DESIGN OF THE ACCELERATOR SAFETY INTERLOCK SYSTEM FOR XFEL IN SPring-8

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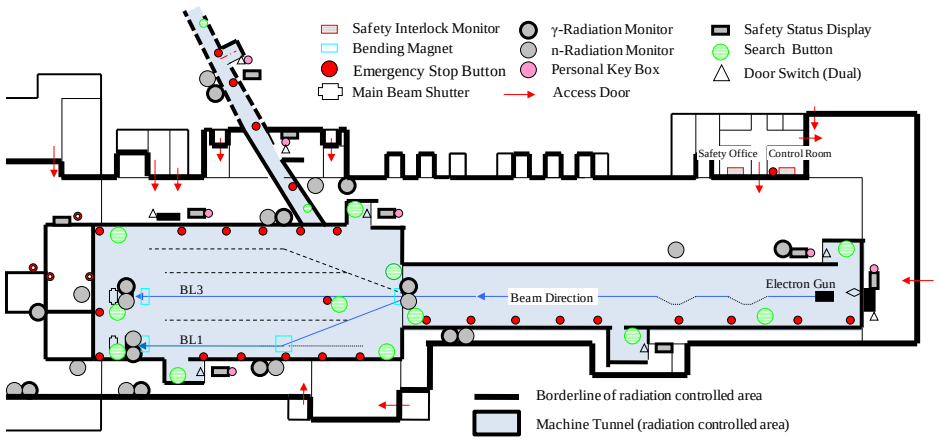
INTRODUCTION

The X-ray free electron laser (XFEL) facility at SPring-8 is currently under construction. The electron beam is injected from the 500 kV electron gun (GUN) and is boosted to 8 GeV by the linear accelerator. The boosted electron beam is switched to the beamline (BL) with a bending magnet. The maximum repetition frequency of the electron beam is designed to be 60 Hz, and the bending magnet switches the direction of the electron beam between BL1 and BL3. In the final plan, the electron beam is switched among five BLs. The switched electron beam is injected into the undulator to generate XFEL radiation and is dumped at a beam dump. In addition, the XFEL-to-Storage ring beam transport line (XSBT), which connects from the XFEL linac to the existing 8 GeV storage ring at SPring-8, is now under construction.

The accelerator safety interlock system (ASIS) has been established with the objective of protecting personnel from radiation hazards. It controls the permission signal for the accelerator and monitors the access to the machine tunnel. If the conditions are unsafe, the ASIS denies permission to the accelerators and stops the electron beam.



BASIC CONCEPT

- It must be fail-safe so that even in the case of a single fault, the system goes into a safe beam-inhibiting state.
- It requires double structure of the logic and signal translation.
- It must monitor the equipment related to the machine tunnel, the emergency stop buttons, and the electron beam route. We have designed three independent systems that monitor the equipment.
- If the electron beam route is unsafe, it must stop the electron beam within 16.6 ms (=1/60 Hz), since the next electron beam must be stopped.
- It controls 73 radio frequencies (RFs) and the GUN by giving the permission signal.

SYSTEM LOGIC

The ASIS has three safety states: "STOP", "READY", and "RUN". These states are switched by a system key and the safety condition. These states control the access to the machine tunnel and the accelerator operation.

STOP
- Accelerator operation is not permitted.
- Personnel can access the machine tunnel. A person who enters the machine tunnel should take a key from the personal key box (PK-BOX) set up near the access door. While in the tunnel, one must carry the key.

Normal Transition

READY
- This state does not permit accelerator operation.
- Access to the machine tunnel is denied to all but the person who carries the system key.
- Before starting accelerator operation, a search is launched to verify that no one is present in the machine tunnel. As the tunnel is searched, buttons are pushed to indicate that the area was visited by the search team.

Normal Transition

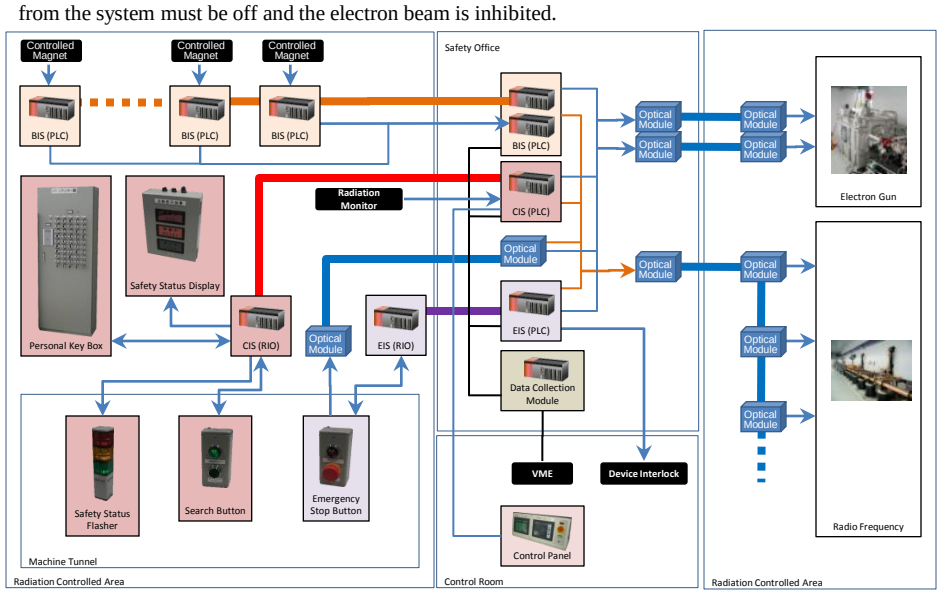
Trip to "READY"

unsafety

RUN
- No one is permitted to enter the machine tunnel.
- A warning message is announced in the machine tunnel by an audible alert and a red flash.
- When the safety conditions given below are met, accelerator operation is permitted after 1 min.
  - •All access doors of the machine tunnel are closed and locked.
  - •All keys of the PK-BOX are returned.
  - •All emergency stop buttons are energized (not pushed).
  - •The tunnel search is completed (all search buttons are pushed).
  - •All radiation monitors, the electron beam route, and all BLs are normal.

SYSTEM CONFIGURATION

The ASIS consists of a central interlock system (CIS), an emergency interlock system (EIS), and a beam route interlock system (BIS). All three systems are implemented on a programmable logic controller (PLC). The three independent interlock systems communicate with each other by inputting/outputting hardwired signals or using an optical module. If any system trips, or if any system is unsafe, the permission signal from the system must be off and the electron beam is inhibited.



Central Interlock System(CIS)

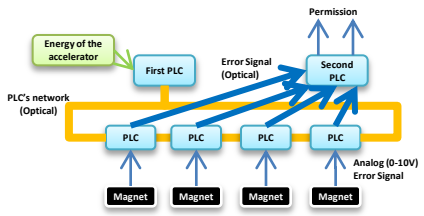
The CIS is main interlock system in the ASIS. It monitors the machine tunnel security, changes the safety state, and gives the permission signal to controlled equipments.

Emergency Interlock System(EIS)

The EIS is established to monitor the emergency stop buttons, which are located in the tunnel at intervals of about 50 m. If the buttons are pushed, the EIS does not give the permission to the GUN and RF.

Beam-Route Interlock System(BIS)

The BIS monitors the consistency between the predefined electron beam route to the downstream insertion devices and the actual transport route by inputting the current of the bending magnet at the beam switching points. The monitored magnet consists of the switching magnet, the kickback magnet of BL, and the beam dump magnet of BL.



1. The first PLC accepts the energy of the accelerator operation through the graphic panel. The values of the current of the magnets are calculated and transmitted to the PLC for the magnet.
2. The PLC for the magnet compares the calculated current with the actual current of the magnet. If the result is over ±1%, the PLC outputs an error signal to the second PLC.
3. The second PLC checks the conformity of the electron beam route, and if the beam route is unsafe, it does not permit accelerator operation and stops the electron beam.

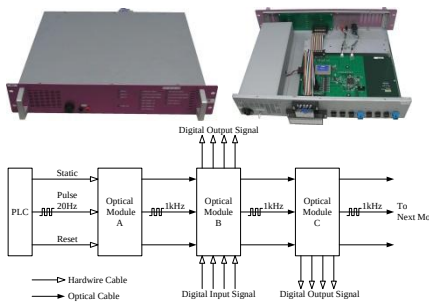
Optical Module

The optical module has been developed to transmit the permission signals for the GUN and for all RFs at a high speed. There are three types of optical modules:
- •The A type interfaces with the PLC.
- •The B type relays between the modules and inputs the signal from the external instruments.
- •The C type outputs the permission signal to the controlled equipment.

HARDWARE

Each module sends and receives signals through three fibre optic cables.
- ✓A static signal (high-speed)
- ✓A pulse signal (reliability)
- ✓A reset signal.

When either signals trips, the trip state is held until a reset signal is transmitted.



Data Collection Module

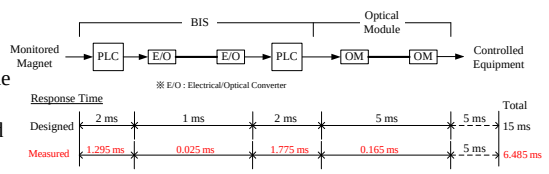
ASIS information is recorded in the host computer system. The ASIS and the host computer system are connected through an FL-net. Since the ASIS must be protected from unauthorized access from the network, this module is separated from the computer network.

The data collection module is implemented on a PLC; it collects information from CIS, EIS, and BIS through an independent FL-net. The collected information is transmitted to the host computer system.

Transmission Speed

We measured transmission speed of the permission signal by using the optical module and the component of BIS.

As a result, the transmission speed satisfied the targeted response time (16.6ms).



CONCLUSION

As a safety system, it should be reliable, stable, and easy to maintain. Further, the accelerator safety interlock system should be capable of high-speed transmission and should be independent. Therefore, we developed an ASIS consisting of three interlock systems; we also developed the optical module and the data collection module.

The hardware of the CIS and the EIS was already produced as the end of September, 2009. The optical module prototype was developed and was successfully tested in a noise environment. The ASIS is planned to be operational in October, 2010.