

THE FLEXIBLE CUSTOMIZED SUPERVISOR AND CONTROL SYSTEM FOR UTILITY IN TPS

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Abstract

In order to maintain and operate a synchrotron radiation light source well requires quite a few efforts. All parts of the big machine, including vacuum system, all kinds of magnets, RF facility, cryogenic equipments, radiation security, optic devices and utility equipment must cooperate in harmony to provide high quality light. Any one of the above system contains lots of analog or digital signal transmission, not to mention the vast range of utility. Numbers of programmable automation controllers (PACs) are applied in utility system in TPS to ensure the utility operates normally. In addition to the high reliability and distribution, the flexible programmability of PAC is the most critical feature in this project. A well-designed program, Archive Viewer, provides a platform for showing these big data from all distributed systems. The architecture of the server system for utility is described in this paper as well.

INTRODUCTION

There are mainly three kinds of resources provided by the utility group in NSRRC. First, the de-ionized water (DIW) system offers cooling water to carry out waste heat generated by accelerator operation. The DIW system is composed of four subsystems in TLS and TPS respectively. The copper (Cu) DIW subsystem provides with cooling de-ionized water to take out exhaust heat while the magnet system and power supplies operate. The vacuum chambers in NSRRC are mostly made of aluminium; therefore, the aluminium (Al) subsystem is in charge of waste heat from the equipments of the vacuum group. The RF subsystem is for RF transmitters and cavities, and the Bl (beam line) and Bo (booster) subsystem is for the usage of all beam line devices. Second, the air system including air-condition system and compressed air system offers an environment with stable temperature and sufficient air pressure for pneumatic equipments running. The last part is the most critical, the reliable electric system ensures all electronics are working. All the three elements seem fundamental, however, an advanced facility like particle accelerator need a stably-operated and well-controlled utility system to realize. Referring to former studies of utility group in NSRRC, it is strongly proven that the stability of utility affects the operation of accelerator [1]. This article will focus on the water system and air system of TPS utility.

The temperature of DIW system is globally controlled within $\pm 0.1^\circ\text{C}$ in TLS due to former efforts [2]. With the

experiences from TLS, the precise temperature control could be achieved by many local controllers. The specifications of TPS water subsystem are listed in Table 1. The capacities of cooling water, chilled water and hot water are larger than normal consumption. The over design capacity avoids unexpected heat load shock and ensures all systems work under the most suitable conditions.

Table 1: Specifications of Water Subsystems of TPS

	Temperature	Pressure	Capacity
Cu DIW	$25 \pm 0.1^\circ\text{C}$	$7.5 \pm 0.1\text{ kg}$	1659 GPM
Al DIW	$25 \pm 0.1^\circ\text{C}$	$7.5 \pm 0.1\text{ kg}$	380 GPM
RF DIW	$25 \pm 0.01^\circ\text{C}$	$7.5 \pm 0.1\text{ kg}$	1284 GPM
Booster DIW	$25 \pm 0.1^\circ\text{C}$	$7.5 \pm 0.1\text{ kg}$	1238 GPM
Cooling Tower	$32 \pm 0.5^\circ\text{C}$	$2.5 \pm 0.1\text{ kg}$	12000 RT
Chilled Water	$7.0 \pm 0.2^\circ\text{C}$	$2.5 \pm 0.1\text{ kg}$	8400 RT
Hot Water	$50 \pm 0.3^\circ\text{C}$	$2.5 \pm 0.1\text{ kg}$	1600 kW

CONTROL SYSTEMS OF TPS UTILITY

There are three typical controllers used in the utility system of TPS. They are Programmable Automation Controller (PAC), Direct Digital Control system (DDC) and Programmable Logic Controller. Direct digital control is an automated control by a computer, which is broadly used on HVAC (Heating, Ventilation and Air Conditioning) control systems based upon PLC technology. In the TPS project, DDC controllers are widely used in every AHU (Air Handling Unit) to achieve precise temperature control. Local controllers are responsible for the temperature steadiness of local area. Due to the diversity of air condition demands, there are quite a few typical models to satisfy all kinds of requirements.

The mathematical model had been established to find out the relationships between the beam orbit and the supplied air temperature [3]. The beam orbit stability will become worse once the fluctuation of environmental temperature exceeds 0.2°C . Based on this thesis, lots of efforts had been made to increase temperature steadiness during TLS. With the endeavours of TPS project, the fluctuation of supply air temperature is greatly reduced within $\pm 0.1^\circ\text{C}$. By means of PAC, the fluctuation could be minimized within $\pm 0.01^\circ\text{C}$ in laboratory. Owing to much more accurate sensors and high performance

controllers, most complicated algorithm could be applied to carry out precise control. The architecture of the utility archive server system is shown in Figure 1. It is divided into five levels: Device Level, Controller Level, Data Processing Level, Data Service Level and Viewer Level. Device Level, including all kind of actuators, variable air volume (VAV) boxes, flow meters and so forth, which are communicating with local controllers by RS-485 protocols. These PAC and DDC controllers exchange data with PAC server and DDC server individually. These servers process these data and send them to the data centers to keep in reserve for historical data. The mirror server back up the data centers. These PAC or DDC controllers will send commands to local devices by following the algorithm. All upper and lower limit values are defined in servers. If these values are beyond the limitations, alarm messages will be sent to responsible colleagues by SMS message or e-mails. The colleagues can check the latest data or review the past readings by their personal computers or portable devices with Archive Viewer, which is a data archive in NSRRC.

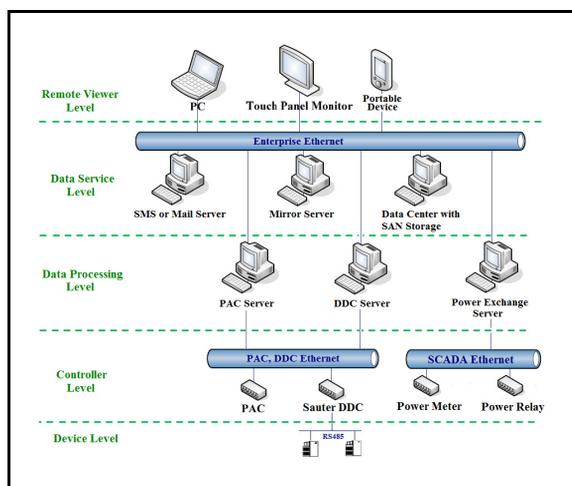


Figure 1: The architecture of the overall archive server system.

Figure 2 shows one of the human machine interface (HMI) of the Archive Viewer. From the HMI window, most important information is revealed on this simplified system diagram. The red parts represent heat exchanger system, the blue ones are cool exchanger system, and the green ones are de-ionized water system respectively. This diagram shows us the temperatures and pressures of inlet and outlet of the devices. By clicking these graphics, the commands could be sent to the local controllers and modify the parameters of the local devices. Remote control let finite utility personnel handle a huge site like TPS well.

Based on the architecture, local control and monitoring system could be established easily as long as the network is available in such area. Over the years, these controller systems have been used in high precision temperature control system, vibration measurement [4], power

monitoring system [5] and so on. Thanks to the variety of I/O module devices, these controllers are applied in many applications.

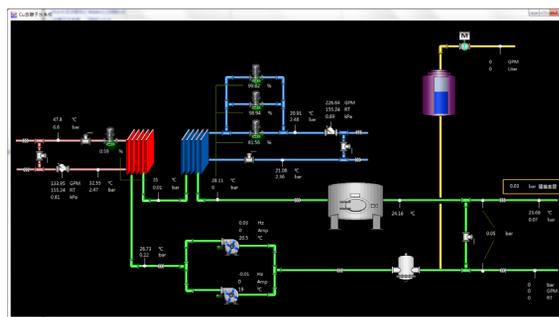


Figure 2: Human machine interface of the archive viewer.

The Compact RIO of National Instruments is widely used in utility application in TPS. Its ability of high speed analogue measurement is suitable for high-speed dynamic measurements, such as vibration and sound. The rugged and reliable embedded hardware meets in harsh environment and confined space. Size and weight are critical in many embedded applications, especially in industrial standard. Most important, the variety of controllers, reconfigurable chassis and hundreds of functional I/O modules give the flexibility required to go from prototype to deployment to multiple controllers.

DATA VARIATIONS AND SYNCHRONIZATION

In order to achieve precise control, it takes more considerations on sensor selection. The commercial 24-bit RTD module manufactured by NI ranging from -200 to 850°C is chosen to meet the requirements of precise temperature measurement. It could operate in high-resolution mode with 0.003°C noise level, or in high-speed mode with less resolution but higher frequency. As shown in Figure 3, the noise level in high-resolution mode is nearly neglectable comparing to the noise level in high-speed mode. Before 3200s, the temperature variations is less than 0.003°C, and increases to about 0.15°C after 3200s which is in high-speed mode. The application of sensors and operation modes should be chosen carefully to avoid undesired signals.

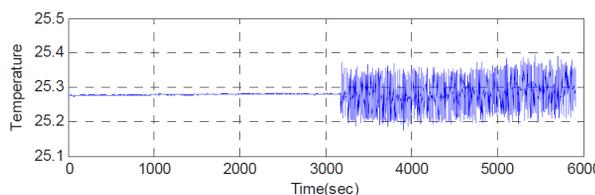


Figure 3: Noise level of RTD module in different modes.

The synchronization of separated controllers affects the judgement of event timing. Each controller has its own clock rate to manage the data timeline. Since all data will be collected to servers, the synchronization of different

controllers and servers could be the clues finding if there is any block among network. As Figure 4 shows, the eight rows of dots present eight individual timelines of servers. Left side of the window indicates each server clock. The third and the fifth servers are 2 seconds faster than other servers. It means either these servers have larger data loading or the server network jams.

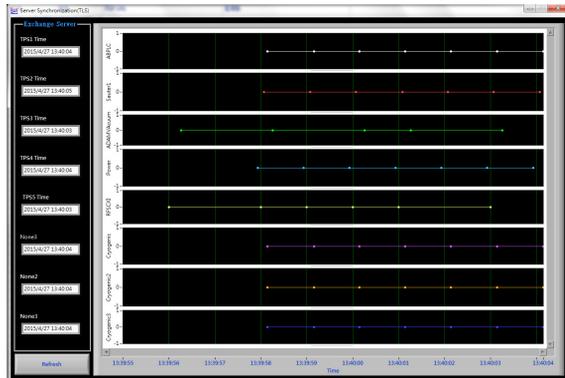


Figure 4: Synchronization of utility servers in TPS.

CONCLUSION

In this article, the most common controller systems used for utility in TPS are represented. The DDC system is used mainly in HVAC systems, and the PAC is in charge of de-ionized water and precise control systems. The flexible usage makes electromechanical control and system monitoring easier and more reliable. Whole utility system works well relying on these sturdy and accurate local controller systems. As the progress of computer technology, more complicated algorithms can be applied in these controllers. Many readings could be calculated in advance in controllers and then saved in servers as historical data through network. Local controlling ensures the utility operation without interruptions and response as soon as possible. It help us to manage the extensive site with the minimum human resource.

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