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Optimization of Operation Scheme for Subway Environmental Control System

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Abstract

This paper analyzes the theories of ventilation and heat transfer of subway environmental control system, and a relevant network model of subway lines has been built. Based on this model which can calculate air volume and thermal load of subway lines, the air flow distribution in each area of station under closed ventilation condition, opened ventilation condition, minimum fresh air condition, night ventilation condition and obstruction ventilation condition has been simulated, and the influence of open or close piston duct and bypass duct, mode of air supply and exhaust, air temperature in station hall and platform, minimum fresh air of air conditioning and VRV system of equipment room on the thermal environment has been studied. Finally concludes the specific affection of these factors to energy consumption of subway environmental control system and temperature of tunnel, and optimizes the operation scheme for subway environmental control system in different period and seasons.

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Keywords: Water conservancy network model,State space method, subway environmental control system, Energy saving ;

1. Introduction

As the rapidity and convenience of urban rail transport system, there are more and more people travel by metro. It has a great significance to carry out researches on energy conservation of the environmental control system, as it has made a great contribution to energy consumption of the metro [1][2][3][4][5].There are many factors affect energy consumption of the environmental control system, Hu and Lee [6] found that the PSDs was able to isolate the piston wind so that decreased the air conditioning load. Zhao [7] found that the effect of energy conversion became more

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remarkable when adjustable louvre was added to the PSDs. And he also discussed the application of frequency conversion technology in metro for energy conversion one year ago[8]. Liu and Deng [9] used the demand control ventilation method to regulate the environmental control system of station with island platform and analysed energy-saving effect. Liu [10] found multi-objective optimization control strategy can not only saved energy effectively, but also improved the station air quality. M. Vaccarini [11] used model predictive energy control to adjust the ventilation system and concluded that it improved the air quality while reducing the ventilation energy consumption effectively. However, the previous researches mainly aimed at a single influencing factor of energy consumption of environmental control system, or just use the control method to optimize the system, but did not consider the synergistic effect of multi- factors. Base on the specific impacts of multi- factors on energy consumption of environmental control system, this paper formulates an innovative energy saving operation scheme.

2. Methods

The subway line to be studied is Metro Line 1 of Nanjing, the Subway Thermal Environment Simulation Software (STESS) was used to establish the network model of the subway line to simulate the thermal environment of tunnel and station, and then to optimize the operation of the environmental control system.

2.1. Theoretical model

The ventilation of the subway system is a three-dimensional model, and it's very complicated to calculate, but when it was treated as one-dimensional flow, the problem will be simplified [12]. For a certain constant section pipe, the one-dimensional flow momentum conservation equation is

$$\frac{dV_i}{d\tau} - f_{xi} = -\frac{1}{\rho_i}\frac{\Delta p_i}{L_i} \tag{1}$$

Where V_i is flow rate of branch i (m/s), τ is the time (s), Δp_i is pressure difference between outlet and inlet of branch i (Pa), ρ_i is density of air (kg/m^3), L_i is Branch length (m), and f_{xi} is the mass force which consists of three parts

$$f_{xi} = (DH_i - S_i\,|\,G_i\,|\,G_i - \Delta Z_i\,\Delta\rho_i\,g)/\rho_i L_i \tag{2}$$

The first part is the pressure produced by fans or pumps, the second one is the pressure loss caused by the flow resistance, and the last one is the floating force caused by the density difference between the fluid in the pipe and fluid outside. The equation (2) generation into (1)

$$\frac{d\overline{W}_i}{d\tau} = [BEB^T]^{-1}(\overline{DH} - \overline{S}\,|\,G\,|\,G - \Delta\overline{Z}) \tag{3}$$

Where DH_i is the fluid pressure of branch i (Pa), W_i and G_i are mass flow rate (kg/s) and Volume flow rate (m^3/s) respectively, S_i are Branch impedance (pa/(m^3/s)), ΔZ is height difference between outlet and inlet (Pa), B and E are both Constant matrix.

As to the solution of the model, the MMKP method is suitable for ill condition, and the RKS3-4 [13] iterative method is suitable for the opposite condition.

The heat storage of the surrounding soil must be considered while calculating heat transfer of the underground space, so the differential equation of heat conduction can be expressed as

$$q_W(\tau_0) = \int_{-\infty}^{\tau_0}\sum_{j=1}^{n} W_{1,j}\cdot e^{-\mu_j(\tau_0-\tau)}t_a(\tau)d\tau + W_0 t_a(\tau_0) + \int_{-\infty}^{\tau_0}\sum_{j=1}^{n} W_{2,j}\cdot e^{-\mu_j(\tau_0-\tau)}t_s(\tau)d\tau + \overline{K_0}\cdot\overline{t_0} \tag{4}$$

Where $q_W(\tau_0)$ is heat transfer between soil and air (W), t_a and t_s are air temperature (℃) of tunnel and of outdoor (℃) respectively, $W_{1,j}$ is the number j reaction coefficient of t_a, $W_{2,j}$ is the number j reaction coefficient