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Research on condensation prevention of hydropower plant based on temperature and humidity independent control system

Yong-Qi Gong[1], Jian Deng[1,3], Shen-Yang Liu[1], Zhong-Hua Cheng[2], Quan-YueMa[2]

Abstract. The purpose of the present problem is to avoid condensation problems in hydropower plantwhentemperature and humidity independent control (THIC)system lower the temperature of electronic equipments,whichcorrodes its electronic equipment. This paper theoretically analyzes condensation problem of hydropower plant firstly, then establishes general ventilation model of THIC system,finishresearches onthe influence of humidity ratioand temperature supplied of hydropower plant. The result shows that hydro-plant air-conditioning system decreases humidity ratio of supplied air and the minimum fresh flow rate, where energy saving rate can reach 20.39%. At the same time, supplied cooling water temperature should be moderate (approximately 9-12 °C) to reduce total energy consumption, where energy saving rate can reach 23.3%.

Key words. THICsystem, condensation problem, the state of supplied air, hydropower plant .

1. Introduction

With the development of science and technology, more and more hydropower plant are built. There are a lot of electronic equipment in hydropower plant, such as generator, voltage regulator, etc. When these electronic equipment work, they will produce a lot of heat, which have bad effect on working performance of electronic equipment[1].However,whenair-conditioning system of hydropower plant supply cold air or water, the air of hydropower plantalways turns up drops of water, which

[1]Workshop 1 - Department of Aviation Material Four Station, Air Force Logistics College, Xuzhou, China

[2]Workshop 2 - Department of Equipment Command & Managemant, Mechanical Engineer college, Shijiazhuang, China

[3]Corresponding author:Jian Deng

corrodes electronic equipment, circuit and waterpipeof hydropowerplant[2].

This paper willestablishes general ventilation model of THIC system, and focuses on influence of different humidity ratio of supplied air and supplied cooling water temperature difference to energy consumption to discover the optimal way of supplied air of hydropower plant air-conditioning system.

2. General ventilation model

General ventilation model of THIC system is established in Eq.(1).Given air-supply volume and air-supply humidity ratio, air humidity ratio of hydropower plant can be solved at any time.

$$d_\tau = (d_s + \dot{Q}/G)[1 - \exp(-G\tau/(\rho V_r)] + d_o \exp[-G\tau/(\rho V_r)] \tag{1}$$

Where $d_o$and $d_s$represent the initial air humidity ratio of hydropower plant and air-supply humidity ratio, respectively(g/kg), G is the required flow rate of the environment air(kg/h), $\dot{Q}$is moisture generationof hydropower plant (g/h), $V_r$is volume of hydropower plant (m^3),$\tau$is ventilation defrosting time(s).

When$\tau \to \infty$, the final humidity ratioof hydropower plant will be

$$d_\tau = d_s + \dot{Q}/G \tag{2}$$

The final humidity ratioof hydropower plant is only relate to air-supply humidity ratio, moisture generation and required flow rate, which is not concerned with the initial humidity ratioof hydropower plant and volume of air-conditioning system, as indicated by Eq.(2).

When$G\tau/(\rho V_r) \geq 2.5$in the process of actual ventilation, it's can be considered that air state reach stabilization in hydropowerplant.

The maximum humidity ratio of dewing prevention in hydropower plant can be calculated by Eqs.(3)-(4).

$$t_L = t_o - \Delta t \tag{3}$$

$$\ln P_L = 23.196 - 2816.44/(t_L + 227.02) \tag{4}$$

$$d = 0.62188 P_L H/(P_b - P_L H) \tag{5}$$

Where t_o and Δtrepresent the initial air temperature of hydropower plant and supplied air temperature difference, respectively(°C),t_L is the maximum temperature of dewing prevention in hydropower plant(°C), $P_L$is water vapor pressure of saturated air(kPa), $P_b$is standard atmospheric pressure(kPa).The minimum fresh flow rate in hydropower plant can be solved by simultaneous Eq.(1) and Eq.(5).

The state of supplied air can be calculated by Eqs.(6)-(8), main including supplied air temperature and humidity ratio of supplied air. Then the latent load of THIC system in hydropower plant can be calculated by Eqs.(9)-(10), and the sensible load can be calculated by Eq.(11), Eq.(12) shows total heat load of THIC system.

$$t_s = t_o - \Delta t \tag{6}$$

$$d_s = d_o - \Delta d \tag{7}$$

$$\Delta d = \Delta t(1.005 + 1.86d_o)/(\varepsilon - 2501) \tag{8}$$

$$Q_{latent} = G_{\min}(d_o\omega_o - d_s\omega_s) \tag{9}$$

$$\omega = 2501 + 1.82T \tag{10}$$

$$Q_{sensible} = G_{\min}(t_o - t_s) \tag{11}$$

$$Q = Q_{latent} + Q_{sensible} + Q_1 \tag{12}$$

Therefore energy consumption of centrifugal fan can be calculated by Eq.(16), and energy consumption of THIC system in hydropower plant will be:

$$\Delta P_1 = S_{flow}G_{\min}^2/\rho_a^2 \tag{13}$$

$$S_{flow} = 8(\lambda l/d + \sum \xi)/(g\pi^2 d^4) \tag{14}$$

$$W_F = (\Delta P + \Delta P_1)G_{\min}/(\eta_F\rho_a) \tag{15}$$

$$W = Q/COP + W_F \tag{16}$$

Where S_{flow}represent the impedance of pipe, $\rho_a$is the density of the air (kg/m3), $\xi$is coefficient of local resistance,$l$is the length of pipe (m), and d is diameter of pipe (m).$\Delta P$is differential pressure of supplied air (Pa), η_{F} is mechanical efficiency of centrifugal fan, and COP is thermal efficiency of compressor.

3. Results and discussion

When humidity ratio of supplied air is 6g/kg, the final humidity ratio of hydropower plant is 8.9g/kg, and the humidity ratio of hydropower plant that reaches the maximum humidity ratio of dewing prevention need 1.4h, marked t1. When humidity ratio of supplied air is 8g/kg, the final humidity ratio of hydropower plant is 10.9g/kg, and the humidity ratio of hydropower plant that reaches the maximum humidity ratio of dewing prevention need 2.4h, marked t2.When humidity ratio of supplied air are 6g/kg and 8g/kg, t2 is 1.7 times larger than t1, as shown in Fig1.

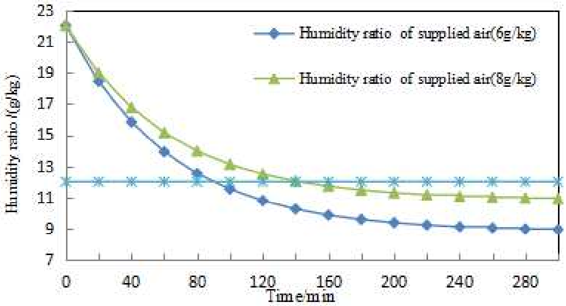

Fig. 1. Humidity ratio in hydropower plant in the process of ventilation

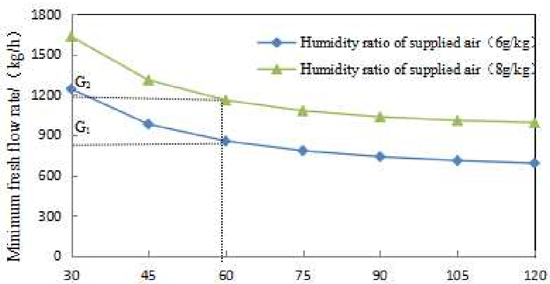

Fig. 2. Time of dehumidification by ventilation and the minimum fresh flow rate

Fig.2 shows that time of dehumidification by ventilation and the minimum fresh flow rate under the condition of different humidity ratio of supplied air.When time of dehumidification by ventilation is 1h, the minimum fresh flow rate on the condition of 8g/kg humidity ratio of supplied air, marked G2, is 1.4 times larger than the minimum fresh flow rate on the condition of 6g/kg humidity ratio of supplied air, marked G2. as illustrated in Fig.4.

This paper chooses three kinds of enthalpy humidity ratio (5000, 7000, 10000) and three kinds of weather parameters [35C70%30 °C 60% 25 °C 40%] to calculate total energy consumption under conditions of different supplied cooling water temperature.

Fig.3 shows total energy consumption of hydro-plant air-conditioning system on conditions of different enthalpy humidity ratio, total energy consumption decreases first, then increases along with the increase of supplied cooling water temperature.Fig.4 depicts total energy consumption of hydro-plant air-conditioning system on conditions of different weather. the supplied cooling water temperature that reaches the minimum energy consumption decreases gradually.

Compared to supplied cooling water temperature of 6 °C and 16 °C, total energy consumption on the condition ofsupplied cooling water temperaturedifference of 9 °C increase 4.5kW and 3.8kW on the condition of enthalpy humidity ratio of 5000, which energy saving rate can reach 13.6%. At the same time, total energy consumption on

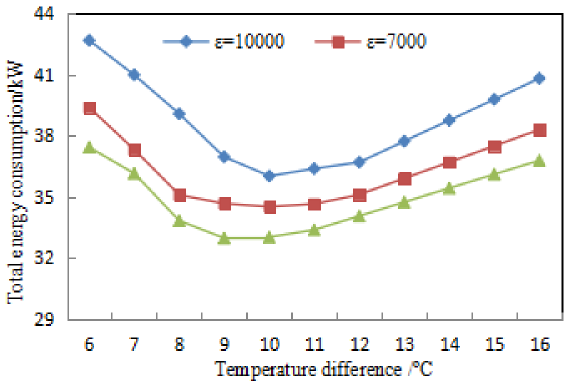

Fig. 3. Total energy consumption on conditions of different enthalpy humidity ratio

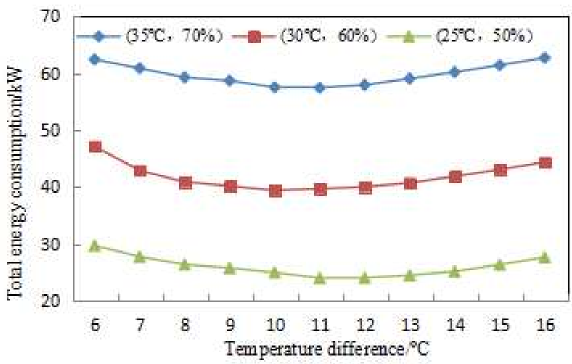

Fig. 4. Total energy consumption on conditions of different weather parameters

the condition ofsupplied cooling water temperatureof 12?Cincrease 5.6kW and 3.6kW on the condition of weather parameter of (25 °C, 50%), which energy saving rate can reach 23.3%. Therefore supplied cooling water temperature difference should be moderate (approximately 9-12 °C) to reduce total energy consumption.

4. Conclusion

This paper analyzes the changing process of humidity ratio in hydropower plant, and gets the minimum fresh flow rate. Finally total energy consumption of hydropower plant air-conditioning system is analyzed under conditions of different enthalpy humidity ratio and weather. The followings are the conclusions:

(1) To avoid dewing condensation, humidity control subsystem supply dry air to hydropower plant, then temperature control subsystem supply cold water to regulate environment of hydropower plant.

(2) Time of dehumidification by ventilation decreases along with Humidity ratio of supplied air,and the minimum fresh flow rate decreases along with the decrease of

humidity ratio of supplied air. Compared 8g/kg humidity ratio, the minimum fresh flow rate of 6g/kg humidity ratio is 1.4 times. Decreasing humidity ratio of supplied air and time of dehumidification by ventilation can reduce energy consumption, which energy saving rate can reach 20.39%.

(3) Total energy consumption decreases first, then increases along with the increase of supplied cooling water temperature under conditions of different enthalpy humidity ratio and weather. Therefore supplied cooling water temperature should be moderate (approximately 9-12 °C) to reducetotal energy consumption, where energy saving rate can reach 23.3%.

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