. And it proposes that it is necessary to run chilled-water pumps, air handing unit (AHU) fans and back/exhaust fans with frequency conversion technology (FCT). Then it uses the thermodynamic method to analyze the impact of running chilled-water pumps with FCT. The results show that running chilled-water pumps with FCT can reduce the total power consumption of system, although increases chiller energy consumption. Then the temperature and velocity fields of the platform and station hall are simulated by CFD software according to the variable air volume. And the results show that under the condition of running the VAC system with FCT, temperature and velocity fields distribution are both in the comfortable range. Finally, by taking a typical summer day for example, this paper analyzes the energy savings of chilled-water pumps, AHU fans and back/exhaust fans on the initial, recent and long-term phase, and the calculation results show that the respective total energy savings are 1103.4 kWh, 1064.3 kWh and 926.2 kWh, and the respective total power saving ratio is 73.4%, 71.2% and 59.5%.

1. Introduction

With the development of economy, urbanization and urban expansion, it increases pressure on urban transport and makes environmental degradation in China. In order to ease the traffic pressure and reduce environmental pollution, major cities begin to build metro which is efficient, green and has large passenger capacity. However, its high energy consumption cannot be ignored, only 20 km to the opening of the Shenzhen Metro, for example, its annual electricity consumption accounts for 1/3000 of the total electricity consumption in Shenzhen [1], of which the metro air-conditioning energy consumption accounts for about 35%. According to the code for design of metro, the maximum long-term load determines the capacity of the VAC equipments of metro station, which has 10–20% of the wealthy [2]. In the process of operation, full load operation time of the VAC will be less than 5% of the total runtime, especially in the initial stage. Meanwhile, metro's characteristics of morning peak and evening peak make the air-conditioning load of metro extremely volatile in a working day.

Therefore, it is necessary to carry out energy-saving research on the VAC of metro [3].

Because of the climate difference and different metro design concept between southern and northern in China, the VAC of the metro station is different. According to the actual situation, the different energy-saving control program need to be constituted for the different place. In this paper, a metro station with designing and

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Nomenclature

Q_e	chiller refrigeration capacity, kW
$Q_{e,0}$	chiller rated refrigerating capacity, kW
Q_0	refrigerating capacity, kW
W_p	pump power, kW
W_{wc}	chiller power, kW
K_e	evaporator heat transfer coefficient, kW/(m^2 °C)
$K_{e,0}$	evaporator rated heat transfer coefficient, kW/(m^2 °C)
F_e	evaporator heat transfer area, m^2
$V_{w,e0}$	chillers rated water flow, m/s
t_e	evaporation temperature, °C
t_{ei}	return chilled-water temperature, °C
COP_I	integrated chiller COP
E_p	overall energy consumption amount of chilled-water pumps, kWh
E_f	overall energy consumption amount of AHU fans, kWh
E_{bf}	overall energy consumption amount of back/exhaust fans, kWh
E_1	quantity of energy saving by chilled-water pumps frequency conversion, kWh
E_2	quantity of energy saving by AHU fans frequency conversion, kWh
E_3	quantity of energy saving by back/exhaust fans frequency conversion, kWh
E_4	increased energy consumption amount of chiller, kWh
ξ_t	total power saving ratio

Abbreviations

VAC	ventilation and air-conditioning system
AHU	air handing unit
FCT	frequency conversion technology
VPF	variable primary flow system
VAV	variable air volume technology

installation of platform screen doors in the south China, for example, its corresponding energy-saving program is proposed and studied. The VAC of the metro station principle diagram is shown in Fig. 1. At present, one of energy-saving measures of the ground building is to use FCT to control the fluid machinery (fans and pumps) of VAC, which this article will introduce. Through empirical analysis, this paper intends to study the feasibility of FCT used in the equipments of chilled-water system and ventilation system of the station public area.

2. Station passenger traffic and air-conditioning load analysis

Hourly forecast passenger traffic is shown in Fig. 2, which shows that the passenger traffic difference is very large at different times a day, and the morning and evening peak passenger flow are very clear, with a variation hump-shaped.

According to passenger forecasts and other information, and basing on the typical year weather data provided by special meteorological data set of analysis of china building thermal environment [4] and according to code for design of metro, this paper takes a typical summer day for example, hourly station air-conditioning loads of the initial, recent and long-term stage are calculated and shown in Fig. 3. Most of the time, the air-conditioning load is 60–80% of the maximum long-term air-conditioning load. In a day, the chilled-water flow changes dramatically, because air-conditioning load reflects the needed of the chilled-water flow directly.

According to the station load, air supplies of the initial, recent and long-term stage are calculated, and the result is shown in Fig. 4. Air supply of the station public area also changes dramatically throughout a day. Especially in the initial and recent phase, the air supply is less than 60% of the maximum long-term phase.

The prediction of hourly passenger traffic, air-conditioning load and air supply show that change of metro passenger traffic leads

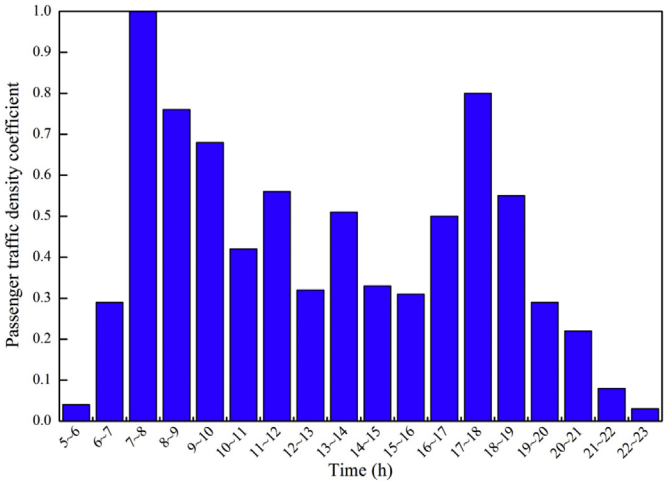

Fig. 2. Hourly distribution of station passenger (the morning rush is unit volume 1).

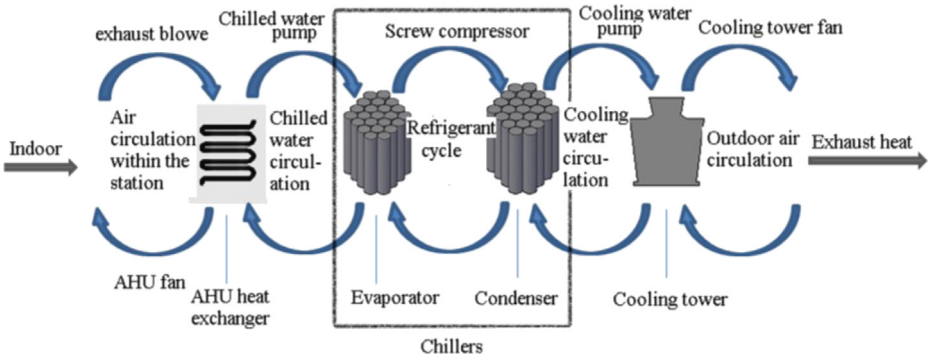

Fig. 1. The metro station VAC principle diagram.