THE SSRF RADIATION SAFETY INTERLOCK SYSTEM

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Abstract

Radiation Safety Interlock System (RSIS) for the Shanghai Synchrotron Radiation Facility (SSRF) is composed of two subsystems, the Access Control System (ACS) and the Radiation Containment System (RCS).The ACS prevents personnel from being exposed to the extremely high radiation inside the SSRF shielding tunnel (or called the interlock area) during machine operation. The RCS prevents personnel from being exposed to the high radiation outside a shielding tunnel during either normal or abnormal operation. The implementation of the ACS is based on the Programmable Logic Controllers, key transfer interlocking systems and ID Card System. The RSIS is based on fail-safe, redundancy, multiplicity. Any violation of the RSIS will result in the inhibiting of redundant permission to the associated interlock systems, and cease the injection process and eliminate the entire stored electron beam in the SSRF. This paper describes the design philosophy, the logic, and the implementation of the RSIS at SSRF.

INTRODUCTION

SSRF includes a 150 MeV electron linac, a 3.5GeV booster, a 3.5GeV storage ring and a number of experimental beam lines utilizing synchrotron radiation. RSIS is composed of four independent parts corresponding to the SSRF's constitution: Linac RSIS, Booster RSIS, Storage Ring RSIS and the Beamline RSIS. The last one is designed by the Beamline Control Group and will not be discussed in details in this paper.

Each part of RSIS is designed to be associated with a beam stopper. One beam stopper between the Linac and Booster(LTB Stopper) is used to separate the Booster from the Linac, and two beam stoppers between the Booster and Storage Ring (BTS Stoppers) to separate the Storage Ring from the Booster. The beam stoppers are controlled by the RSIS Control Console. Linac can be operated by inserting the LTB stopper while permitting personnel entry to Booster. Booster experiments can be operated by inserting the BTS stoppers, and personnel can entry to Storage Ring. The operation modes in SSRF are listed in table 1.

DESIGN GUIDELINES

The basic principles followed for the design and the implementation of the RSIS are based on Chinese legal documents and some international guideline documents [1], [2]. Some experience gained from other Synchrotron Radiation Facilities also be referenced [3], [4], [5]. The RSIS primary design guidelines for SSRF are as follows:

- The system adopts fail-safe circuits and components. Any type of failure of the safety device or of power to the device will turn the accelerator off and render the area safety. In order to enhance reliability, redundancy of critical devices is employed.
- Emergency-off and search confirmation buttons are also provided in high-radiation areas, and are clearly visible, easily distinguishable, unambiguously labelled, and readily accessible.
- Emergency exit mechanisms are provided in entrance doors of interlock area. Emergency entry features for interlocked doors are provided, too.
- When an interlock has been tripped , it could not be resume automatically until it being manually resetting controls at the location where the interlock has been tripped , and lastly at the main control console .
- Clearly labelled status indicators and warning lights reflecting actual conditions are provided at entrance doors and control console.
- If intentionally bypassing a radiation safety interlock system is necessary, such action should be authorized and done by operator in charge. All procedure of the bypassing action should be recorded in an operation logbook and posted at the control console and location of the interlock . The bypass should be removed soon after the necessary action is completed .
- The RSIS is unrestrictive and testable.
- All safety and warning devices should be checked for proper operation at intervals not to exceed 6 months .

Table 1: The operation modes in SSRF

No.	Linac	Booster	Storage Ring
1	On	On	On
2	On	On	Off
3	On	Off	On
4	On	Off	Off
5	Off	On	On
6	Off	On	Off
7	Off	Off	On
8	Off	Off	Off

The No.5 and No.6 indicate the machine studies in Booster in no beam case.

SYSTEM DESIGN

Access Modes

The RSIS is designed to provide the following three different security access modes (Controlled Access Mode, Restricted Access Mode and No Access mode). (Fig.1)

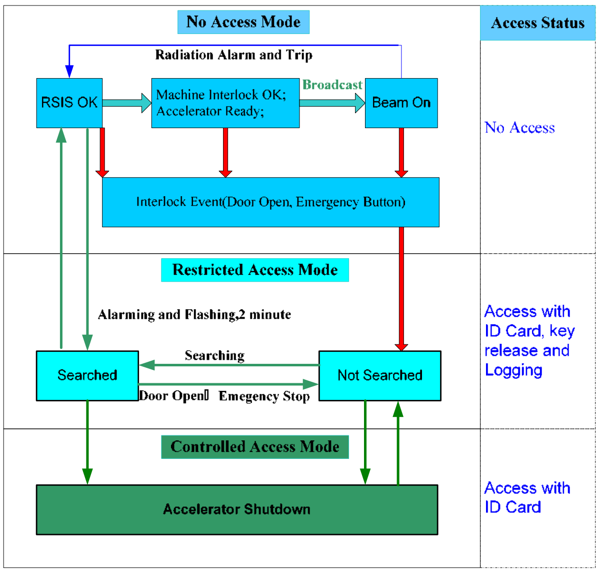

Figure 1: Security Access Modes.

The Controlled Access Mode (CA): In this mode the tunnel has not been searched. The RSIS permits free access to the tunnel areas using the personnel ID card. The Linac RF, Booster RF, Storage ring RF and the tunnel electrical hazards are off. Beam is OFF.

The Restricted Access Mode (RA): In this mode the tunnel has been searched and secured. The electrical hazards in Linac, Booster and Storage ring tunnel may be energized. The RSIS restricts personnel access to the interlocked areas. Access in this mode requires using the personnel ID card plus a key release and logging of entries. Beam is OFF.

The No Access Mode (NA): In this mode the tunnel has been searched and secured. LTB stopper and/or BTS stoppers may be opened. The electrical hazards and RF in Linac, Booster and Storage ring tunnel may be turned ON. No person is permitted to access the interlocked tunnel areas for any reason. Beam may be turned ON.

The access mode transfer in RSIS is always done in a sequence to accommodate various operating scenarios. (Figure 2) The RSIS will return to a safe Access Mode when an interlock violation occurs. The transfer from **The No Access Mode** to **the Restricted Access Mode** refers to the case that the excessive radiation is measured in occupied areas. Other transfer refers to the case that the safety condition is no match.

The **Search Procedure** must be carried out before the **Controlled Access Mode** transfers to **the Restricted Access Mode.** Its function is to certify that no person remains in the interlocked tunnel areas before the machine operation. It is controlled by many Search Station installed inside the accelerator tunnel. The Search Procedure is successfully completed after a series of search buttons are energized in a specific sequence. If the right sequence is not satisfied and the time energized between two search buttons is exceed the pre-specified time (e.g. 40 second), the Search Procedure will be cancelled and must be repeated.

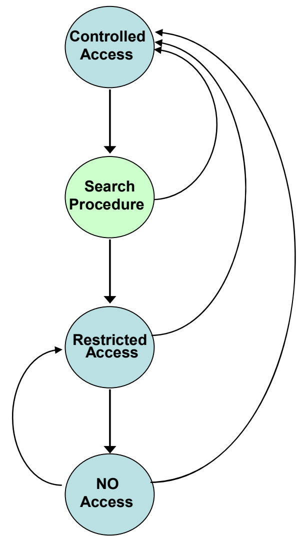

Figure 2: The transfer between three Access Modes.

ACS Hardware

The implementation of the ACS is based on the Programmable Logic Controllers (PLCs), key transfer interlocking systems and ID Card system. PLCs are adopted because of its reliability and flexibility. The RSIS use the SIEMENS PLCs. There are four field control stations which are composed of SIMATIC S7-300 PLC, PROFIBUS-DP, ET200M I/O Stations, I/O models, and lots of search stations and emergency stations. The locations of the search stations and the emergency stations inside the accelerator tunnel are list in Figure 3.

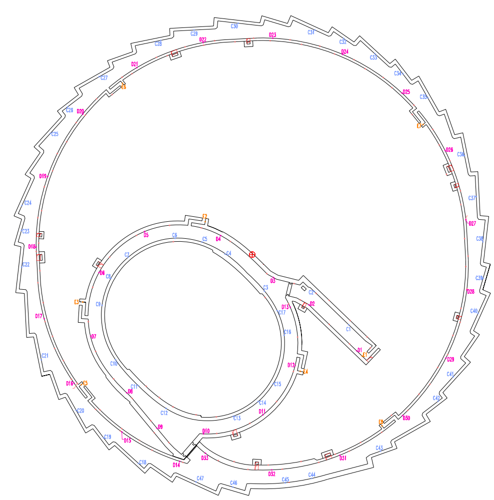

Figure 3: The locations of the search and the emergency stations.

Key Transfer System

The Key Transfer System is adopted in RSIS. It offers a mechanical key solution to prevent personnel from the dangerous tunnel when the accelerator is operating. It has robust modular to provide a long lifetime for use. An internal release function is also provided in Key Adaptor. It is used to open the tunnel door from inside and escape if the beam is ON. The key system ensures that the accelerator cannot operate before the door open key is returned to the key control cabinet at the centre control room.

The sketch map of the Key Transfer System is showed in Figure 4.

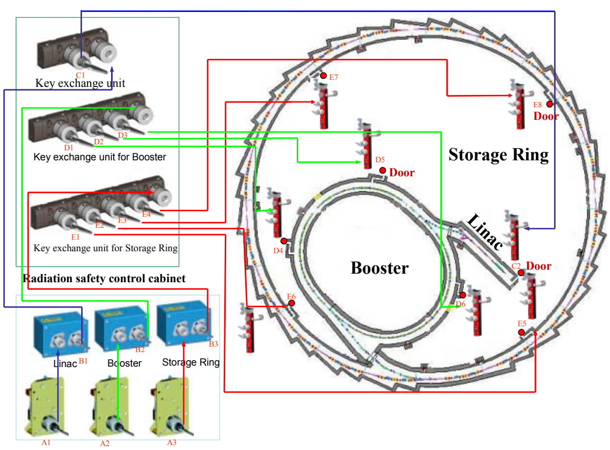

Figure 4: The Door Key Transfer Systems.

ID Card System

The ID Card system is used for the access permit and administrate the numbers in and out the tunnel area. Each worker can get an ID card which includes personnel information indicating when and where you should go. The access information is automatically recorded by a control computer in the ID Card System. The number of persons in the tunnel is interlocked by ACS. In the Restricted Access Mode, the access into tunnel must be authorized by the console at the centre control room.

Radiation Containment System (RCS)

The RCS consists of an active radiation monitoring system, power limiting devices, shielding and dump/collimator. SSRF radiation monitoring system is composed of area radiation monitoring system and environmental radiation monitoring system. Both monitoring systems contain two types of detector, neutron detector and gamma detector. A cylindrical and spherical ionization chamber filled with high pressure argon is adopted as area gamma detectors and the gamma monitor for environmental radiation monitoring, respectively. The neutron detectors consist of a BF3 proportional counter surrounded by a 6.5cm of polyethylene moderator. A neutron detector and a gamma detector are mounted side-by-side at each monitoring location. The area and environmental radiation monitors have local display functions of the audible and visual warning. It warns personnel working near the area when an unexpected high radiation level occurs. Although monitors at some critical locations can be interlocked to RSIS through a trip function which a trip level can be preset, it has not been used.

CONCLUSION

The implementation of the RSIS is based on the technology of the PLCs, mechanical key transfer system and intelligent ID Card system. The redundancy and warm backup PLCs have been selected. At least two methods are used to shut off the electron beam, RF power. RSIS and critical devices are designed to be fail-safe. The number of persons in and out tunnel is interlocked to RSIS to increase the safety. Commissioning of the RSIS has been down since Dec. 2007. No incidents which inflict injury on humans occurred. The shutdown of the accelerators due to the failure of RSIS has not occurred.

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