UPGRADING BEAM LINE INTERLOCK AND CONTROL SYSTEMS AT THE BSRF

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Abstract

At the BSRF (Beijing Synchrotron Radiation Facility), the beam line interlock and control systems have been in use for over ten years [1]. Since 1995, this system has been gradually upgraded to improve hardware reliability and performance, to reduce faults and to provide additional system functionality. The centralized monitoring system for BSRF beam lines has also been redesigned at a reasonable cost. The old controllers have been replaced with new (Programmable Logic Controller) PLC-based ones.

1 INTRODUCTION

At present, there are four beam ports and nine beam lines installed around the BEPC(Beijing Electron-Positron Collider) storage ring at the BSRF. The nine photon beam lines include five wiggler X-ray beam lines, an X-ray UHV compatible beam line, a VUV beam line and two soft X-ray beam lines. All beam lines share a common vacuum with the BEPC storage ring. Beryllium windows are not used for VUV beam lines. For the X-ray beam lines 0.25-0.5 mm thick beryllium windows are used to separate the storage ring vacuum from the rough vacuum in the downstream beam line components, thus allowing the operation of monochromators, mirror boxes and sample chambers in rough vacuum or in helium atmosphere.

Because of beryllium window breakage or other accidents in beam lines, the possibility of vacuum failures is substantial. Such a shock wave caused by beryllium window failure, bellow breakage or gas leakage at the beam lines will result in serious damage to some components and the vacuum of the storage ring. A catastrophic damage would result in machine shutdown and interrupt the operation of all experimental stations.

To protect the vacuum of the BEPC storage ring and other beam lines from such catastrophic vacuum failure of a single beam line, each beam port has been equipped with an independent vacuum protection system. At the same time, the protection system can also protect beam line components from being damaged by thermal loads produced by high brilliance hard X-rays.

In addition, synchrotron radiation produced by wiggler or bending magnet is introduced through the beam lines to the experimental stations. Thus radiation safety interlock systems are used to provide personnel (users) access control to prevent inadvertent entry into experimental stations when hazardous radiation conditions exist. This will also warn personnel of changes in safe operating conditions inside the experimental stations.

Consequently, each beam line interlock and control system consists mainly of vacuum protection system for the beam lines and radiation safety interlock systems for the experimental stations.

2 CENTRALIZED MONITORING SYSTEM

The basic hardware configuration of the centralized monitoring system is shown in Fig .1.

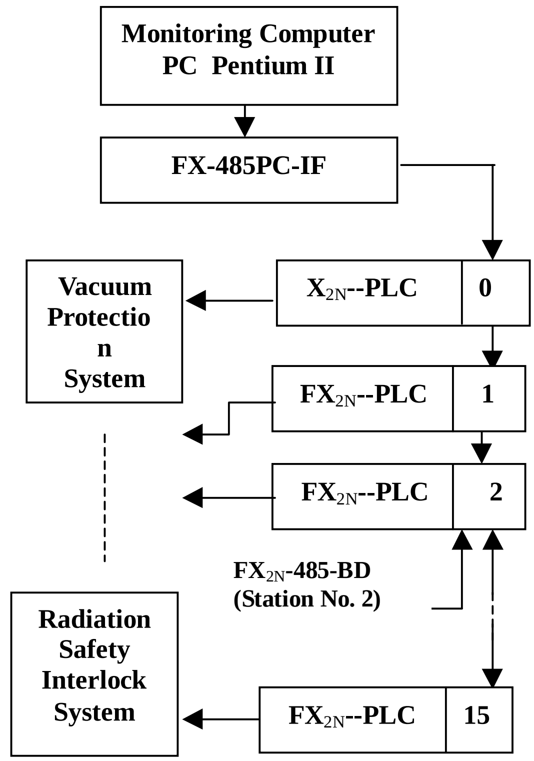

Fig.1. Block diagram of the hardware configuration for the centralized monitoring system.

This monitoring system will be used to collect, log, and display the operation status from the beam line interlock and control systems. The monitoring computer will be serially connected with 16 sets of FX_{2N}PLCs via the FX-485PC-IF (RS232/RS485 converter) and the FX_{2N}-485-BD (RS485 interface from station No. 0 to station No. 15) communication links [2].

At BSRF, each old beam line interlock and control system consists mainly of one vacuum protection system for beam lines and two (or three) radiation safety interlock systems for experimental stations. In order not to change the configuration of the old system, Programmable Logic Controllers (PLCs) are used to re-design the controllers in the system. In this system, there are two types of new PLC-based controllers for each beam port. One controller is responsible for vacuum protection system for beam lines, which includes the vacuum equipment interlock and controls, and the other controllers are used for the radiation safety interlock systems for experimental stations. The interlock and control program for each type of PLC-based controller is almost the same.

Each new controller includes a Mitsubishi FX_{2N} PLC as a main hardware device. Each set of PLC consists of a CPU module, an ADC module, a digital I/O module, and an RS485 communication link. Each new PLC-based controller is installed in a separate equipment chassis and the operating panel is installed in front of each controller for local operation. All PLC-based controllers can be serially connected to the centralized monitoring computer (PC Pentium II) via the FX-485PC-IF (RS232/RS485 converter) and FX_{2N}-485-BD (RS485 interface) communication links.

The beam line interlock and control systems also includes 2 programs: One runs in the PLC (the actual interlock and control programs), which has been completed, and the other is a user interface and monitoring program running on the centralized monitoring computer (PC Pentium II). However, the monitoring program on the PC is currently under development.

3 VACUUM PROTECTION SYSTEMS

The main functions of the vacuum protection system for BSRF beam lines was to protect the BEPC storage ring and other photon beam lines from sudden catastrophic vacuum failure at a single beam line. The second goal was to protect the uncooled beam line components from exposure to synchrotron radiation and the water-cooled beam line components from the interruption of the cooling water flow.

The new hardware for the vacuum protection systems is based on the PLCs. The basic design requirements and configurations of the new systems are much the same with the old systems described previously [1]. The new PLC-based vacuum interlock system is used to replace the old relay-based vacuum interlock systems. This includes FX_{2N} PLC with about 90 I/O points, an ADC module (FX_{2N}-4AD) with 4 input channels, and a RS485 serial communication link (FX_{2N}- 485-BD). The I/O points are used to acquire status from the field devices (e.g., positions of water-cooled movable mask, all-metal UHV valve and fast-closing valve, as well as ionization gauges output relays, pressure switches for cooling-water flow to cooled components and compressed air, etc) in addition to sending commands to them. The ADC channels are used to read the analogue outputs of ionization gauges. The PLC-based controller for each vacuum protection system can be serially connected to a centralized monitoring computer (Pentium II) via the RS485 link.

The software for the vacuum interlock and controls involves two tasks: drawing the ladder diagram and entering it into the PLC via a special packet (MEDOC). The new PLC-based vacuum controller is a high reliability fail-safe interlock and control device. The operating panel is installed in the front of each new PLC-based controller for local operation.

For the 3W1 high-power (2.54 KW) wiggler beam lines, the challenge of the PLC-based controller for the vacuum protection system is to protect the fast-closing valve from synchrotron radiation when it is triggered to close. The closure time for the fast-closing valve is less than 7 milliseconds. In order to prevent the blade of the fast-closing valve from overheating before the water-cooled movable mask closes (about 2 seconds of closure time), a titanium-alloy blade with melting point of 1680 °C is used.

4 RADIATION SAFETY INTERLOCK SYSTEMS

The new PLC-based controllers for the Radiation Safety Interlock System (RSIS) replaces the old radiation safety interlock systems based on relays. Each set of the PLC-based for the RSIS hardware contains a FX_{2N} PLC with an RS 485 interface. Components include user control panel and status displays, door position sensors (limit switches), electrically-driven door locking mechanism, search-and-secure boxes, emergency beam-stop, voice alarm and visible warning indicators, safety shutter and photon shutter, etc. The equipment cabinet for each set of the RSIS is placed close to each experimental station.

Personnel/users access into these stations can be controlled via the RSIS during beam line operation. The system hardware provides for emergency beam shut-off and emergency egress. A station search and secure must be completed before synchrotron radiation is transported into a station. During this procedure the users are forced to depress the search buttons inside the station in a predetermined sequence and close the station doors within a given time period (~20 sec) to mark the station as secure for radiation. Voice alarm and visual indicator are given during the search process. At the completion of a successful search, the safety shutter and photon shutter can be opened if the other interlock conditions are also satisfied. The opening of the doors and the shutters are fully controlled by the interlock system. In the opposition way, if one of the interlock conditions is not satisfied, only one of the two shutters can be opened.

The RSIS control chassis is the station control panel. This panel is used to open and close safety shutters and photon shutters, gain safe access to the experimental station and display the status of the safety shutters and photon shutters. as well as other devices related to the RSIS. For example, the LED indicators in the panel are green if the safety shutters are opened and are red if the safety shutters are closed.

5. REFERENCES

[1] Xiong Shen-shou et al, " The vacuum control and protection system for BEPC synchrotron radiation beam lines", Nucl.Instr. and Meth. A282 (1989) 418-421.

[2] User's manual for the FX_{2N} PLC, M I TSUBISHI.