DEVELOPMENT AND CONSTRUCTION OF SAFETY AND CONTROL SYSTEMS FOR THE TPS FRONT END INTERLOCK

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Abstract

The Taiwan photon source (TPS) at NSRRC (National Taiwan Photon Source) is a 3rd generation, 3 GeV storage ring with designed current of 500 mA. In phase-I, six insertion device beamlines have been available to users after the safety interlock systems were commissioned and reviewed. National Instrument (NI) compact RIO 9030 is used for the front end interlock control system, and both scan and FPGA modes are activated in a hybrid mode to enhance the safety reliability. The personnel and machine protection system as well as EPICS communications of the TPS control system are presented in this paper as well.

INTRODUCTION

TPS front end (FE) interlock system has two main functions, personal radiation safety and machine protection. FE is located between storage ring and beam line, Figure 1 [1] illustrates standard FE components, that is, TPS FE consists pre-mask, fixed mask, photon absorber, x-ray photon beam position monitors, fast closing shutter, all metal gate valve, heavy metal shutter, and gate valve. For the control system, a stage control system, an interlock control system and a vacuum control system which with 5 ion pumps and 1 NEG, that the vacuum pressure 10^{-8} Pa [2] is reached. Due to its high power density and a wide horizontal fan of radiation [3], the front end mechanical design and safety interlock system in the TPS have to be reliable and stable.

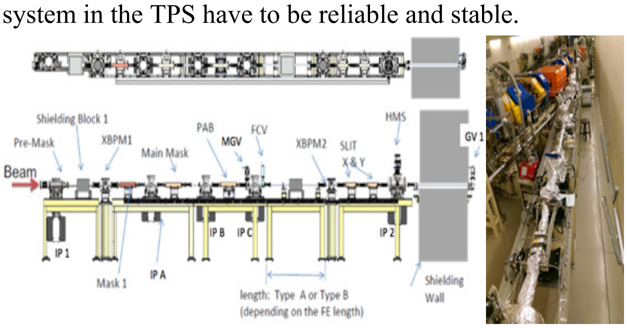

Figure 1: Schematic of the TPS FE.

CONTROL SYSTEM

The FE control system is integrated into the general interlock control system, archive system and the stage control system. This architecture enables communication with the Central-control room, Radiation safety, Beam line and Storage ring systems are by either physical cables or TCP/IP protocol. Some signals related to personnel or machine protection are connected by physical cables with a 24 VDC digital I/O, while all analog data or status signals communicate through the experimental physics and industrial control system (EPICS) and the Modbus protocol in a network is shown in Fig. 2.

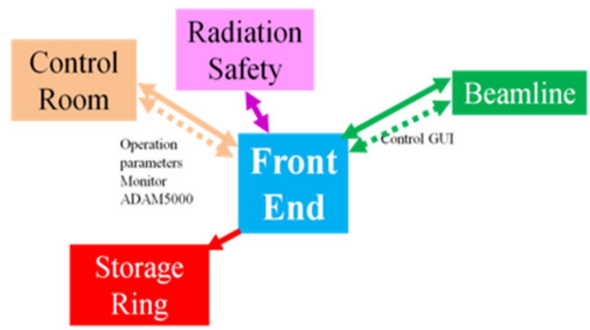

Figure 2: Communication system for the TPS FEs.

The TPS FE safety interlock system uses the NI compact RIO 9030 (cRIO 9030) as the main controller, the NI 9476 is used as the digital output module with 250 mA/ch from 6 to 36 VDC outputs , whereas the NI 9425 is a digital input module with 7 us sinking digital input. The control program and graphics user interface (GUI) are programmed with LabVIEW and it follows the TCP/IP protocol. In order to achieve a highly reliable radiation safety protection system, a YOKOGAWA FAM3 PLC redundant system is also implemented to constantly monitor the NI cRIO 9030 status Four conditions, watch dog, CPU loading, I/O validity and emergency beam trip, are combined in an AND gate, in case one of above status indicates false, it will trigger PLC to shutdown the corresponding FE. The architecture of the control system is shown in Fig. 3.

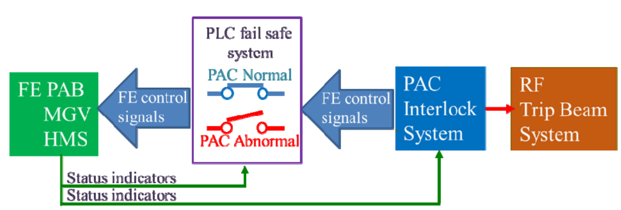

Figure 3: The control structure of the FE interlock with a failsafe feature.

As was mentioned before, as to NI cRIO 9030, all I/O nodes are arranged by FPGA controller in the hybrid mode, they are integrated in the Real-time and FPGA systems and to execute the interlock logical program. The FPGA controller is a highly reliable safety signal control system and the Real-time system, they are programmed in Linux with high flexibility for data communications and State-chart functionality programming. All variables that

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relate to the TPS FE control are built in one project and share variables for LabVIEW programming, Modbus as well as EPICS protocol. The system architecture is shown in Fig. 4.

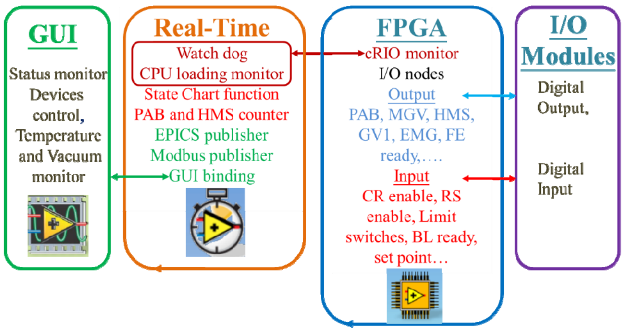

Figure 4: FE interlock system architecture.

In the YOKOGAWA FAM3 PLC, dual CPU modules F3SP71-4S are used for redundant protection, the main CPU monitors the NI cRIO 9030 status and the handshake with a secondary CPU. If the monitor status signal from the Real-time system of the NI cRIO 9030 is malfunctioned, the main CPU will activate a PAB, MGV and HMS shutdown in sequence. In addition, if the handshake between two PLC internal CPU fails, the redundant CPU will shut down the FE in the same sequence. This protection logic is shown in Fig. 5.

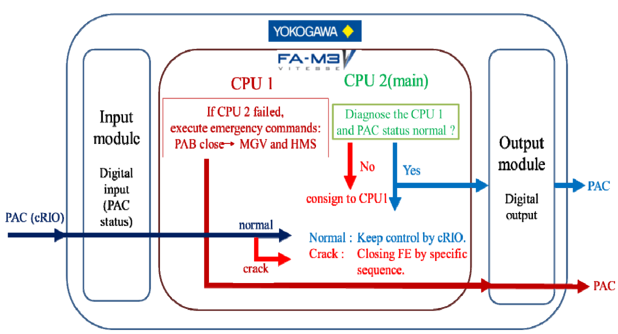

Figure 5: Control structure of the PLC fail-safe system.

VACUUM SYSTEM

The vacuum protection logic is based on all metal gate valves (MGV) to separate the storage ring vacuum Installation of FCV protects both the storage ring vacuum and beam line in case of a vacuum breach The vacuum protection logic is shown in Fig. 6, where two logical pathways respond to up- and down-stream vacuum protection in the front end.

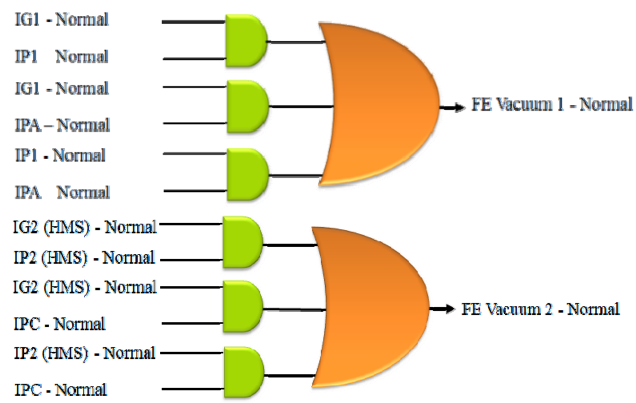

Figure 6: TPS FE vacuum protection logic.

COOLING SYSTEM

The main function of a front end system is to confine the synchrotron radiation beam size to beam line user. The high heat load components such as Masks, Photon absorber and Slits are used to absorb the high X-ray intensity which is generated by the insertion device (ID). Due to its high power density [4], these components must have water cooling to dissipate the heat load. There are three independent cooling water circuits with a flow rate of about 12 liter/min in each FE as shown in Fig. 7. Each circuit includes flow rate meters at the inlet and outlet. If two meters in the same circuit send an alarm signal for more than three seconds, an RF beam trip signal will be triggered for machine protection.

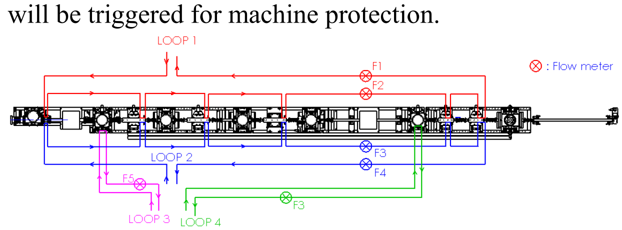

Figure 7: TPS FE cooling circuits.

FRONT END INTERLOCK LOGIC

The logical concepts are the main features of the TPS FE interlock system. Four main logic sequences are used to secure radiation safety protection such as PAB, MGV, HMS control logic and emergency beam trip logic as shown in Fig. 8-10. Since HMS is not able to expose to the high heat load even in few milliseconds, PAB is designed to be the first cooling component to intercept the beam, and is the last one to leave the beam going through tot eh beam line. In the interlock logic, a Stat-chart function which is built into the LabVIEW program is used to ensure that PAB, MGV and HMS are opened and closed sequentially (as shown in Fig. 11), with the PAB opening after both, enable signal and upper limit switches in the high status of the MGV and HMS arrive. If any condition for opening the MGV and HMS are not met, the PAB is unable to open.

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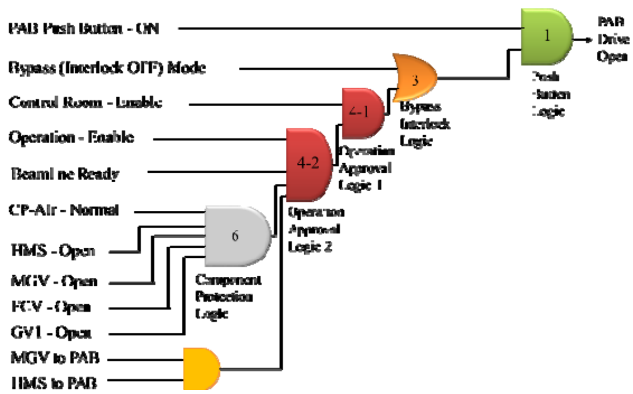

Figure 8: PAB control logic.

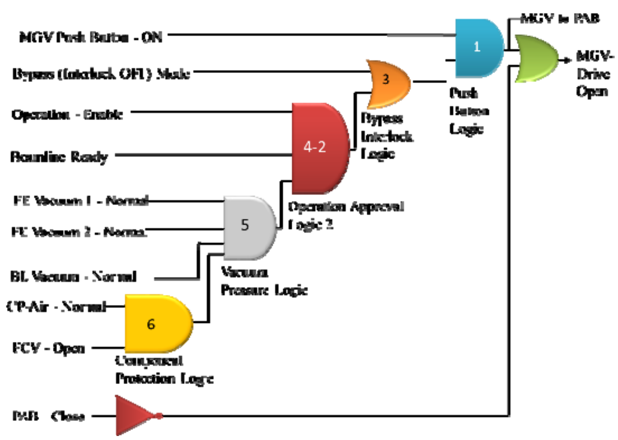

Figure 9: MGV control logic.

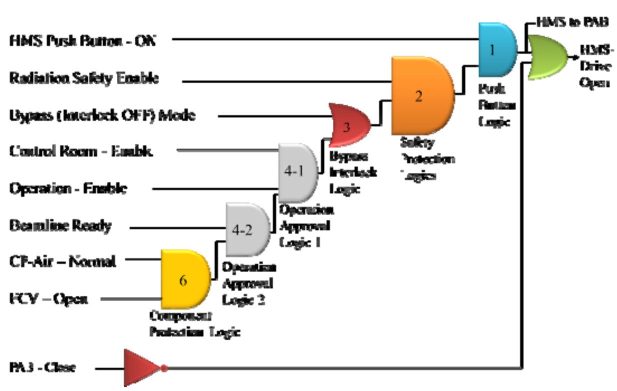

Figure 10: HMS control logic.

On the other hand, in order to avoid a certain sequence of closing malfunction leading to possible damage to the machine, a redundant logic hardware circuit is installed in the control system which is shown in Fig. 12.

A relay circuit with timer allows the detection of the HMS and PAB closing, and when the PAB is closed for more than three seconds or the HMS is closed for more than five seconds, an emergency signal is delivered to trip the beam. Furthermore, there are four conditions for emergency RF beam trips, for example, when the beam line hutch emergency button is pushed and the HMS is not in the close position, the cooling water alarm is active for more than three sec, the FCV trigger is closed and the interlock bypassed. The emergency beam trip logic is shown in Fig. 13.

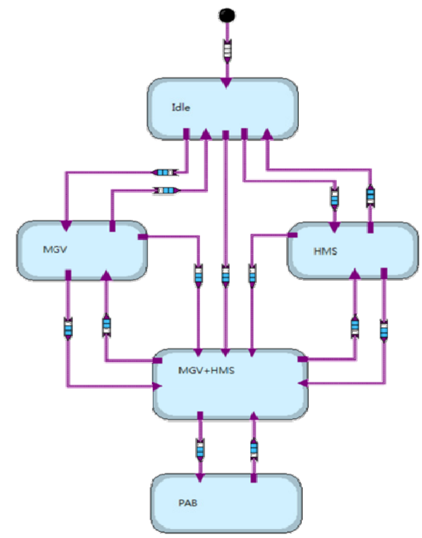

Figure 11: LabVIEW State-chart flow diagram.

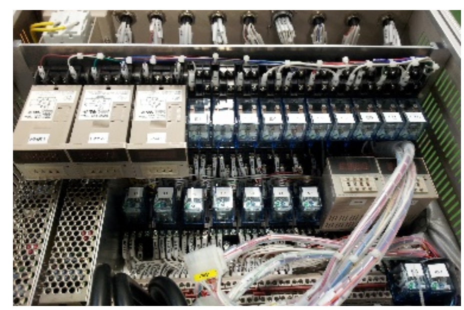

Figure 12: Redundant emergency beam trip circuits.

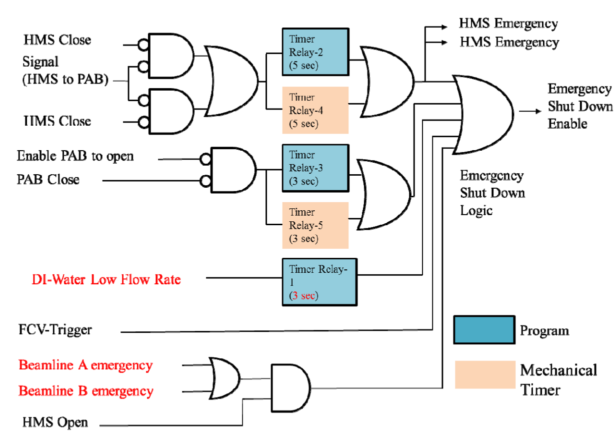

Figure 13: FE emergency beam trip logic.

CONCLUSIONS

Six insertion device beamlines in TPS are available for users after the safety interlock systems were commissioned and reviewed. In order to enhance the stability if the FE interlock system, all PPS and MPS logics from the RT system to the FPGA are developed. In order to improve the fail-safe stability, a YOKOGAWA FAM3 PLC is used as a redundant system which monitors the NI cRIO 9030 status and is enabled to shutdown the TPS FE if the cRIO 9030 failes.

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