DESIGN OF FRONT END SAFETY INTERLOCK SYSTEM FOR TAIWAN PHOTON SOURCE

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Abstract

A safety interlock is one of critical subsystems in synchrotron radiation accelerator. A prototypical system of front end (FE) safety interlock was designed, fabricated and initially tested in Taiwan Photon Source (TPS). The basis of the design of TPS FE interlock logic is modified based on existing Taiwan Light Source (TLS), and taken into account the differences of accelerator parameters between TPS and TLS. Programmable automation controller (PAC) is incorporated within the FE safety interlock system due to its reliability, convenience, processing capability, communication and stability in a user interface. In the FE PAC system, touch panels serve as the graphical user interface (GUI) to control and to monitor FE components. With GUI control, it also serves as a monitoring device of the beam position and to confine the size of the beam aperture for beam line users. The interlock design including data acquisition and parameter monitoring of the pressure in vacuum system, the flow rate of cooling water, the pressure of compressed air, the temperature of the chamber and water, and the overall interlock logic are also presented in this paper.

INTRODUCTION

Taiwan Photon Source (TPS) is a low-emittance and high-density 3-GeV and 500-mA synchrotron radiation accelerator with circumference 518-m, and is currently under construction in National Synchrotron Radiation Research Center (NSRRC). The front end (FE) is a critical subsystem in a synchrotron radiation accelerator with the functions of maintenance of the stability and quality of the photon beam, confinement of the beam size and monitoring of the beam position, protection of the ultrahigh vacuum (UHV) in the storage ring, and prevention from exposure to radiation for downstream beam line users. With these design requirements, the safety interlock of a FE plays an important role in the overall accelerator system. This FE safety interlock control system includes not only monitoring of the device status applied in the safety interlock logic, but also analogue signals of components, such as ionization gauges (IG), ionization pumps (IP), flow sensors of cooling water, pressure gauges of compressed air (CP-Air), resistance thermal detectors (RTD), and control of stepper motors assembled in X/Y stages. The prototype of a FE interlock control system is already designed, fabricated and tested. The hardware for the control system and the safety interlock logic are described in the next sections.

HARDWARE FOR THE CONTROL SYSTEM

The FE interlock control system is divided into five parts in its hardware – a touch-panel computer, control boxes for the interlock, archive, motor and potentiometer. Each part of this hardware for the control system is described individually below.

(a) Touch-panel computer: A graphical user interface (GUI) programmed with LabVIEW is developed to control and to monitor devices. Valve drivers and their status, enabling signals for subsystems, trigger signals for devices, analogue readout, and motor control are all integrated into the GUI; an operator can monitor and control the system graphically. Figure 1 shows the FE GUI panel, which is continually being modified and optimized.

(b) Interlock control box: This control box is assigned to execute safety logic criteria; its reliability and stability are thus highly important. Based on logic, a programmable automation controller (PAC) (NI, cRIO-9074 series communicating via Ethernet) and digital input (DI) and digital output (DO) modules are adopted for its advantages of reliability, convenience, processing capability, communication and stability. The interlock logic is embedded into the controller to prevent normal programming from being affected by a malfunction of other devices, such as a touch-panel computer breakdown or a broken Ethernet line.

(c) Archive control box: The PACs (Advantech, ADAM-5000/TCP series communicating via Ethernet) with analogue input modules are adopted. The monitored statuses are pressure in the vacuum system, flow rate of cooling water, pressure of compressed air, and temperatures measured with IGs and IPs, flow sensors, pressure gauges and RTDs, respectively. Figure 2 shows a GUI schematic of temperature indicators for RTDs attached on a pre-mask in the temperature page.

(d) Motor control box: A motor controller (Galil DMC-4080 series) is adopted and connected to motor drivers and stepper motors assembled in X/Y stages with the functions of position adjustment for fixed masks, XBPMs and slits [1].
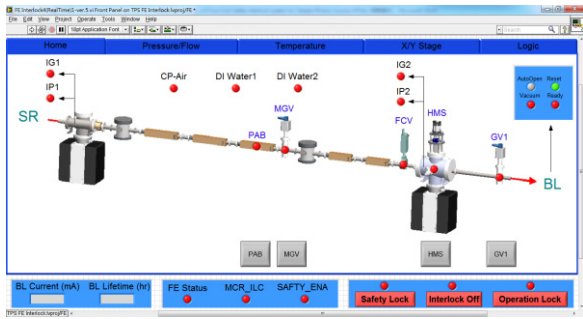
Figure 1: FE GUI schematic showing the indicators of components and subsystem status, analogue readout, and motor control in separate pages.
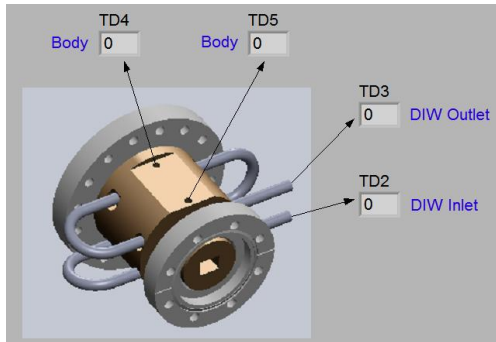

Figure 2: GUI schematic of temperature indicators for RTDs attached on a pre-mask showing the temperature readout in each component part including the body and the cooling loop.

(e) Potentiometer control box: The microprocessor panel controller meters (AXE MMX-A series) are included to indicate the position of potentiometers assembled in X/Y stages.

SAFETY INTERLOCK LOGIC

Based on the functions and the purposes of FE described above, the safety interlock is designed accordingly. All FE interlock rules in TPS are designed and modified according to those in Taiwan Light Source (TLS) taking into account the parameter discrepancies between TLS and TPS, and are described in the followings.

(a) Pneumatic device logic: Figures 3, 4 and 5 are logic diagrams for a photon absorber (PAB), a metal gate valve (MGV) and a heavy metal shutter (HMS), respectively. The other pneumatic devices introduced into the FE safety interlock are a fast closing valve (FCV) and metal gate valve 1 (GV1). The introduction and functions of these devices are all described in [1] and [2]. To protect the normal functions of devices, the logics were designed and applied into the FE safety interlock mechanism. The PAB is restricted by enabling signals, such as MCR_ILC-Enable and Beam Line Ready dominated by the control room and the beam line group, respectively. MGV is restricted by Beam Line Ready and the vacuum status of the FE and the beam line.

HMS is restricted by enabling signals, such as Radiation Safety Enable, MCR_ILC Enable and Beam Line Ready dominated by the radiation safety group, the control room and the beam line group, respectively. As pneumatic devices are driven with compressed air, the pressure of air is also introduced into their interlock logics.

(b) Pneumatic device action priority logic: To protect devices from melting caused by direct exposure to the photon beam, the opening and closing sequences must be strictly specified. Figure 3 describes that a PAB is allowed to open when downstream devices, such as MGV, FCV, HMS and GV1, are in an open status when FE is ready. If MGV or HMS is triggered by a fault signal during operation, it begins to close after the PAB completes a closing action through the PAB-Close in MGV or HMS logic.

(c) Beam abortion logic: To protect the normality of the entire system and personal safety, the risk that might result in an impact should be taken into a higher level of safety logic. The beam abortion action is to avoid impact and to decrease risk as much as possible. A failure of a closing action for PAB or HMS will cause a severe impact on the system and users, therefore the safety closing timing is defined. When the closing time exceeds the set point, the beam will be aborted immediately. The flow rate of cooling water is also introduced to the safety interlock [3], as it directly influences the efficiency of thermal dissipation for the heat-load components. It is believed that insufficient flow rate might increase the risk of component melting. As the flow rate decreases below the set point, a timer will initiate a countdown. After countdown reaches its set point, the beam abortion will be triggered immediately. Closing of FCV will also trigger beam abortion to avoid a direct exposure to the photon beam.
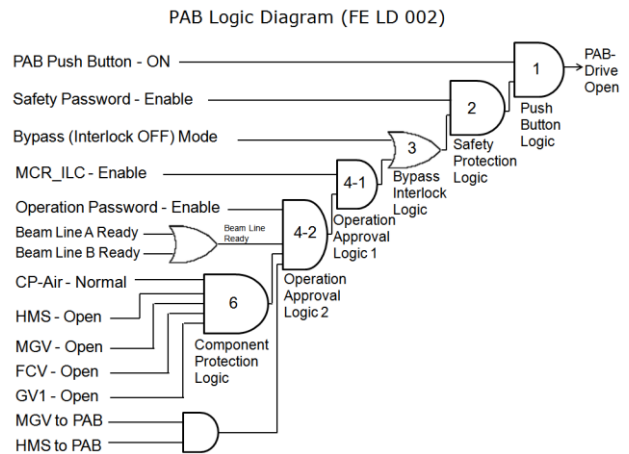

Figure 3: Safety interlock logic diagram for a photon absorber, indicating the enabling relation of subsystems and components.
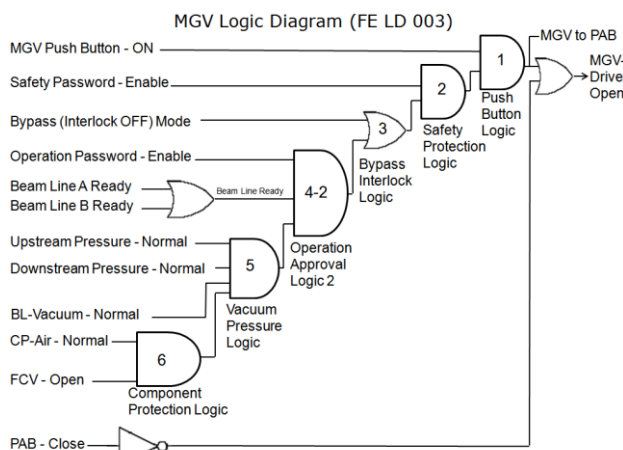
Figure 4: Safety interlock logic diagram of a metal gate valve indicating the enabling relation of subsystems and components.
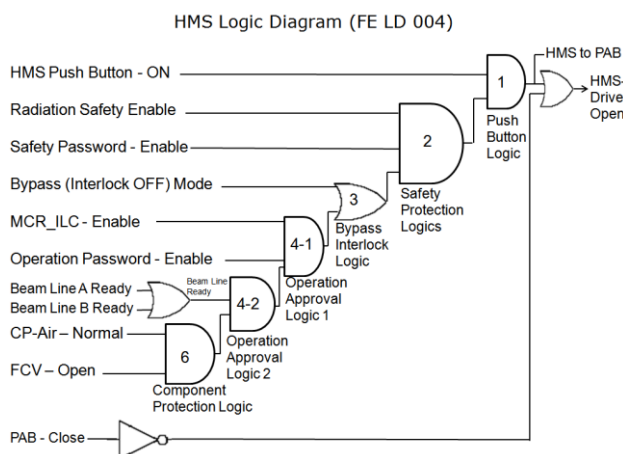

Figure 5: Safety interlock logic diagram for a heavy metal shutter indicating the enabling relation of subsystems and components.

(d) Controller failure logic: The pneumatic components, such as PAB, MGV and HMS, close simultaneously through an initialization caused by a failure of the interlock controller. This condition causes a risk that non-heat load components are exposed to the photon beam without the protection of safety logics. To prevent this from happening, the closing sequences of pneumatic valves must operate normally. Timer relays are introduced into the control system to define the closing delay of downstream components including the MGV and HMS, and they begin to count down when the operation of the interlock controller fails. The closing delay ensures that the closing action of the MGV and HMS always follows after that of the PAB.

CONCLUSIONS

A prototype of a FE control system, which includes systems for safety interlock, data acquisition and motor control, has been designed, fabricated and initially tested for TPS in NSRRC. A prototype of the FE control GUI is designed, fully based on the needs of operators, and includes overall readout and status in separate visual pages. The hardware devices used in the control system have been defined and tested for their reliability and compatibility with the overall system. The FE safety logic of TPS is designed based on that of TLS and moderately modified for the parameter discrepancies between these accelerators. The white-box test will be applied in a reliability test for the safety interlock system, and its hardware is being continually designed and fabricated. The signal transmission between the individual subsystems will also be tested as the overall set-up of an Experimental Physics and Industrial Control System (EPICS) in TPS is completed.

ACKNOWLEDGMENT

REFERENCES

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