THE SILF ACCELERATOR CONTROLS PLAN

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Abstract

The Shenzhen Innovation Light Source Facility (SILF) is an accelerator-based multidiscipline user facility planned to be constructed in Shenzhen, Guangdong, China. This paper introduces controls design outline and progress. Some technical plans and schedules are also discussed.

INTRODUCTION

The SILF is a fourth-generation medium-energy synchrotron radiation light source that envisions a future with over 50 beamlines. Its primary focus lies in supporting the development of domestic core industries, advancing frontiers in basic science research, and addressing strategic imperatives, including integrated circuits, biomedicine, advanced materials, and advanced manufacturing.

The SILF project received approval from the Shenzhen Government on September 10, 2020. The feasibility study was successfully completed in 2022, and the preliminary design phase is currently underway. Detailed plans for the construction phase of the project are currently being developed.

The accelerator complex is composed of a 200 MeV linac, a booster with ramping energy from 0.2 GeV to 3.0 GeV, and a 3.0 GeV storage ring as shown in Fig. 1. Two transport lines are designed to connect the linac, booster and storage ring. The circumference of the storage ring is 696 m, which includes 28 hybrid seven-bend achromat (H7BA) lattice periodic units to achieve the emittance below 100 pm·rad. The top-up operation mode (300 mA, 928 bunches) is considered, and a brightness of about 10^{22} s^{-1} mm^{-2} $m \cdot rad^{-2}$ $(0.1\%\ bandwidth)^{-1}$ is expected at the photon energy of 10 keV for SILF, as illustrated in Fig. 2. Considering machine errors and correction, the dynamic aperture of the storage ring is 7.2 mm, which meets the requirement for off-axis injection [1].

Furthermore, we have placed significant emphasis on the control system, which plays a pivotal role in providing and assuring high availability and reliability, laying a solid foundation for successful user experiments. In light of initial budget constraints, recent efforts have marked the commencement of research and development (R&D) activities. These R&D endeavours encompass the development of the EPICS7 development platform, the prototyping of vacuum control systems and PLCs, the creation of timing prototypes, machine protection prototypes, and the exploration of potential applications for orbit feedback.

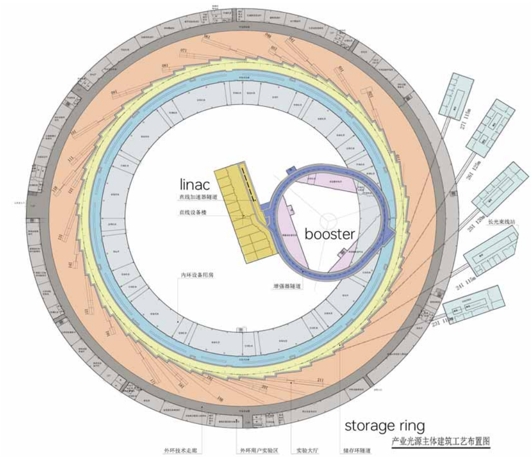

Figure 1: Schematic layout of the SILF project.

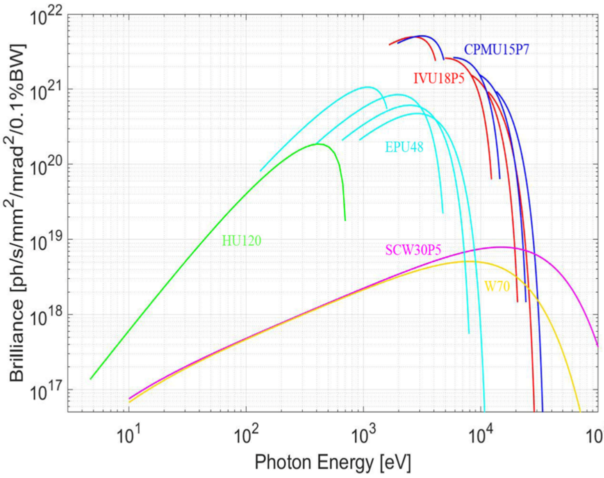

Figure 2: The available spectral brightness for SILF operated in the high brightness.

CONTROL SYSTEM SCOPE

SILF uses the EPICS family of distributed control system software for the creation of a facility-wide data communication layer, which integrates all technical systems that participate in photon production and experiments [2]. The typical EPICS usage model of SILF is a three-tier system including the presentation layer, the middleware service layer and the frontend device layer as shown in Fig. 3.

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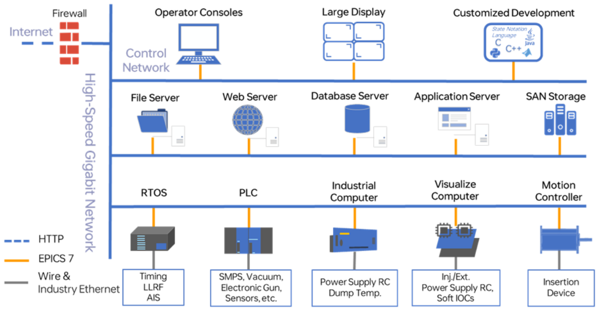

Figure 3: EPICS typical usage model of SILF.

Hardware and Software Platform

The accelerator control system comprises a network of interconnected and distributed control and computing systems, serving various control domains and purposes. To ensure optimal performance, we will employ standardized hardware technologies, including MicroTCA, EtherCAT, and common industrial automation technology. Additionally, multiple PLC-based systems will be deployed for equipment interlock and conventional facilities. Industrial computers-based Soft IOCs will facilitate communication with the PLCs via Ethernet/IP, with each IOC featuring precise data timestamping.

The following sections provide detailed descriptions of the key components and infrastructure within the accelerator control system, including local and remote controls, global control systems, high-level applications and services, integration of conventional facilities, as well as insertion device controls and beamline management.

Local and Remote Controls

Vacuum Control The vacuum control system shares the architecture and the communication infrastructure of the main control system. However, it often requires specific solutions at the process level to accommodate a large variety of equipment (such as pumps, gauges, valves, interlocks, etc.). Additionally, it measures the temperature of the vacuum chamber, photo-absorber, and RF bellows. These measurements will be conducted using PLCs, which are pivotal for managing pump and gate valve ON/OFF status as well as temperature monitoring. The serial port server will be chosen for the gauge and pump monitoring via RS-422/RS-485.

Power Supply Control Interface The power supply control system will transmit commands, setpoints, and waveforms to the power supplies, as well as retrieve status information, current values, and waveforms from them. Despite the diversity of these power supplies, the control interface for each of them will be standardized, utilizing the Ethernet port with the Modbus/TCP protocol.

RF Control Interface The Low-Level RF (LLRF) control is an EPICS system, and its control software is built upon the MicroTCA bus Platform. The IOC processes the data and makes it accessible to all other IOCs and services within the facility's middleware service layer. This ensures that the data is readily available to users for monitoring, analysis, display, or archival storage within the control system.

Cryogenics Control Interface The local control of the cryogenics system is built with Siemens's PLCs. S7nodave for EPICS is a device support based on Asyn and libnodave facilitating communication with S7 (or compatible) PLCs.

Beam Current Monitoring Interface The AC current transformer (ACCT) is responsible for measuring the beam current. A signal conditioning board is utilized to convert the ACCT's signal into a format compatible with a data acquisition device. Subsequently, the MicroTCA controller digitizes the signal and transmits it to the EPICS layer.

Global Control Systems

Networks and Infrastructure All systems, components, human workstations, and data processing facilities within the SILF control network are interconnected through a set of data networks. The network infrastructure will establish connections between the centralized server room of the control system and the local control and instrumentation areas, using both single-mode and multi-mode fibre. A firewall will be implemented to separate the control network from the campus network. The control network will be equipped with a central core switch located in the centralized server room, as well as edge switches deployed in each local control and instrumentation area. EPICS CA gateway will be employed for various IOC PV access, ensuring effective traffic management and security.

Virtualisation and Container Technology The control system requires a significant allocation of computing resources to operate EPICS and other software services. Ensuring the high availability of these computing services is a top priority, and this is achieved through extensive use of virtualization and container technology. Consequently, many of the EPICS IOCs and other software services are hosted on virtual computing systems or isolated software processes. These virtualized environments are established on high-availability, managed computer clusters situated within centralised server rooms. This approach offers several advantages, including flexible resource allocation, load balancing, a closely regulated and secure environment, and efficient resource utilisation, all contributing to the goal of maintaining high availability.

Timing system he timing system is event-based and incorporates both MRF and SINAP MicroTCA bus event system products. It delivers precise trigger and clock signals to various devices distributed throughout the entire facility, including beam instruments, RF systems, power supplies, and beamline instruments.

Machine Protection System Machine protection plays a crucial role in ensuring the operational availability needed for photon production by implementing dedicated protection functions to prevent component damage. Beyond safeguarding components and minimizing unplanned downtime, this system also collects data on the root causes of errors. This information is then used for in-depth analysis and ongoing system enhancements.

The machine protection system (MPS) comprises two parts: one is the PLC-based slow protection system

(SMPS), and the other is the FPGA-based active interlock system (AIS).

Fast Orbit Feedback System The SILF storage ring is comprised of 28 cells, with each cell featuring a “cell controller” that forms the foundation of the fast orbit feedback system infrastructure. The implementation of the fast orbit feedback system aims to mitigate various disturbances and enhance orbit stability [3]. The feedback logic of Fast Orbit Feedback (FOFB) is shown in Fig. 4.

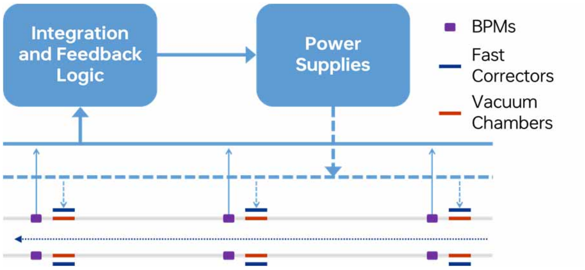

Figure 4: Feedback logic of FOFB.

High-Level Applications and Services

At the SILF facility, a rigorous naming convention is strictly followed to ensure that every element is named in a manner that facilitates understanding. This practice is essential for avoiding ambiguity and ensuring clarity in the interpretation of names. The naming convention is consistently applied to both accelerator and beamline experiment instruments.

Control System Studio(CSS) toolsets serve as comprehensive high-level applications for various control system functions, including data display, operator interfaces, alarming, and data analysis. CSS is a versatile collection of tools, encompassing an alarm handler, multiple operator interface options, and control system diagnostic tools. Among these tools, data browser, probe, and message history are frequently employed during routine operator operations.

For electronic logging, the CLOG2 tool serves as the accelerator's electronic logbook. CLOG2 simplifies access to information for accelerator personnel through a user-friendly web interface. This interface allows users to browse and search entries, download files, and optionally provide comments on entries [4, 5].

Integration of Conventional Facilities

The environment and equipment necessary for operators, scientists, and engineers to interact with SILF systems must be made available. A key focal point is the central control room, where photon beam production is centrally controlled and supervised, and related operational activities are carried out. Additionally, local control rooms will be provided for device commissioning and troubleshooting.

Insertion Device Controls and Beamline

SILF is a fourth-generation synchrotron facility with a strong focus on insertion device sources, primarily undulators. The control system is designed based on EtherCAT, a real-time Ethernet fieldbus protocol for industrial automation. Communication between EPICS IOCs and EtherCAT devices is facilitated through the Modbus/TCP protocol.

Additionally, an FPGA-based active interlock system has been implemented to safeguard insertion devices and vacuum chambers from the potential thermal damage caused by high-density synchrotron radiation power. Figure 5 shows the layout of AIS architecture and the connection between sub-stations.

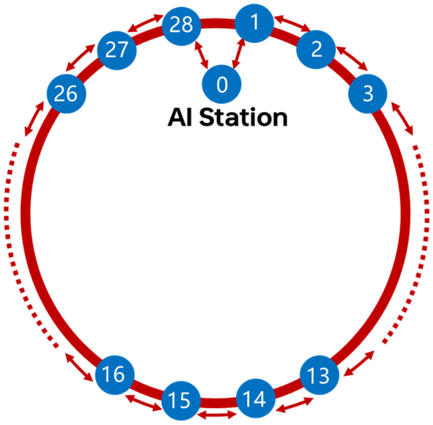

Figure 5: Layout of AIS architecture.

CONCLUSION

The control system will leverage the latest advancements in hardware and software to deliver high performance, robust functionality, and cost-effective control solutions. Well-defined device control interfaces have been established for various components, including power supplies and insertion devices, among others.

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