THE STRATEGY BETWEEN HIGH PRECISION TEMPERATURE CONTROL AND ENERGY SAVING FOR AIR-CONDITIONING SYSTEM

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Abstract

In the Taiwan Light Source (TLS), several studies related to the temperature stability of an air-conditioning system continue to progress. Use of a new control philosophy can minimize effectively the variations of temperature. A highly precise control of temperature within ±0.05 °C for an air-conditioning system has been conducted to meet the more critical requirement of stability. Because energy saving is important, the power consumption of an air-conditioning system was upgraded with the intention of a major decrease. This paper addresses some experience between highly precise control of temperature and energy saving in the operation of an air-conditioning system. The significant improvements prove that both targets can be achieved concurrently.

INTRODUCTION

In the accelerator field in general, thermal waste can be treated with deionized water (DIW) and air conditioning. The cooling systems must be well designed so that the accelerator machine can be less subject to thermal effects. As the utility system is a highly critical subsystem affecting the beam quality and reliability, much effort has been devoted to its design. Here we address mainly the specific design of the heating, ventilation and air-conditioning (HVAC) systems of the finalized utility system. To achieve a highly precise control of the temperature of air within ±0.05 °C, the preliminary work [1] on the HVAC system serves as a basis of further comprehensive investigation for the future Taiwan Photon Source (TPS). Besides the stable quality, the utility system is chosen carefully with a satisfactory energy-efficient ratio (EER) and coefficient of performance (COP). In general, the utility system has always sufficient capacity to meet a variable thermal loading caused by the variations of season, day-and-night or facility addition.

The components of HVAC systems include dampers, supply and exhaust fans, filters, humidifiers, dehumidifiers, heating and cooling coils, ducts and various sensors. Most of these components relate to HVAC system directly affect the stable control and energy consumption of a HVAC system. Because of a space limitation, we focus on only several aspects to improve energy efficiency, including heat recovery, temperature set-back, adjustable-speed drives, systems for energy monitoring and control, and address the control philosophy for a compromise between temperature stability and energy saving.

RUN-AROUND HEAT AND MOISTURE RECOVERY SYSTEM

Several systems for heat recovery, including the rotary wheel, fixed plate, heat pipe and run-around coil, have been considered in laboratory applications. The performance of a run-around coil applied in laboratory buildings has demonstrated that heat recovery plays an important role in energy conservation [2]. It can recover both sensible and latent energy and has no direct cross contamination. Except for the pump, the system has no moving parts, and the pressure drop accounts for the fan power required to move air between the pre-cooling and pre-heating coils. The operating cost of such a system is thus expected to be minimal.

These two coils are connected to form run-around coils as shown in Figure 1. The hot end absorbs heat from the return air. The absorbed thermal energy is transferred to the cold end, at which the cold supply air is heated. The run-around coil decreases mechanical cooling and heating energy as the return air entering the cooling coil and the chilled air entering the heating coil. Water is circulated continuously through two coils. This system might decrease the need for a dehumidifying and reheating source and thereby decrease the operating cost of the system.

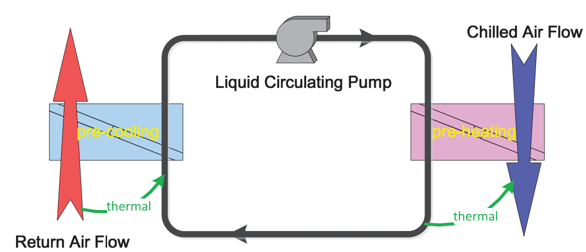

Figure 1: Scheme of run-around system to recover heat and moisture.

The proposed HVAC with run-around coils, illustrated in Figure 2, has the advantage of an operating cost that is smaller than for any other method. The four heat exchangers include pre-cooling, cooling, pre-heating and heating coils. To maintain a suitable room humidity, the temperature of the air flow via a cooling coil is controlled at 13 °C. To achieve a highly precise control of temperature, the temperature of the air flow via a heating coil must be maintained at a constant temperature 20 °C, within ±0.05 °C. Sensible heat withdrawn from the warm air on its way to the pre-cooling coils is carried by the circulating water to the pre-heating coils. The latter coils

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then return the sensible heat to the chilled air leaving the pre-heating coils. Any sensible heat added to the air flow by the pre-heating coils is exactly equal to the heat removed by the pre-cooling coils. The required refrigerating capacity thus decreases with the run-around cycle to reheat a chilled air supply. The larger is the amount of heat transferred from the pre-cooling coils to the pre-heating coils by the circulating water, the greater is the required surface area of the coils and the larger is the quantity of required circulating water. The water circulating pump with an inverter can distribute thermal energy among four coils to achieve concurrently the purposes of energy saving and stable temperature control.

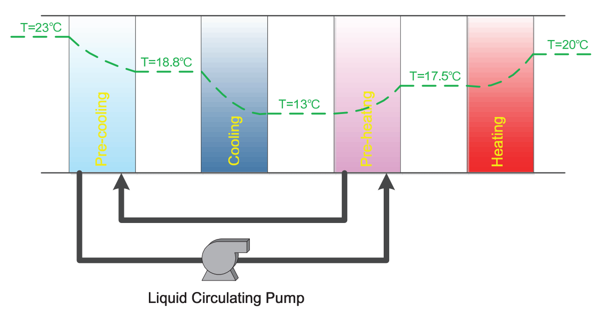

Figure 2: Proposed AHU with run-around coils.

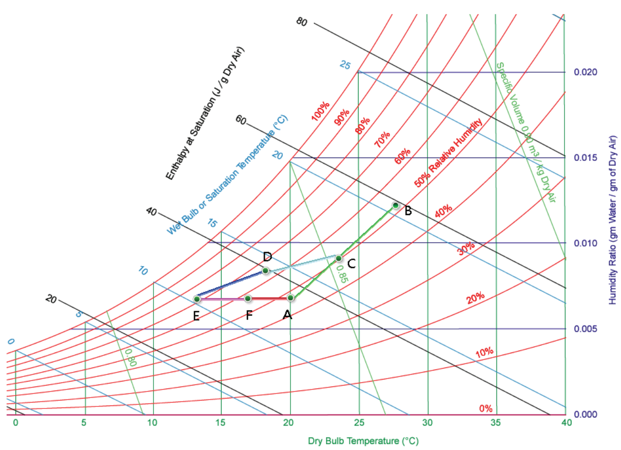

Figure 3: Psychometric diagram of HAVC commissioning with run-around coils.

The cycle that the air follows is illustrated on the psychometric chart as shown in Figure 3. Point A represents the air in the conditioned room; point B represents the exhaust air from machine. Point C is the condition of the mixture of conditioned and exhaust air entering the pre-cooling coils. The air mixture is cooled with the pre-cooling coils along a line to point D. The air at D enters the cooling coils, and is cooled along curve DE to point E. Air at E is then heated with the pre-heating coil to point F. By means of the highly precise control of temperature, air at point F is heated again by the heating coil. The air at A is then delivered to the conditioned room in which it absorbs heat and moisture. Air at lines CD and EF has a strong correlation with the water circulation pump. The pump speed should be controlled carefully for a compromise between energy saving and temperature control.

EFFICIENCY UPGRADE FOR HVAC

Besides the run-around system for heat and moisture recovery, the work focuses on several aspects to improve energy efficiency as follows.

Temperature Set-back

If the HVAC supply for general users, such as in offices, includes turning building temperatures down in winter or up in summer and decreasing ventilation during periods not in use, such as at weekends or non-machine times, these measures can result in significant savings in HVAC energy consumption.

Adjustable-speed Drives

A partial load is always operated in the HVAC system, because the design of the cooling capacity is based on the stiff condition. Adjustable-speed drives or inverter drivers can be installed on recirculation fans to match precisely the flow based on the system demand. Energy consumption can be decreased considerably, as the fans are not constantly running at full speed.

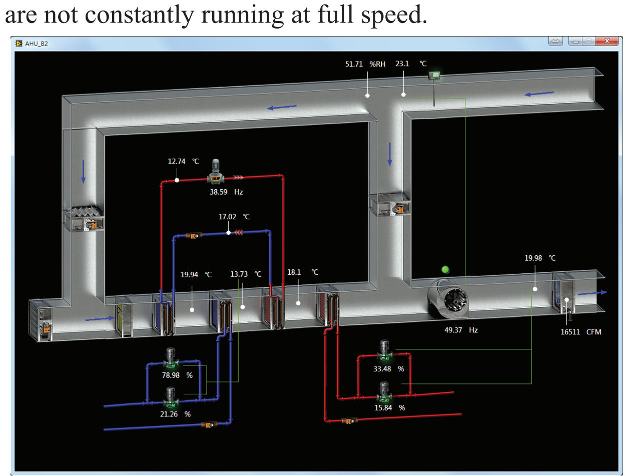

Figure 4: Graphic view of online monitor of the HVAC system.

Control and Monitoring System

An effective system for energy monitoring and control provides the operation of HVAC equipment by efficiently managing and optimizing the consumption of HVAC system energy. This system also provides valuable diagnostic data to track energy consumption and to identify potential HVAC system problems. We thus designed an integrated architecture of a control and archive system for a utility facility [3]. The programmable automation controllers (PAC) with a FPGA function have also been implemented in this run-around system for heat and moisture recovery for applications of highly precise control of temperature and optimal energy. This system adopts mainly PSP protocols to enable all human-machine interface (HMI) servers or local touch-screen panels to exchange information as shown in Figure 4. The archive can provide the past commission status for operators to decide a strategy for operation and maintenance.

OPTIMAL CONTROL FOR A STABLE TEMPERATURE AND ENERGY SAVING

For precise control, we use a commercial controller (NI PAC), which has a 24-bit RTD module with a temperature range -200 ~ 850 °C that is operable in a high-resolution mode with noise level 0.003 °C. The air flow via the cooling coil is controlled based on the dew-point temperature for humidity control. According to the outlet temperature feedback, the supply air via the heating coil must be well controlled within ±0.05 °C, as shown in Figure 5. The temperature sensor and control valve must be chosen carefully. In general, an equal percentage of control valves has been selected corresponding to the heat exchangers. However, the action of the control valve cannot match the control command, because valves generally have a rangeability 2~3 %, which results in a step control and misleads for a continuous PID control. This variation of the temperature of the supply air has drifts and jumps. To overcome this problem, an oscillating control of valves has been implemented. The control mode can actuate the valve control below 2 % fine tuning, unlike previously. So as to cover the large fluctuation for on-off thermal loading, a heuristic logic for two valves of disparate size has also been adopted

Besides, the return air also have been controlled based on the inlet air temperature by adjust fan speed with inverter driver. The purpose is to maintain the room temperature with constant temperature gradient for thermal expansion effect of machine and decrease energy usage. Between the two run-around coils, the water flow also has been adjusted by pump speed with inverter to distribute thermal energy among four coils. The overall control blocks are shown in Figure 6.

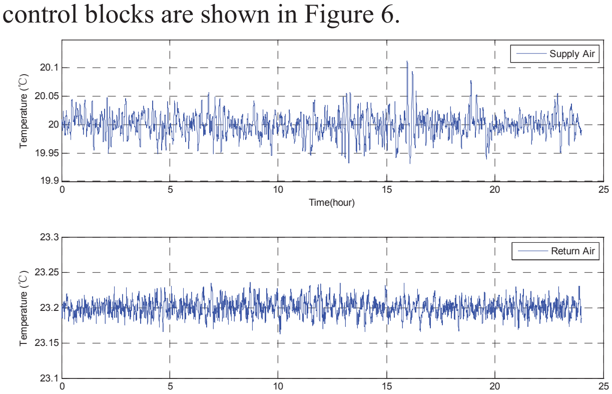

Figure 5: Highly precise control of temperature with run-around coils.

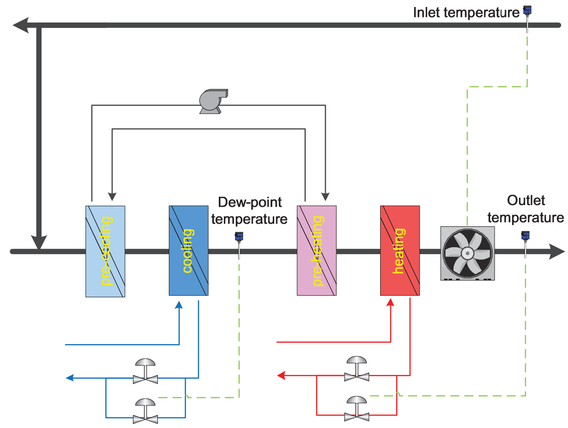

Figure 6: Block diagram of the control philosophy.

CONCLUSION

This paper presents an integrated strategy between highly precise control of temperature and energy saving for an air-conditioning system. The efforts are devoted to develop a run-around system for heat and moisture recovery combined with highly precise control of temperature. Our experimental results show that the temperature can be controlled within ±0.05 °C, and the energy saving can attain a 30 % decrease. The schemes and experience of the TLS can been adopted for the future Taiwan Photon Source.

ACKNOWLEDGEMENT

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