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Distributed Pumping Chilled Water Hydronic System for Air-conditioning Systems

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Abstract

The most prevalent systems used in commercial chilled water pumping systems are Primary only, Primary-Secondary and Primary-Secondary-Tertiary systems. Pumping energy accounts for about 20% to 30% of the total chilled water plant energy. Code requirements in Singapore necessitate a pump power limitation for chilled water pumps of 349 kW/m^3/s (SS553, 2016). Similar pumping power limitation requirements can be found in ASHRAE 90.1 2016. Newer system designs are required to meet or exceed this pump power limitation in order to improve the overall chiller plant efficiency. This has increased the necessity to revisit some pumping strategies that have not been traditionally used for systems with standard sizes.

Coil pumping strategy is known to be the best solution for systems serving large air handling units (Taylor, July 2011). A Primary-Coil Secondary (P-CS) system is also introduced in the past (EDR, 2009) which uses a coil pump at the AHU’s and primary pump in the chiller plant. Recent improvement in efficiency of low flow high head pumps with variable speed drives have made using a P-CS type configuration more economical viable. This article provides the results of application of a Primary-Coil Secondary pumping system to a small commercial building.

System Description

The building consists of office areas and a factory floor as shown in Figure 1. The office areas are provided comfort cooling by chilled water based Air Handling Units (AHU’s). The factory floor is unconditioned with the exception of a testing room. The chilled water system is also used to supply cooling to process equipment.

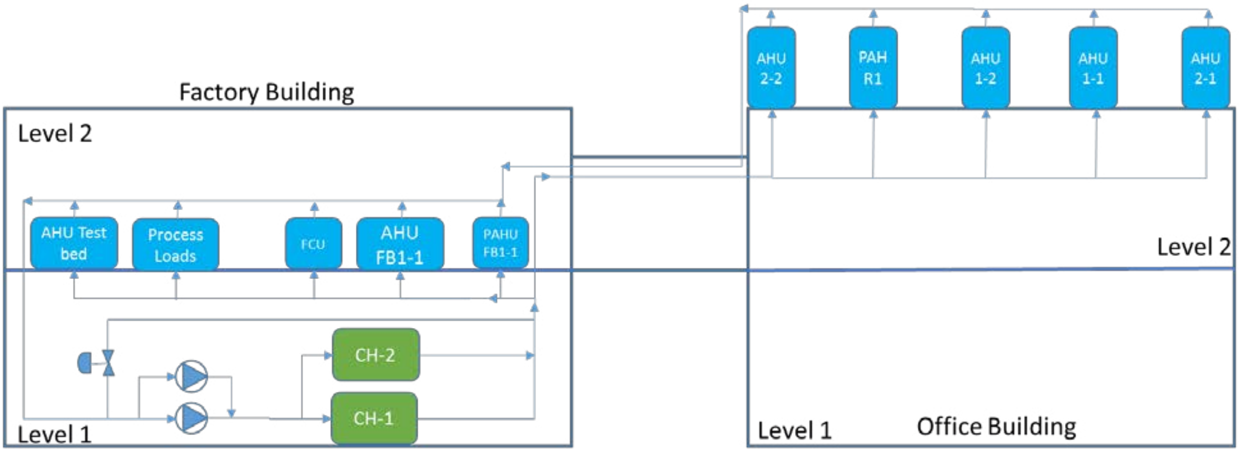

Figure 1 Pumping Schematic for the existing chilled water system

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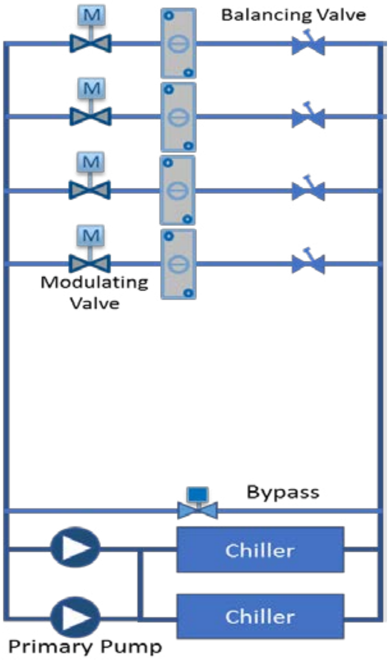

Figure 2 Variable Primary-Only Pumping System

Primary-Only System

The existing pumping system in the building is a primary only pumping system with two-way valves at the AHU's Figure 1. The two-way cooling coil valves are controlled to maintain the supply air temperature at its set point. Some meeting rooms and small office spaces are served by Fan Coil Units (FCU's). The FCU's are also equipped with modulating control valve that maintain the room temperature. For process equipment, a plate and frame heat exchanger with modulating control valve is used. A testing room in the factory block is conditioned using a constant volume AHU. A binary open/close valve is used to start and stop chilled water flow through this coil.

Chilled water is generated using two screw chillers which maintain the chilled water supply temperature at 10 °C. Two primary pumps distribute the chilled water through the system. The pumps are connected in a common header arrangement and equipped with Variable Frequency Drives (VFD's). One of the two systems is used as standby. The primary pump speed is controlled to maintain the loop differential pressure at a fixed set point. The differential pressure sensor is located at the main chilled water header closer to the chiller plant.

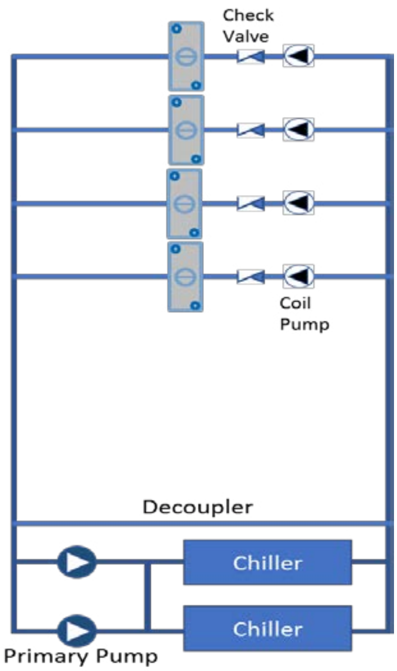

Figure 3 Primary-Coil Secondary Pumping System

Primary-Coil Secondary System

A primary-coil secondary system schematic is shown in Figure 3. The system consists of a primary pump which is used to circulate water in the primary loop and coil pumps at each load. The primary pump is used to ensure that fluctuation in the primary loop flow rate are at a minimum. The minimum pump speed is based on the minimum flow required by the chiller. A magnetic flow meter is used to measure the flow rate in the primary loop. Sudden flow variations in the loop can trip the chiller on low evaporator pressure when the chilled water supply temperature is set low. For AHU's and FCU's the coil pump speed can be modulated to maintain the supply air temperature. Alternatively, multiple loads in a branch can be supplied by a single coil pump. In such case the pump can be controlled to maintain the pressure in the particular loop.

The modulating control valve can be replaced by a check valve. In the current implementation of the modulating valve was used as on/off valve based on the pump status. This is done to prevent short-circuiting of water when a particular load is switched off. The coil pumps modulate the speed to provide the required flow to the load. Balancing valves are not required in such a system since the pumps control the flow through each coil. In addition to reduced pressure drop this can also help in off-setting some of the cost of the coil pump.

Computer Simulation

The cooling load of a building changes dynamically depending on the variation of occupancy, solar irradiance, outdoor temperature and humidity. The dynamic changes in relationship between the pressure and flow rate at different locations of the piping network and under various load conditions must be understood clearly to ensure that the control strategies can meet the ever-changing conditions. A 1-D Computation Fluid Dynamics (CFD) simulation software package was used to perform the simulations.

Based on the as-built Air-Conditioning and Mechanical Ventilation (ACMV) drawings, a virtual piping network of the building located in Singapore was developed. Virtual models for a P-only system and a P-CS system were created. Figure 4 is the P-