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Experimental Study on a Novel Optimal Differential Pressure Reset Method for Online Application in Chilled Water System

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Abstract

This paper firstly define most unfavorable thermodynamic loop to reflect the dynamic situation of terminal cooling load distribution, then present its online identification method that can easily applied for optimal reset of differential pressure. We use the optimal domain of maximum valve position among whole braches in chilled water system to calculate the variation of differential pressure setpoint, and control the pumps according to the optimal setpoint. We applied presented method to a VWF retrofit project in a Suzhou factory building and evaluate its energy saving effect through its equipped building energy management system. Experimental results showed that presented method can achieve 22%-53% pump power consumption savings compared to traditional control method. During the test period, the average level of valve position of presented method was highest among all tested control strategies. The optimal reset method of differential pressure presented in this paper is an energy efficient, high stability and easily online applied control method.

Keywords: Chilled water system; Optimal control; Differential Pressure Reset; Pump frequency control

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1. Introduction

The constant differential pressure (DP) set-point control strategy is adopted as a common control method in most VWF air conditioning systems in Mainland China. Its pump power consumption is generally very large because its

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DP set-point is generally higher than necessary. Therefore, the DP set-point should be continuously reset according to the variation in user load, which is called the variable DP set-point control strategy. In this control strategy, the method used to reset the DP set-point and the most suitable parameters for use as the optimal reset reference are critical issues that must be investigated. Aiming at exploring these issues, many researchers have emphasized DP optimal control strategies in various ways.

Early studies [1-3] have shown that the variable speed pumping technique produces a significant energy-saving potential in HVAC chilled water systems and cooling water systems. However, these studies have not paid specific attention to the regulating strategy of the pump control reference, such as DP, chilled or cooling water temperature. Some researchers have discussed the optimal reset of related controlled variables in variable pump control as one component in the entire system optimization based on various reference models. Cascia [4] introduces the temperature difference between supply chilled water and return chilled water to express component power consumption and notes that pump efficiency varies from 40%~80% in most variable speed control cases. Ma et al. [5] present an optimal control strategy using a systematic approach for the online control project of central chilled water systems. The strategy employs a model-based performance predictor, cost estimator, optimization technique, supervisory strategy, and a number of local control strategies to optimize the controlled variable for higher energy efficiency. Wang and Burnett [6] develop an online strategy to adjust the pressure set-point, which is referenced by the variable speed control of condenser cooling water pumps in an indirect water-cooled chilling system. The strategy connects the total power with pressure and identifies the system parameters to update the reference equation using an adaptive algorithm. Moore and Fisher [7] optimize DP to keep 1 valve almost completely open at all times for minimum pump power consumption; they apply this strategy to a secondary chilled water system. Jin et al. [8] investigate optimal reset strategies involving the optimal resetting of DP and supply chilled water temperature independently and the optimal resetting of DP prior to supply chilled water temperature in a secondary chilled water system. Their study shows that the optimal resetting strategy, integrated with DP and supply chilled water temperature, is the ideal choice.

The studies noted above show that the variable DP set-point control strategy has become a critical component of air conditioning water system optimal control. Most current studies focus on specific system and control problems, leverage the optimization of intelligent algorithms and the monitored parameters (valve position or temperature difference) for DP optimal reset, and obtain the desired energy-saving results. Variable DP set-point optimal control should take into account both online applicability and global user energy supply assurance. Therefore, it is necessary to further investigate DP optimal reset's reference entity or object and provide simple theoretical support for DP optimal reset that can reflect global user load change and be easy for online application.

This paper aims to demonstrate that the air conditioning water system DP optimal reset's reference entity is a most unfavorable thermodynamic loop. Based on the proposed most unfavorable thermodynamic loop's online identification method, the air conditioning water system's variable DP control method is further improved, and this method's feasibility is verified by practical application.

2. Methods-Definition of a most unfavorable thermodynamic loop

Fig. 1 shows a typical variable volume air conditioning water system. The system has *c* water chilling units, *m* primary pumps, and *n* air handling units (AHUs); G_{WSi} and G_{WRi} are the volumes of *i*th segments of the water supply main pipe and return water main pipe, respectively, expressed in units of m3/s; G_{Wi} is the chilled water volume of branch i, expressed in units of m^3/s; S_{Si} and S_{Ri} are the resistances of *i*th segments of the supply and return water main pipes, respectively, expressed in units of s^2/m^5; S_{Bi} and S_{Vi} are branch *i*'s pipe section resistance (including surface cooler resistance) and valve resistance, respectively, expressed in units of s^2/m^5; t_{WOi} is the surface cooler return water temperature of branch *i*, expressed in units of ºC; t_{SAi} and t_{Rai} are the supply air temperature and return air temperature of *i*th AHU, respectively, expressed in units of ºC; *i*=1, 2, •••, n.