DESIGN OF THE VACUUM INTERLOCK SYSTEM FOR THE TPS STORAGE RING

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Abstract

Aluminium alloy was chosen as the material for the vacuum chamber, and oil-free manufacturing and ozone-water cleaning were used to obtain an ultrahigh vacuum in the TPS vacuum system. The vacuum system of the storage ring is divided into 24 periods and there are six ion gauges, eight ion pumps and six gate valves in one cell. An interlock system is designed to monitor and to control the vacuum devices to maintain an ultrahigh vacuum. As the vacuum chamber is directly exposed to the powerful synchrotron light, the status of the cooling water and temperature of the vacuum chamber are also monitored. The hardware, software and their associated interlock logic are described herein.

INTRODUCTION

Taiwan Photon Source (TPS) is a low emittance 3-GeV synchrotron storage ring under construction in Taiwan; the circumference is 518.4 m and it has 24 periods of unit cells (bending section) and straight sections, six of 12 m and 18 of 7 m. The large aluminium bending chamber for the beam duct was designed for localized pumping near the crotch absorbers in the antechamber and to obtain a low impedance with a smooth surface. The booster ring is inside the storage-ring tunnel; its circumference is 496.8 m. The vacuum pressure of electron storage ring < 20 nPa is designed to reach 10h beam lifetime at 400 mA beam current [1]. In the TPS vacuum system, an interlock system is designed to protect the ultrahigh vacuum condition and to monitor the status of all vacuum devices and to provide a remote-control capability of each device.

Since a vacuum interlock system for Taiwan Light Source (TLS) has been developed since 1993. The status of all vacuum devices is monitored; the vacuum system is hence protected when vacuum failure occurs. In addition, an alarm system is established to monitor the temperature of the vacuum chamber and the rate of flow of cooling water to avoid the vacuum chamber melting. In 2005, the interlock system was upgraded on including interlock systems on all front ends and a temperature alarm system to assure the quality of the vacuum of the storage ring. The vacuum interlock system and logic-design concepts are described in the following sections.

INTERLOCK SYSTEM

Figure 1 illustrates the layout of a typical vacuum system for one period with straight and bending sections, which has two sector gate valves with RF shielding (SGV), two pumping gate valves (PGV), two front-end valves (FEV), six metal angle valves (MAV), six ionization gauges (IG), ten non-evaporable getter (NEG) pumps, eight sputtering-ion pumps (IP), and eight turbo-molecular pumps (TMP). The vacuum chambers of the bending section contain two short ducts S3, S4, and two bending chambers B1, B2, whereas ducts S1 and S2 are located on both ends of the straight section [2].

There are four trenches located inside the tunnel between the inner wall and each unit cell to serve the cabling and piping from suppling system of vacuum devices: cooling water with 25℃ for aluminium chambers (Al system) and absorbers (Cu system); compressed air at 6 kg/cm^2 for pneumatic valves and connection cable of length 20 m between the sensors and the controllers located in the control-instrument area (CIA), distributed in the core area of the storage ring. There are four cooling-water loops for aluminium chambers and four loops for absorbers; each loop contains a flow meter and temperature sensor to monitor the status of the cooling water. Figure 2 shows the geometry of one unit cell, control instrument area, and the location of the trenches. Four racks are used for the vacuum power requirement in the control instrument area for each unit cell. Uninterruptable power supplies (UPS) are used to ensure that the devices work well when the line power fails.

The programmable automation controllers (PAC, National Instrument, NI) with real-time controllers and field-programmable gate arrays (FPGA) are used to undertake all distributed data acquisition. This FPGA function enables us to incorporate extremely time-critical functions into the hardware, which uses the ability of sampling rate 1-2 kHz, and then a DMA and interrupt function to transfer data into the real-time controller RAM without delay. The main server located on the same network can access these data via Ethernet to conduct rapid data storage [3]. The network architecture of the control and archive system is shown in Figure 3.

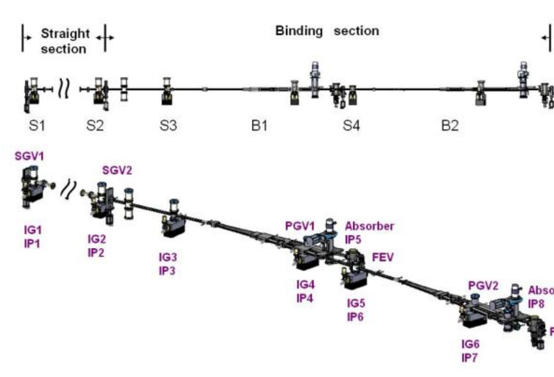

Figure 1: Layout of a typical vacuum system for one period including straight section and bending section.

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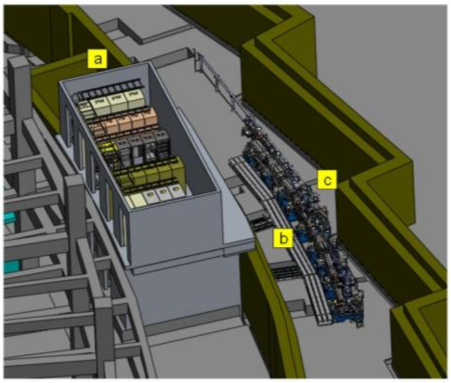

Figure 2: Geometry of (a) control instrument area (CIA), (b) trenches, and (c) one unit cell.

In one vacuum period, about 200 signals including vacuum readings, pressure trigger points, valve status, control button and temperature readings of vacuum chamber etc., are collected into the interlock system, programmed as a logic control panel, and recorded in data archive servers for analysis and monitoring. Each control panel that corresponds to one period can communicate and be subject to remote control via Ethernet anywhere. One prototype of the interlock control panel as SR02 section is shown in figure 4.

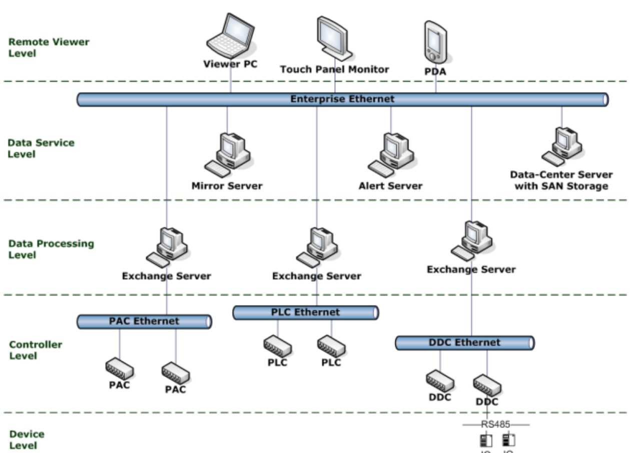

Figure 3: Network architecture of the control and archive system.

LOGIC DESIGN

The vacuum-interlock control system maintains the ultrahigh-vacuum condition and protects the vacuum devices of the storage ring. The logic considerations are described in the following [4].

(1) Manual on and fail-safe principle: To maintain the vacuum devices safely, all devices can be switched on only after push buttons are confirmed, and be switched off automatically as soon as the interlock is triggered. For example, ion pumps are switched off automatically when the vacuum pressure suddenly increases beyond 1×10^{-4} Pa, but can be switched on manually only as soon as the pressure recovered.

(2) Ion-pump protection: The ion pump can be switched on only when the local pressure is less than 1×10^{-4} Pa. This practice extends the lifetime of the ion pump and prevents particle production from inducing a dust-trapping problem on the electron beam.

(3) Pumping consideration: During initial operation, two roughing systems with turbomolecular pumps are installed downstream of the bending chambers to pump the gas load from the crotch absorbers irradiated with synchrotron light. A self-protection mechanism for the roughing system, including turbomolecular pump, dry-pump unit, convectron gauge (CVG) and solenoid angle valve, is used for remote control and monitoring in the interlock system. An uninterruptable power supply (UPS) is connected to the roughing system for preventing the pumps from power loss. The operational status of turbomolecular pumps is dependent on the judgement of the pumping-gate valve; if the turbomolecular pump is in normal operating status, it is allowed to control the pumping-gate valve. Although a signal indicating the operating status of the dry-pump unit is necessary for the running of the turbomolecular pumps, a convectron gauge is used to ensure that the pressure is appropriate for the turbomolecular pump to operate in a normal condition.

(4) Local overrides remote principle: To make a correctional action during an emergency or other necessity, sector and pumping-gate valves have a local control button to allow switching on or off locally. We can switch off by pressing the local button independently of the logic.

(5) Temperature protection mechanism: To prevent the vacuum components from melting due to synchrotron light, cooling systems for aluminium chambers and absorbers serve to dissipate the thermal load, and PT-100 temperature sensors are installed to monitor. The output of the flow-meter trigger (3 L/min as lower limit) and temperature readings (35℃ for alarm and 100℃ for beam abort) are taken as the interlock judgement of the vacuum system. Eleven absorbers were made in front of vacuum bellows and gate valves, which have no cooling channel, to prevent irradiation by synchrotron light directly in each cell unit. A valve for maximum flow speed 2 m/s was designed to avoid corrosion occurring in water tubes.

(6) Front-end valve protection: There are 48 beam lines for TPS and 4 ID beam lines will be required in phase I. The front-end valve (FEV) is used for vacuum isolation between the storage ring (SR) and the front end (FE). Because the front-end valve will be directly irradiated with synchrotron light, a photon beam absorber (ABS)

with cooling channels is designed to protect the front-end valve so as to avoid melting. The status of absorbers, front-end valves and the rate of flow of cooling water will be under the interlock control system. One self-protection logic was designed also so that, when the front-end valve is in the open status, the photon beam absorber can be opened to allow synchrotron light to pass, but if in the closed status the opening of the photon beam absorber is inhibited.

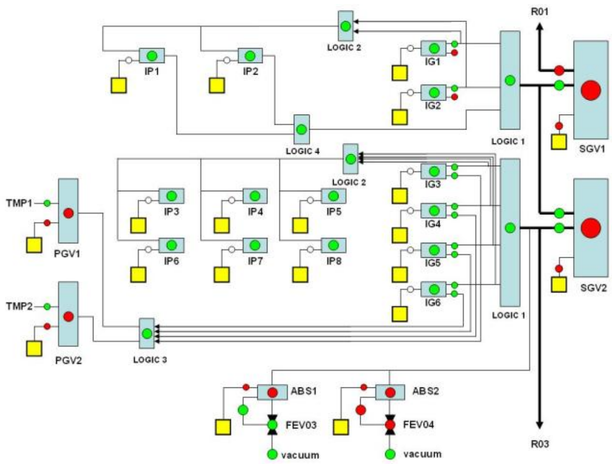

Figure 4: Layout of the vacuum-interlock control panel as SR02 section. The circle is a light indicator and the empty square is the push-button. The green, red and red flash lamps indicate the status of ready (open), fault (close) and not ready, respectively.

CONTROL LOGIC

Three interlock logics serve to maintain the ultrahigh vacuum condition and to protect the vacuum devices of the storage ring. The pressure readings of the ionization gauge are taken as the basic logic judgement inputs to control the opening and closing of the sector gate valve, whereas monitors of the cooling system and temperature are used to protect the vacuum devices.

The interlock logic uses the trigger outputs of the ionization gauge and the ion pump to close the sector gate valves so as to protect the vacuum pressure. Two pressure levels – 1×10^{-4} Pa and 3×10^{-8} Pa – are chosen as the trigger points for the interlock logic. If there are two pressure reading signals greater than 1×10^{-4} Pa at either end of the valve, logic 1 functions; this sector gate valve then closes to protect the vacuum at the other end and the ion pump is switched off by logic 2. In contrast, if the pressure is less than 3×10^{-8} Pa, the opening of pumping gate valves in front of the turbomolecular pumps is inhibited. This function is worked by logic 3 to decrease the risk of the failure of turbomolecular pump and the dry pump unit.

A self-protection mechanism for the front-end valve was designed. When the front-end valve is in the closed status, the absorber behind is triggered in the down status to prevent melting by synchrotron light.

CONCLUSIONS

The prototype of an interlock control system has been designed and tested for vacuum testing of a R02 unit cell in NSRRC. The logic-control panel and data acquisition function in the archive system have control and history views. The control logic will be optimized with unit-cell construction, and the signal transmission and interface communication will be tested in the future.

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