UPGRADE OF RADIATION MONITORING SYSTEM AT SSRF FOR TOP-UP OPERATION

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Abstract

The radiation monitoring system (RMS) at Shanghai Synchrotron Radiation Facility, SSRF, is required to upgrade to have dose interlock functions for top-up operation as an important safety issue. This paper describes the basic requirements, design criteria, signal network, and functions of the upgraded radiation monitoring system. Both the prompt dose rate and the accumulative dose alarm were archived for the safety issue after the upgrade. The reliability and stability of the upgraded RMS are in testing for getting operation permission from authority for radiation safety issue.

INTRODUCTION

As recognized the multi-advantages of top-up mode operation for an advanced third generation light source, Shanghai Synchrotron Radiation Facility, SSRF, was designed originally both for machine operation in decay mode and top-up mode. SSRF is a third generation synchrotron radiation facility, which consists of a 150 MeV linear accelerator (LINAC), a 150MeV-3.5 GeV full energy booster synchrotron (BS), a 3.5GeV storage ring (SR) with 432 m circumference, and beamlines. It has completed in 2009 followed by 52 months construction and machine commissioning, and opened to user operation in decay mode since May 2009.To achieve its original design goal to operation in top-up mode, SSRF has set a goal to start the commissioning of top-up operation in 2011 and to open to users in 2012. To this goal, serials updates and modifications of related systems have been carried out during limited machine study period since 2011, and safety analysis has been carried out. Upgrade of the radiation monitoring system at SSRF is required to have dose interlock functions for top-up operation as an important safety issue. This paper summarized the upgrade of the radiation monitoring system at SSRF as a portion progress report to top-up operation mode.

CURRENT RIDIATION MONITORING SYSTEM

For easy understanding, general description of the current radiation monitoring system at SSRF is given as background information. The RMS at SSRF has been designed and installed to monitor gamma and neutron radiation in the radiation working area and the environment. The system consists of real-time gamma and neutron area monitors, which a high gas-pressurized ion-chamber as the gamma detector and a BF_3 proportional counter inserted in a polyethylene modulator as the neutron detector. The details in the detector specifications were given in the past work summaries [1]. In total, 109 detectors including 51 neutron detectors and 58 gamma detectors are installed for on-line service currently. The detectors are distributed in the working area radiation safety concerned in SSRF, including the LNAC, BS, SR and the experimental hall where the beamline stations are set, as well as the campus boundary for environmental monitoring.

The system consists of distributed detectors, central control computer and data acquisition server, as illustrated in Fig.1. Each detector has its own data processing module and data memory which allows data saving for a month maximally locally, and is able to transfer data via a dependent Ethernet network special designed for the radiation monitoring system. The data of gamma and neutron dose measured are sent to the central control computer via Ethernet network and also to the data acquisition server to be stored in a database for historic data survey.The local data processing module provides real-time prompt dose rate display and both low and high level dose rate alarm.

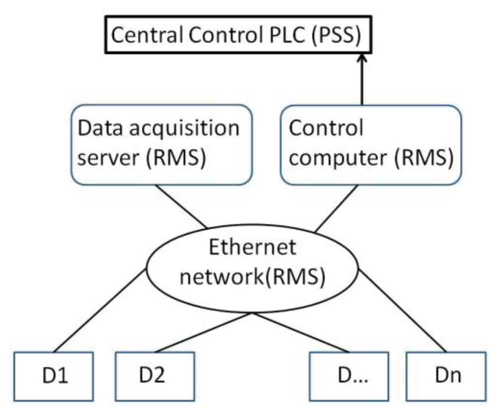

Figure 1: Schematic layout of current radiation monitoring system at SSRF

The prompt dose rate and the alarming data are sharing with the Personnel Safety System (PSS).There is no accumulative dose information and corresponding alarm in the current RMS. The accumulative dose level in an expected time interval or period is more significant comparing with the prompt dose rate for operation in top-up mode from the viewpoints of radiation safety. Additionally, the dose rate data cannot be triggering the PSS to interlock in necessary.

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UPGRADED RIDIATION MONITORING SYSTEM FOR TOP-UP OPERATION

Basic Requirements

After two years successful operation in the decay mode, SSRF has been prepared to start top-up mode operation for users in 2012. As well-known, top-up operation is a worldwide accepted and well developed operation mode for the third generation synchrotron facilities, and experienced successfully in several synchrotron facilities [2][3][4][5]. Top-up mode provides a constant thermal load on the storage ring vacuum chamber and beamline optic elements, which are essential to the photon beam position stability, and overcomes the short beam lifetime problem caused by low energy and low emittance beam as well as the extensive use of small gap undulators in storage rings. Therefore it can significantly reduce thermal effect of beamline optical elements, provide more stable and intense photon beams.

Differing from the decay mode operation, in top-up mode, the concerned radiation risk to the users at the experimental hall is that the radiation dose resulted from frequent injections in top-up mode when safety shutters (SS) of beamlines are opened, whereas, in decay mode, the injections can only allowed when the safety shutters of beamlines are closed. This will be controlled by the radiation safety interlock system (RSIS). Therefore, to ensure personnel radiation safety in the operation in top-up mode at SSRF, several upgrade and modification of related systems should be implemented. These included both the related software and the hardware. The necessary inputs for starting the top-up mode are considered as the following:

- Storage current: hardware-interlocked with at least 100 mA of electron beam must be stored in the ring before start top-up mode.
- Energy changes: the power supplies of the dipole magnets of BS to SR and the SR should be hardware-interlocked to stay within specific voltage and current limits to ensure an acceptable energy changes. The quadrupole magnets' can be soft-interlocked.
- Injection efficiency: soft-interlocked to stop the top-up when injection efficiency falls below 50% or lifetime drops below 10 hours.
- Radiation dose: radiation dose hardware-interlocked to stop the top-up mode if the detected accumulated dose exceeds a setting value.

With the above-mentioned basic requirements for the operation in top-up mode, upgrade of the RMS is necessary.

Design Criteria

The design criteria for the RMS upgrade should be:

- Independent, reliable, fail-safe, testable, unrestrictive and redundant should be followed basically
- The RMS should be hardware-interlocked for a high reliability operation
- Detectors involved in the dose interlocked RMS should be selected based on the radiation field characteristics.
- The RMS should be available to set both prompt dose rate and accumulative dose alarming.
- The machine operation mode changes from the top-up to the decay mode if any radiation monitor interlocked in the RMS detects an excessively high level of radiation.
- The RMS should be combined to the current Personnel Safety System (PSS) to be a whole radiation safety interlock system (RSIS)

Function for Setting Accumulative Dose Alarm

According to the design criteria for the upgrade and to meet the requirements for the operation in top-up mode, the current occupied RMS needs to be upgraded to enable adding accumulative dose alarm and to keep the prompt dose rate alarm currently available. For setting the accumulative dose alarm, the data processing module for each detector should be upgraded to process accumulative dose dynamically. This was achieved by a software program with an intelligent platform module controller embedded. The prompt dose rate was obtained with data acquisition in each 5s in the data processing module. The module process automatically a serial such data according to a given time period, and the number of data for output the accumulative dose is determined by the time period divided to 5s. Both the prompt dose rate and the accumulative dose are stored temporally in the memory. The preset alarm values are also stored in the memory. , The dose alarm signal is forward to a Programmable Logical Controller (PLC) additionally set for the RMS.

Hardware Interlocked RMS and Logic Control of RSIS

Following the design criteria for the RMS upgrade, the RMS should be hardware-interlocked. The upgrade of hardware and the related logic control were carried out.

The hardware upgrade included the modification of the data processing module, setting of the PLC for the RMS, and central control PLC for the PSS.

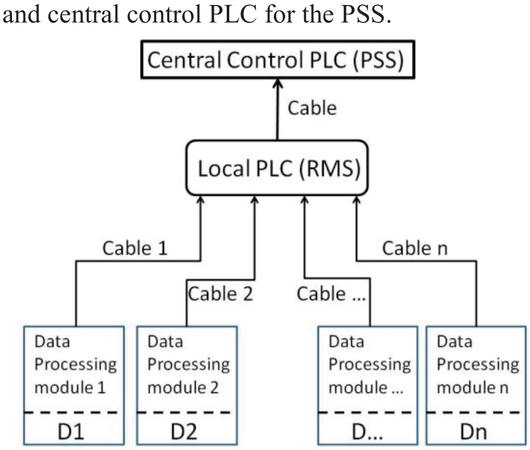

Figure 2: Hardware and data/signal transfer of the upgraded radiation monitoring system

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As shown in Fig.2, all data/signal transfer between the detectors and the Local PLC, as well as the Central control PLC is designed to be connected via independent cables.

Fig.2 is also showing the signal network for the upgraded hardware parts. Each detector output trigger signal for dose alarm to the local PLC, the local PLC analyzes all the signals from each detector, and forwards it to the central control PLC. The electric power supply of the RMS is backed up by UPS to improve the redundancy.

To combine the RMS to the PSS to be a whole radiation safety interlock system (RSIS), the logic control was modified. Fig.3 shows the general logic diagram of the interlock system for the operation in top-up mode.

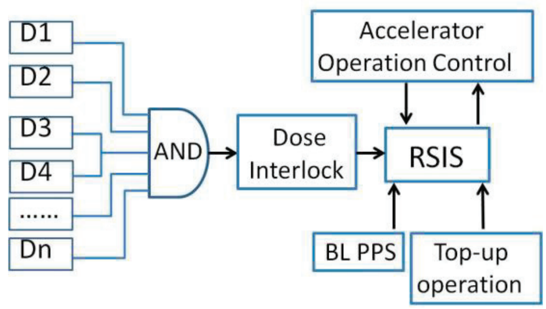

Figure 3: The logic diagram of the interlock system for the operation in top-up mode

In this interlock logic, the upgraded RMS and the PSS was added to the accelerator operation control system. Once the machine operation asking for top-up mode, the RSIS checks the radiation dose information, and feedback to the accelerator operation control system. The upgraded RMS now can provide two types of alarm, the prompt dose rate and the accumulative dose. The prompt dose rate alarm is same as before the upgrade. It includes both low and high trip levels preset. In the top-up mode operation, the two level alarms are set to be a warning only. The alarm is latched until radiation safety staff on duty cancels it after a quick safety inspection. Stopping injection in the operation in top-up mode only activated if the accumulative dose exceeds the preset value. In this case, the RSIS stops the top-up injection first, then close the beamlines' SSs, and then change to operate in the decay mode. In the decay mode, if the high-level alarm, the RSIS acts as designed function. The alarm values are set as the following during the RMS commissioning, it may change according to the safety review later:

- Gamma dose rate alarm setting: 100 μ Sv/h of gamma dose rate outside the photon beamline .
- Neutron dose rate alarm setting: 10 μ Sv/h of neutron dose rate outside the photon beamline.
- Gamma accumulative dose: 9 μ Sv within 4 hours
- Neutron accumulative dose: 1 μ Sv within 4 hours

Commissioning Results

In the upgraded RMS for dose interlock, eight pairs of detectors were installed at outside of optical hutch of each beamline and one pair was installed in the injection area. The upgraded RMS has capacity to control all interlocked detectors for the future. The commissioning of the upgraded RMS at SSRF has been carried out since 2011 and performed four times fully simulation of top-up operation as designed for routine operation. The commissioning was performed in two ways, one for testing all functions of the upgraded RMS with simulation signal trigger, and the second for testing the RMS and the RSIS in a real top-up operation mode. The results showed satisfy in the former way commissioning. In the later way, the beam current was 200mA, beam energy of 3.5GeV in SR with lifetime of 15 hours. The functional test results of the commissioning showed good system response as design expected basically, except for two failure cases. The reason caused the failure was analysed and discussed to be the power shutdown abnormally, and the event was not occurred in the following on-line test.

SUMMARY

The RMS at SSRF has been upgraded according to the basic requirements for the top-up mode operation. The design criteria of the upgrade was discussed and both hardware and software upgrades were performed to meet the design criteria. The upgraded RMS and the PSS were improved to be a RSIS. Eight pairs of the detectors were successfully installed and occupied on-line for a real-time radiation dose monitoring and dose interlock function required. The commissioning of the upgraded RMS was carried out in two ways and the results showed good functional system responses. The upgraded RMS is available to serve for the operation in top-up mode. The radiation safety review for the top-up mode operation is still ongoing and hopefully SSRF will begin the operation in top-up mode to users in the latest of 2012, after getting the safety approval from national authority as necessary procedure.

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