ISBN: 978-3-95450-221-9 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2021-WEPV039

NOVEL PERSONNEL SAFETY SYSTEM FOR HLS-II*

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Abstract

The Hefei Light Source-II (HLS-II) is a vacuum ultraviolet synchrotron light source. The Personnel Safety System (PSS) is the crucial part to protect staff and users from radiation damages. In order to share access control information and improve the reliability for HLS-II, the novel PSS is designed based on Siemens redundant PLC under EPICS environment which is composed by the safety interlock system, access control system and the radiation monitoring system. This paper will demonstrate the architecture and the specific design of this novel PSS and shows the operation performance after it has been implemented for 2 years.

INTRODUCTION

The Hefei Light Source-II (HLS-II) is a dedicated synchrotron radiation facility which can provide radiation from infrared to vacuum ultraviolet with both Top-Off and Decay operation modes [1].The Personnel Safety System (PSS) is the crucial part of the HLS-II to keep radiation damage away from the staffs and users. The previous PSS in HLS-II was developed by Simens SiPass system which lacked of personnel management function and it's hard to share information. For solving these disadvantages, the novel PSS has been designed for HLS-II.

The Programmable Logic Controller (PLC) and redundant technology are wildly used in the PSS design of big scientific facilities to meet the requirements of the high reliability and stability, such as the European Spallation Source (ESS) [2] and the High Intensity D-T fusion neutron generator (HINEG) [3]. The novel HLS-II PSS is designed based on the Siemens redundant PLC S7-412-5H under the Experimental Physics and Industrial Control System (EPICS). EPICS is a set of open-source software tools, libraries, and applications that are widely used in big scientific facilities [4, 5]. The novel HLS-II PSS contains 3 parts: the safety interlock system, the access control system and the radiation monitoring system. The safety interlock system is used to define the interlock logic to be implemented, the access control system is designed to restrict the access of the staffs and users at HLS-II and provide the personnel management function, and the radiation monitoring system is used to monitor the dose rate in the light source and the surrounding areas.

In this paper, section II introduces the system architecture of the novel HLS-II PSS, section III gives the details about the design of the safety interlock system and the personnel management function in the access control system, and section V shows the operator interfaces (OPIs) design and the operation situation of the novel HLS-II PSS.

* Work supported by National Natural Science Foundation of China (No.11375186)
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SYSTEM ARCHITECTURE

The novel HLS-II PSS ensures the personal safety by monitoring the radiation dose rate, controlling interlock signals and executing interlock actions. We integrate the safety interlock system, the access control system and the radiation monitoring system into EPICS environments for information sharing. Meanwhile, we can use the existing data archiver and alarm toolkits provided by the EPICS community to archive the historical data and publish the alarm information [6]. The system architecture of the novel HLS-II PSS consists of 3 layers: the EPICS layer, the controller layer and the devices layer as Fig. 1 shown.

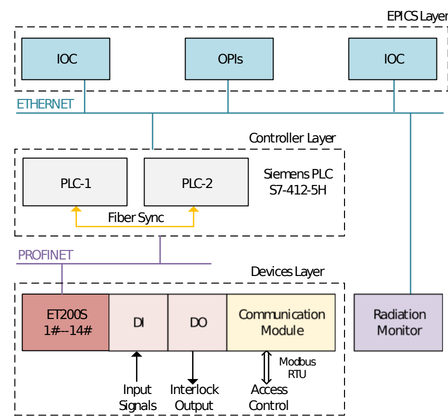

Figure 1: Architecture of the Novel HLS-II PSS.

In the controller layer, there is only one pair of Siemens redundant PLC S7-412-5H. PLC can gather IO signals and access data from 14 IO stations by fiber optic cables, and receive the radiation monitoring signal and commands from other EPICS IOC. The redundant PLC pair has two high performance PLCs that are backed up with each other, one of them takes the role of MASTER PLC and the other one takes the role of SLAVE PLC. During the operation, those two PLCs synchronise programs and real-time data over a high-speed fiber, and the roles between two PLCs can switch over when the MASTER PLC fails.

In the devices layer, 14 Siemens ET200S IO stations are distributed nearby the 14 security doors. The input signals of search buttons, emergency buttons and security doors are collected into the IO stations through the DI modules. The signals of the audible and visual alarm devices, button lamps and the interlock actions are outputted through the DO modules. In addition, the data of card reader is transmitted into the IO station via Modbus-RTU protocol.

According to the design, there are 134 input signals monitored, including 41 search buttons signals, 25 emergency stop buttons signals, 42 security doors signals, and 26 radiation monitoring signals. All the signals are from IO stations, except the radiation monitoring signals. The communication

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between PLC and IO stations adopts PROFIENT Real-Time protocol, the communication cycle time is 2 ms. The communication between IOC and PLC uses Ethernet with a communication cycle time of 100 ms. Radiation monitoring signal is used to monitor the average of the radiation dose in 5 seconds, so the real-time performance for this signal is not high. It is transmitted between IOCs over EPICS Channel Access protocol.

DESIGN OF THE SAFETY INTERLOCK SYSTEM AND ACCESS CONTROL SYSTEM

The radiation monitoring system has been developed based on EPICS and deployed at HLS-II in 2017 [7]. Therefore this section focuses on the design details of the safety interlock system and the access control system.

Safety Interlock System

The safety interlock system is the crucial system to process the interlock logic. Figure 2 shows the workflow chart of the safety interlock system and Table 1 shows the definition and actions of all states. During the operation of the safety interlock system, there are 3 operation states: the released state, the searching state and the interlocked state.

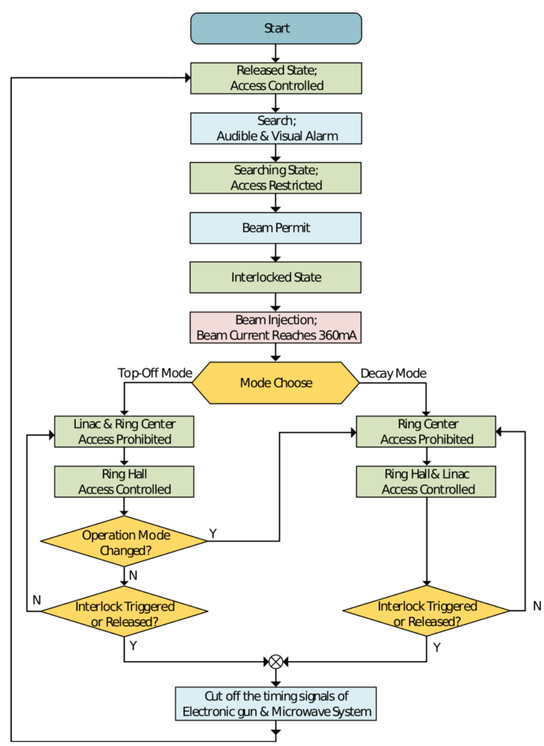

Figure 2: Workflow of the Safety Interlock System.

When the facility is turned on, the safety interlock system enters into the released state. At HLS-II, there are 3 safety interlock areas: the linac, the ring center and the ring hall. In the released state, the interlock system of the 3 areas should be released. All the interlock signals are reset and the search lamps are turned off.

Table 1: States of the Safety Interlock System

States	Definition	Actions
Released State	Release the interlock	Reset interlock logic Turn off search lamps
Searching State	To establish the interlock	Audible and visual alarm Search the interlock areas Turn on search lamps Lock the security doors
Interlocked State	Interlock is established	Beam Injection Operation mode choose

The searching state is aimed to establish the interlock. When the searching state starts, the operator should inform all person to leave the interlock areas by audible and visual alarm, then the operator searches the interlock areas in the order of the linac, ring center and ring hall. If all the search buttons are pressed and the security doors is locked, the operator can give the beam permit command to transit the operation state into the interlocked state.

For the HLS-II, after the beam is injected and the beam current of storage ring reaches 360 mA, there are 2 types of operation modes to choose: Top-Off mode and Decay mode. Top-Off mode is a high performance operation mode, and the beam is injected in every few minutes [8]. Thus the linac and the ring center should be kept in the interlocked state in Top-Off mode. For Decay mode, the beam is injected in every few hours, the interlock of the linac and the ring hall can be released while the ring center must be kept in the interlocked state.

During the interlocked state, if the interlock system is released by the operator or triggered by the interlock signals, such as the emergency buttons is pressed or the radiation monitoring system detects excessive radiation dose, the safety interlock system will cut off the timing signals of the electronic gun and the microwave system, and transit into the released state.

Access Control System

The design of the access control system at HLS-II is based on the principle of classified protection. The interlock areas can be classified into 3 kinds according to the radiation dose rates: the high radiation area, the radiation area and the safety area. The radiation dose rate of the high radiation area is more than 10 µSv/h, of the radiation area is between 1 µSv/h and 10 µSv/h, and of the safety area is less than 1 µSv/h. Table 2 shows the safety classification of the interlock areas at the different PSS state. For the high radiation area, the access of security doors is prohibited, and no personnel is allowed to open the doors under any conditions; for the radiation area, only the staffs have the restricted access authority; and for the safety area, staffs, users and all other personnel can open the security doors with the access card.

At HLS-II, the security doors must be opened by access card. When access card is swiped, the card information

18th Int. Conf. on Acc. and Large Exp. Physics Control Systems ICALEPCS2021, Shanghai, China JACoW Publishing
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Table 2: Safety Classification of the Interlock Areas at HLS-II

Operation States		Linac	Ring Center	Ring Hall
Released State		Radiation Area	Radiation Area	Safety Area
Searching State		Radiation Area	Radiation Area	Radiation Area
Interlocked State	Beam Enable	High Radiation Area	High Radiation Area	High Radiation Area
	Top-Off Mode	High Radiation Area	High Radiation Area	Safety Area
	Decay Mode	High Radiation Area	Radiation Area	Safety Area

will be sent to the PLC. Then the PLC judges the access permission according to the access authorities for each card and the safety classification of the interlock areas. The card number and authentication information are sent to IOC and archived in EPICS database as an event for recording and tracking. Meanwhile, the OPIs can display the access state synchronously.

In the access control system, the personnel count function is realized in the EPICS IOC by state notation language (SNL). SNL is a domain specific programming language which can provide a simple yet powerful tool for sequential operations in a real-time control system. According to the card number and authentication information, the SNL program counts the personnel number for each interlock areas, and writes the count results into the EPICS records.

OPI DESIGN

The OPIs of the novel HLS-II PSS is composed of the OPI of the linac area and the OPI of the storage ring area, as shown in Figs. 3 and 4. The linac area includes the linac tunnel and transport line tunnel. The storage ring area includes the ring center and the ring hall.

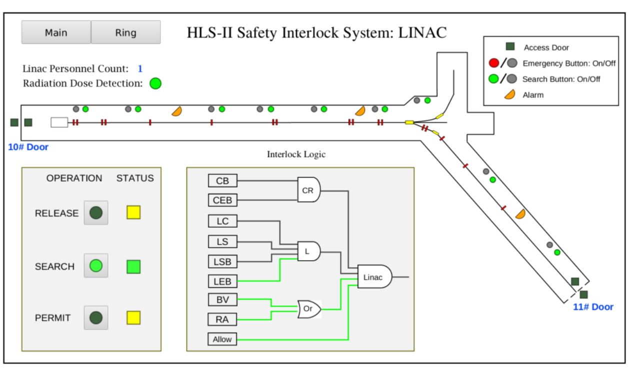

Figure 3: The OPI of Linac.

The OPI can be divided into four parts: 1) the distribution and state of the security doors, the emergency buttons, the search buttons and the alarm devices; 2) the personnel count and the radiation dose monitoring state for the interlock areas; 3) the interlock logic diagram; 4) the operation commands and the related states. The line color in the interlock logic diagram is variable depending on the logic value, it is gray when the logic value is 0, and green when the logic value is 1.

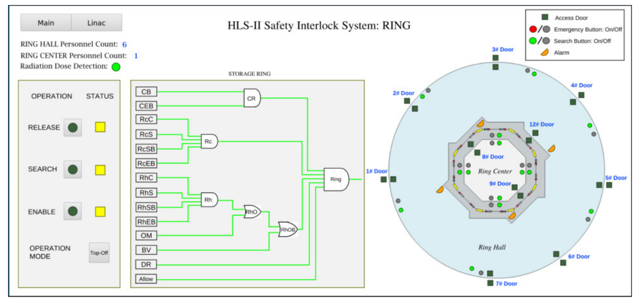

Figure 4: The OPI of Storage Ring.

OPERATION STATUS

The development of the novel HLS-II PSS is completed. To ensure that this system could work as designed, we set up the offline platform and continuously tested for one month. The test results demonstrate that all the devices can run well and stably, the interlock actions can be executed effectively, and the Top-Off mode and Decay mode can be supported successfully. Meanwhile, the offline platform can work properly during the redundant PLCs switch over.

The development of the novel HLS-II PSS is completed and it's deployed during 2019 summer. Figure 5 is the photo of the Door Display OPI which is located beside the No.7 security door. Distinct from the OPIs in Linac area and storage ring area, this OPI will shown the operation modes and access state as well. When the access card is swiped, it can alarm the access result via audio and text at the meantime.

During the 2 years operation, the novel HLS-II PSS keeps running stably behind the control of redundant PLCs. The safety interlock system can executed interlock actions precisely and all 3 interlock states can be switched timely . It also performs well on supporting both of Top-off mode and Decay mode. The new access control system improves the effectivity of personnal management, and the radiation system can be integrated into this novel PSS smoothly. All the data in novel PSS can be shared and processed real-timely under EPICS environment.

CONCLUSION

In the novel design of HLS-II PSS, the safety interlock system, the access control system and the radiation monitoring system are integrated into EPICS environments, it is easy to share information and use the existing toolkits provided by the EPICS community. In the access control

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Figure 5: Photo of the novel HLS-II PSS Door Display OPI.

system, the personnel management function is designed for monitoring the entry and exit of staffs and users to meet the HLS-II management requirements. After 2 years successful operation from 2019, the novel HLS-II PSS has proofed its highly reliability and stability which can fulfull the design requirements.

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