UTILITY COOLING SYSTEM DESIGN FOR THE TAIWAN PHOTON SOURCE

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Abstract

National Synchrotron Radiation Research Center (NSRRC, Taiwan) has completed an open bid for a utility system for Taiwan Photon Source (TPS). The detailed design and criteria of the utility cooling system, including cooling-water and air-conditioning systems, have also been considered and confirmed. From controls to the facility, all devices were designed and optimized to meet critical requirements of great reliability and stability. We focus mainly on the evaluation of the thermal load and its removal to achieve the utmost efficiency and performance of the system. A novel system structure and control strategy have been realized.

INTRODUCTION

TPS infrastructure including a civil and utility system have been under construction since 2009 December. As the utility system is a most critical subsystem affecting the beam quality and reliability, much effort has been devoted to these designs [1][2]. Here we address mainly the specific design of the cooling system of the finalized utility system.

In the accelerator field in general, thermal waste can be treated through deionized water (DIW) and air conditioning (A/C). The cooling systems of the water and air sides must be well designed, so that the accelerator machine can be less subject to thermal effects. The main cooling-water facility of TPS, including cooling towers, chillers, heat pumps and water pumps, have heavy-duty mechanical rotation, which induces vibration and power noise. This heavy-duty facility is located in utility building Ⅲ, as was decided to separate the mechanical and electric interference from the TPS storage-ring building. A trench for all water piping between utility building Ⅲ and TPS storage-ring building is considered also to isolate mechanical and electric interference. The air-handling units (AHU) located on the inner and outer rings provide highly stable cooling air for the storage-ring tunnel, control-instrument areas (CIA), experimental hall and Linac area. The arrangement of all facilities conforms to 3D SolidWorks drawings, which can precisely avoid spatial interference and provide an optimal design for all facilities and machines as shown in Figure 1. Programmable automation controllers (PAC) have been implemented in this hybrid control system for highly precise control.

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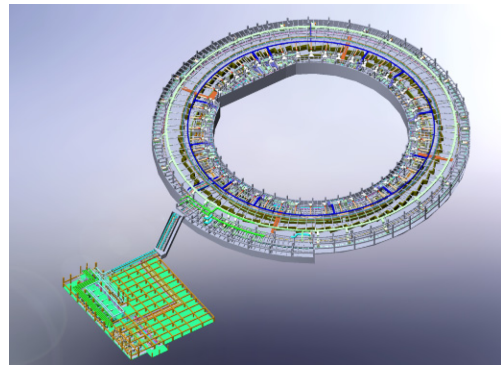

Figure 1: 3D drawing of utility design.

COOLING-WATER SYSTEM

The cooling-water system involves a cooling-tower water, chilled water, hot water and DIW, of which specifications for TPS are listed in Table 1. All water circulates in a closed loop of adequate control, which must provide a cooling source at a stable temperature and pressure. The return DIW flows through heat exchangers for heating and cooling and then flows via a mixing buffer tank for highly precise temperature control. Each DIW system has two pumps with inverters that realize flow regulation, energy saving and uninterrupted commission.

In this aspect of the storage-ring building, each DIW system has been divided into 48 manifolds for the 24 sections of the accelerator machine as shown in Figure 2. Each manifold has filters, flow-balance valves, and sensors for temperature, pressure and flow, which provide optimal flow balance and real-time DIW status as shown in Figure 3. Each inlet and outlet piping connected with the accelerator machine has a flexible design of piping to prevent the propagation of vibration.

Table 1: Specification of the cooling-water system

	Temperature	Pressure	Flow/Capacity
Cu Deionized water	25±0.1℃	7.5±0.1kg/cm²	1670GPM
AL Deionized water	25±0.1℃	7.5±0.1kg/cm²	410GPM
RF Deionized water	25±0.1℃	7.5±0.1kg/cm²	1285GPM
Beamline & Booster Deionized water	25±0.1℃	7.5±0.1kg/cm²	1285GPM
Cooling Tower Water	32±0.5℃	2.5±0.1kg/cm²	12600RT
Chilled Water	7.0±0.2℃	2.5±0.1kg/cm²	8400RT
Hot Water	50±0.3℃	2.5±0.1kg/cm²	2000kW

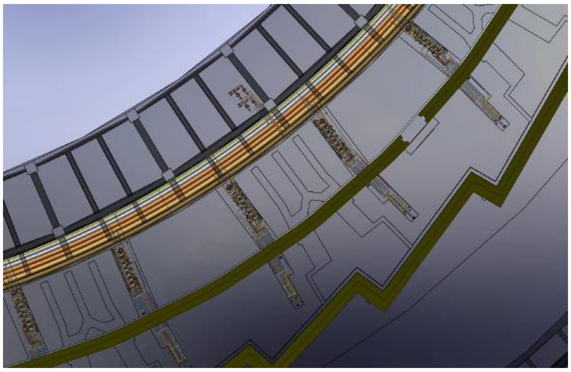

Figure 2: Manifolds for each section of the accelerator.

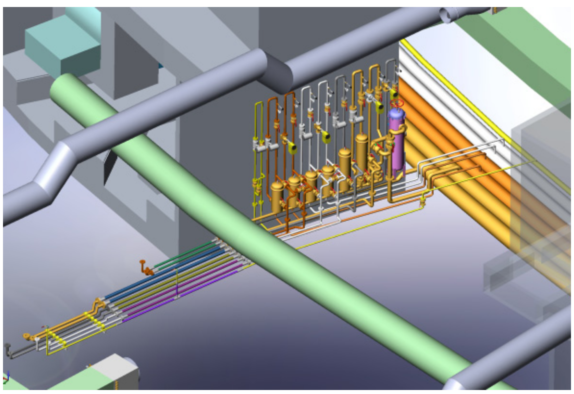

Figure 3: Manifold arrangement near a CIA.

Water treatment is an important issue of a DIW system. Impurities in DIW typically include particles, suspensions, electrolytes, micro-organisms, organic substances and gases that must be removed with a physical or chemical mechanism as listed in Table 2. The sand filter, active-carbon filter, ion-exchange device, reverse-osmosis device, micro-filter, ultraviolet sterilizer and dissolved-oxygen membrane have been designed to sustain the water quality. Of the primary loop flow, 5 % DIW flows through this recycle loop as shown in Figure 4; the entire DIW system must meet specifications listed in Table 3.

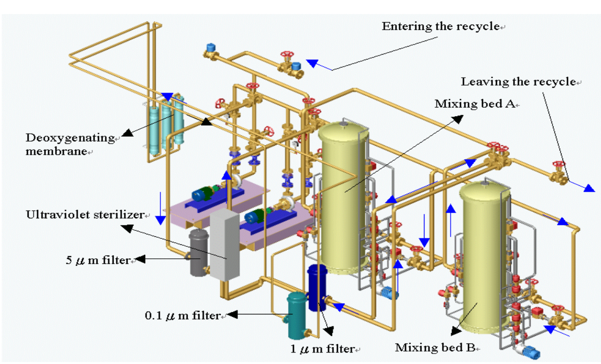

Figure 4: Structure of water treatment.

Table 2: Mechanisms of the water-treatment system

	Suspension	Electrolyte	Corpuscles	Micro organisms	Organic substance	Gas
Sand Filter	○		△	△	△	
Active Carbon Filter			△		○	
Ion-Exchange Device		◎	△		△	
Reverse Osmosis Device		◎	◎	◎	◎	
Microfilter			◎	○	○	
Ultraviolet Sterilizer				◎		
Dissolve Oxygen Membrane						◎

Table 3: Specifications of the water-treatment system

	Resistivity	Dissolve Oxygen	pH
Cu Deionized water	>10M ohm	<10ppb	7±0.2
AL Deionized water	>10M ohm	<10ppb	7±0.2
RF Deionized water	>10M ohm	<10ppb	7±0.2
Beamline & Booster Deionized water	>10M ohm	<10ppb	7±0.2

AIR-CONDITIONING SYSTEM

The A/C system is another critical cooling system relevant to a facility without cooling water such as an insertion device. The main facility, called AHU, is located in the TPS storage-ring building, which is classified into five main areas -- storage-ring tunnel, CIA, experimental hall, Linac area and Linac control room. The detailed specifications of the A/C system are listed in Table 4. The make-up air unit (MAU) provides fresh air to mix with recirculated air as shown in Figure 5. The mixed air sequentially flows through heat exchangers for cooling and heating and then provides cooling air with a highly stable temperature.

Because the issues of spatial interference about all accelerator machines and related utility facilities in a storage-ring building are highly complicated, a 3D drawing is implemented to decide the location of facilities and piping. Figure 6 shows a top view of air-duct piping in one section. Figure 7 shows a zigzag connection between the AHU and CIA area. The exact arrangement avoids all spatial interference for future construction.

Table 4: Specification of the air-conditioning system

	Units	Capacity (RT)	Capacity (CFM)	Temperature	Controller
Tunnel	12	≧43.5	12000	25±0.1℃	PAC
CIA	12 1	≧52 ≧26	6000	25±0.1℃	PAC
Experimental Hall	24	≧81.3	15000	25±1℃	DDC
Make-up Air Unit	12		13000		DDC
Linac Area	1	≧60.2	14000	25±0.1℃	PAC
Linac Control Room	1	≧43.5	10000	25±0.1℃	PAC

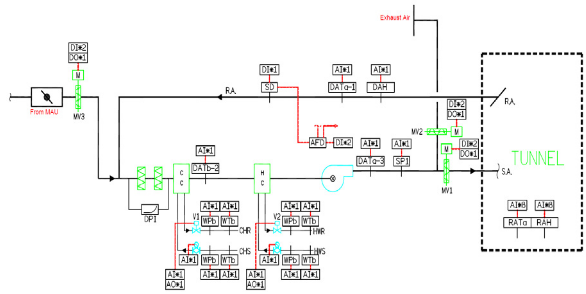

Figure 5: Structure of the tunnel AHU system.

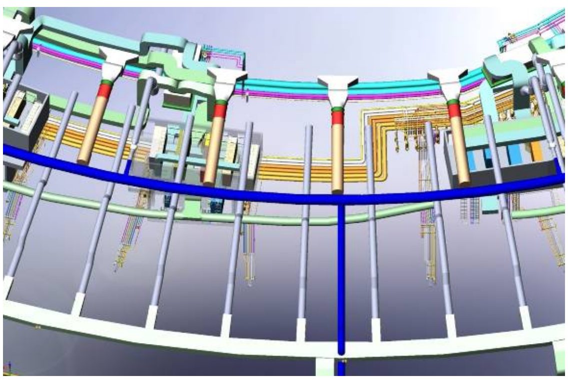

Figure 6: Top view of air-duct piping.

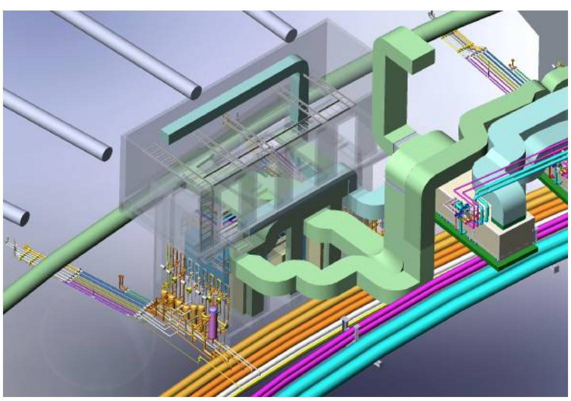

Figure 7: Arrangement of air ducts near the CIA.

CONTROL SYSTEM

We designed an integrated architecture of a control and archive system for a utility facility [3]. A server-client relation is adopted to construct this utility network system. The system has five levels of network architecture -- a remote-viewer level, data-service level, data-processing level, controller level and a device level, shown in Figure 8. The controller level involves a direct digital controller (DDC), programmable logical controllers (PLC) and PAC, which are individually responsible for separate mechanisms for precise control. In particular, a new PAC with a FPGA function is applied in this system for applications of comprehensive and highly precise control. This system adopts mainly PSP and FTP protocols to build a data-exchange platform, which enables all SCADA servers or local controllers to exchange information. The new archive system can provide greater protocol integration, including dynamic data exchange (DDE), OLE process control (OPC), PSP, EPICS, Modbus, dedicated firmware etc. The design of this control system is beneficial for the commissioning, operation, management and analysis of the entire system.

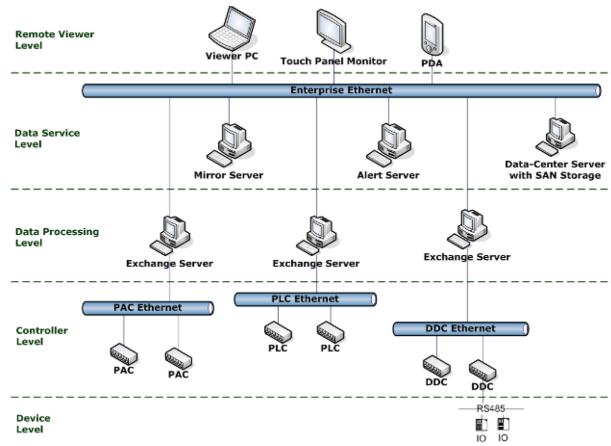

Figure 8: Network architecture of the control and archive system.

CONCLUSION

In this latest design of a utility cooling system for TPS, the main layout has been finished in 3D drawing to solve spatial interference. Some utility schemes and experience of the TLS have also been adopted. For highly precise control, the new design, such as a mixing buffer tank, flow-pattern simulation and new PAC devices have been included. The energy-saving issue has also been carefully considered.

ACKNOWLEDGEMENT

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