17th Int. Conf. on Acc. and Large Exp. Physics Control Systems ICALEPCS2019, New York, NY, USA JACoW Publishing
ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-FRAPP03

STATUS OF CSNS ACCELERATOR CONTROL SYSTEM

Y. L. Zhang†, C. P. Chu, W. C. Gao, F. Q. Guo, Y. C. He, D. P. Jin, M. T. Kang, G. Li, X. Wu, L. Wang, P. Zhu, Institute of High Energy Physics, Chinese Academy of Sciences, Beijing, China

Abstract

The China Spallation Neutron Source (CSNS) consists of an 80 MeV H- LINAC, a 1.6 GeV Rapid Cycling Synchrotron, two beam transport lines and one tungsten target and three beam lines. The designed proton beam power is 100 kW in Phase-I. EPICS(Experimental Physics and Industrial Control System) is chosen as the software platform for the accelerator control system. The accelerator control system mainly consists of 21 sub-systems. VME64x based system with real-time embedded controllers is chosen for the timing system and fast protection system. PLCs and embedded industrial computers are used for the device level slow controls. CSS (Control System Studio) and RDB based techniques are adopted for high level applications. The overall control system was completed in 2018 and transitioned to routine operations in September of the same year. The design and implementation of the overall accele rator control system are introduced in this paper.

INTRODUCTION

CSNS accelerator consists an 80Mev H- LINAC and a 1.6GeV Rapid Cycling Synchrotron (RCS) and two beam transport lines as shown in Fig. 1. The LINAC, which is mainly composed of a H- ion source, a Radio Frequency Quadrupole (RFQ) and four Drift-Tube LINACs (DTL). LINAC and RCS both can be operated at 25Hz. At phase-I, the beam power is 100kW. The whole accelerator reserves the ability to upgrade the beam power to 500kW in the future [1]. In August 2017, the first proton beam was delivered to the target and the first neutron beam was generated after the first shot of proton beam. One year late, in August 2018, the whole facility was passed the national acceptance and open to the users.

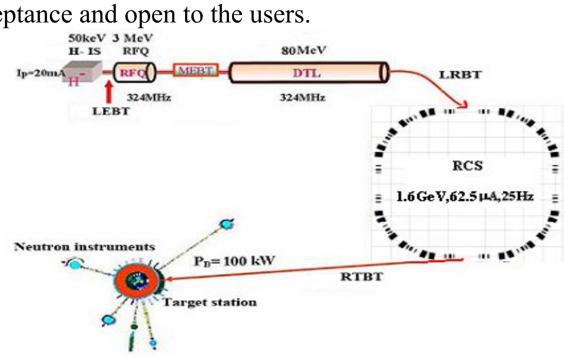

Figure 1: Schematic diagram of CSNS.

CSNS accelerators are designed to accelerate very high intensity proton beam and the uncontrolled beam loss may permanently damage or give a high radiation dose to the accelerator components along the beam line. Therefore, high reliability for control system is the basic requirement.

† zhangyl@ihep.ac.cn

The accelerator control system must be carefully designed so that we can avoid the unnecessary beam loss. Besides, the availability, scalability, maintainability and the budget was also carefully considered in the design and implementation stage.

CONTROL SYSTEM OVERVIEW

The accelerator control system can be divided into four parts: global systems, high level applications, low level and remote device controls and conventional facility integration. The global systems include timing system, machine protection system and control network. High level applications include services, console applications and databases. Low level and remote controls include vacuum control, front end and DTL control, power supply and RF remote control, stripper foil control and etc. Conventional facility integration includes UPS, isolated transformers, cables, racks and control rooms. The whole accelerator control system mainly consists of 21 sub-systems.

The main tasks of the accelerator control system are as the follow:

- To provide global control and communication platform.
- To provide global monitoring, data archiving and querying services.
- To provide global timing signals covering the whole facility, including accelerator, target and beam lines.
- To provide global machine protections.
- To provide data exchange interface to the conventional facility system, personnel protection system (PPS) and the experimental control system.
- Device layer or remote controls.

The design and implementation of accelerator control system is based on the EPICS framework [2]. EPICS toolkits provide standard tools with operator interface builder, data archiving, alarm handling and etc. CSNS control system benefits a lot from the existing EPICS tools and modules, such as Control System Studio(CSS) [3], Archiver Appliance [4], StreamDevice [5] and so on.

In order to minimize the hardware category of the control system, brand and type of the adopted hardware were normalized. For example, all slow control sub-systems must use the YOKOGAWA PLC and Moxa industrial computer. Most of the devices and equipment we chose which can be directly connected to EPICS by using the existing drivers in EPICS community. We only need to develop EPICS drivers for a few devices by ourselves. By this way, we saved a lot of time in the design and implementation stage.

The CSNS accelerator control system complies with the standard large distributed system architecture. The overall control system can be divided into three layers, the presentation layer, the middle layer and the device layer as shown in Fig. 2. IOCs, services and applications distributed in

ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-FRAPP03

three layers connect to each other through the high-speed and reliable control network. Operators can access the EPICS IOCs running in control network from campus network through a dedicated firewall.

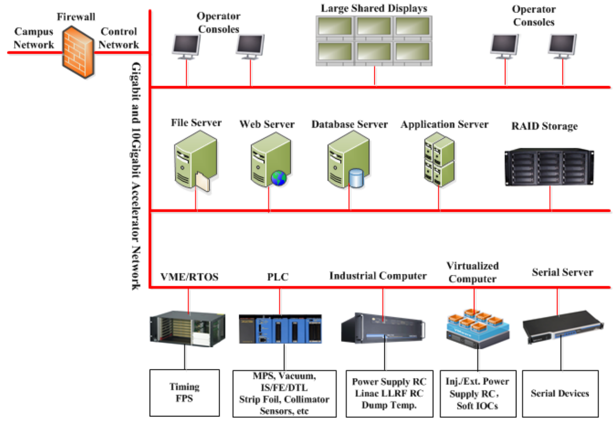

Figure 2: Architecture of accelerator control system.

DESIGN AND IMPLEMENTATION

Run Management System

The CSNS has five beam destinations: LINAC dump (L-DUMP), LINAC dump1 (LRDMP1), injection dump (I-DUMP), RCS dump (R-DUMP) and Target as shown in Fig. 3. The whole facility area can be divided into three independent PPS control areas: the LINAC control area, the RCS control area and the target control area as shown in Figure 2 too. The MPS divides the input signals from the whole facility into 10 sub-areas, and the MPS final interlock area is composed of several sub-areas.

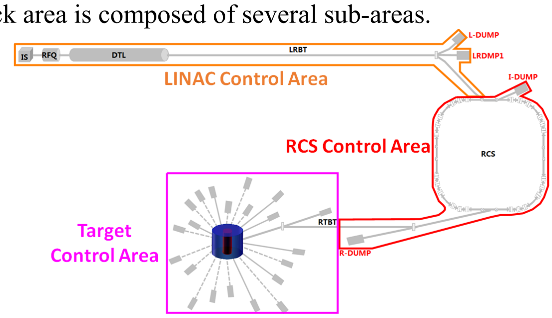

Figure 3: PPS control area of CSNS facility.

The basic requirements for the operation of CSNS facility are as follows:

- Access to the three PPS control areas should be controlled independently. For example, when the LINAC PPS control area is in prohibited access state, the RCS tunnel (within the RCS control area) can be accessed following the regulations without interrupting the state of the LINAC control area, vice versa.
- Beam destinations can be changed safely and rapidly. For a certain beam destination, the required MPS logic must be automatically selected, and the PPS control areas have no need to be re-established, assuming that the current PPS control area already includes all the three control areas. For example, if the current beam destination is target, the destination can be rapidly changed to any of the other four destinations, and the operator has no need to do any verifications rather than switching the machine mode key.
- To ensure that the beam cannot be delivered to the wrong beam destination.
- To ensure that the beam power to a certain dump or the target is in tolerance.

To meet these operation requirements and to address the risks of the operators' mistakes, the run management system for CSNS facility was designed and deployed. The RMS performs the following tasks:

- To set up and publish the machine primary operation area, the machine mode and machine state.
- To verify that the MPS and the PPS is ready for the machine primary operation area and the selected machine mode.
- To ensure that beam could not be extracted from the ion source if the accelerator or any of the PPS control areas involved in the machine primary operation area is not ready.
- To set up the allowed beam parameters for the selected machine mode.
- To provide operator interface (OPI) for control and status display.

Figure 4 shows the machine states transitions, where the "Exception" is defined as the fatal error. Machine state will automatically transit to SHUTDOWN state if an exception occurs, and the machine state will transit to BEAMOFF state if the current state is RUNNING, when the MPS fault signal is received by RMS.

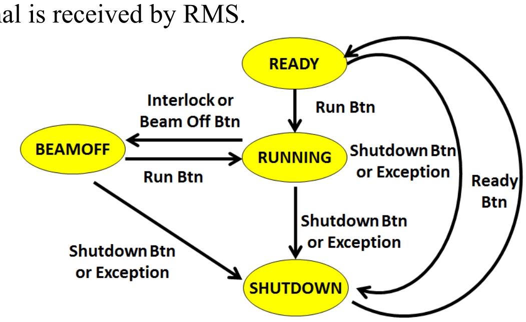

Figure 4: Machine state transition diagram.

Machine Protection System

Machine protection system (MPS) is one of the key subsystems for the control system. MPS plays an important role in beam commissioning and operation. CSNS machine protection system consists of two protection systems, one is the Normal Machine Protection System (NMPS), the other is the Fast Protection System (FPS). NMPS convers the whole facility, including accelerator and target, the required response time for NMPS is less than 30 millisecond. NMPS is a PLC based protection system and the field measured response time is less than 20 millisecond. FPS only covers the LINAC part of accelerator and the required response time for FPS is less than 10 micro-second. FPS was implemented using the FPGA technology and the field measured response time is less 2 micro-second, where the signal transmission is the main time consumption. Figure 5 shows the relations of the all the protection systems.

ISBN: 978-3-95450-209-7 ISSN: 2226-0358 doi:10.18429/JACoW-ICALEPCS2019-FRAPP03

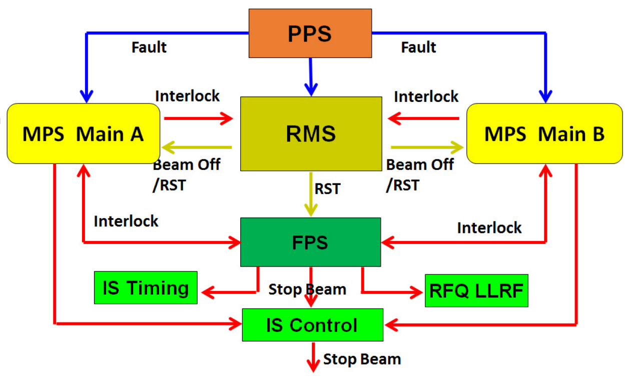

Figure 5: Relations among protection systems and RMS.

NMPS consists of two independent systems, MPS-A and MPS-B, these two systems have their own cable routes to the beam stopping actuators. MPS-A covers the whole facility, while MPS-B only receives signals from a number of critical devices. Beam interlock output signals from both MPS-A and MPS-B are sent to RMS, FPS and ion source control system to stop the beam.

Timing System

The CSNS timing system is an event based timing system. MRF and SINAP VME bus event system modules[6] are both used. The timing system is the facility scope global system. Figure 6 shows the architecture of timing system.

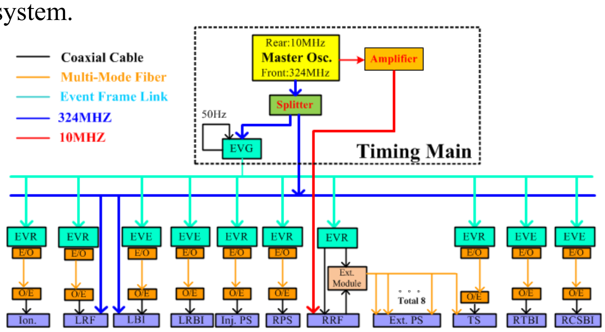

Figure 6: Relations among protection systems and RMS.

The timing system provides two kinds of clock signals, 324MHz RF clock signal generated by master oscillator to the LINAC reference line and Event Generator(EVG) and 10MHz clock signal to the RCS RF system. The trigger signals can be divided into two categories, the scheduled trigger signal and the synchronized trigger signal. Scheduled trigger signals are directly divided from the 324MHz master clock and can be generated by Event Receiver(EVR) or EVE(SINAP's EVR equivalent function module). Synchronized trigger signals, which should be synchronized with the RCS RF clock, are supplied to the LEBT chopper power supply and the RCS extraction kicker system. Figure 7 shows the trigger signal series in one 25Hz cycle.

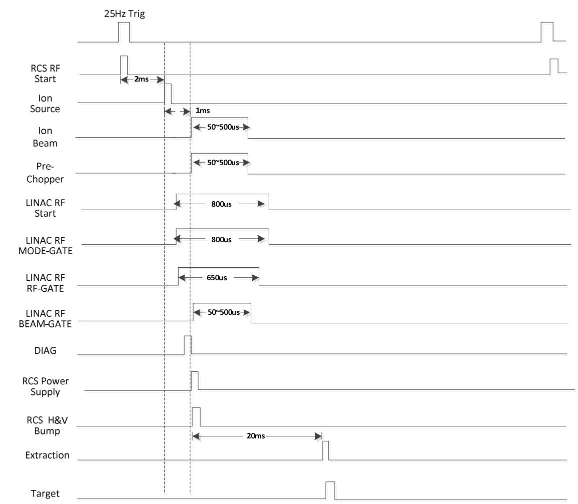

Figure 7: Trigger timing series in one 25Hz cycle.

PLC Based Slow Controls

The PLCs based slow control sub-systems include ion source control, front end control, DTL water cooling control, vacuum control, strip foil control and collimator control. The only brand of PLC used in the whole control system is Yokogawa FA-M3. The system complexity is reduced and maintainability is increased.

YOKOGAWA FA-M3 series PLC has two types of CPU module. These two CPU modules, the sequence CPU and embedded linux CPU (F3RP61), can be installed in one PLC unit. The sequence CPU is used to implement the interlock and logic control and the F3RP61 CPU is used as the EPICS IOC. F3RP61 can directly access the register via PLC bus. Through using this solution, the whole system is very compact and stable.

CONCLUSION

The CSNS accelerator control system take advantages of the latest hardware and software developments to deliver high performance, rich functionality, and economically control system. The whole CSNS control system was completed in 2018 and it meets the first phase of beam commissioning and operation requirement. There are still much upgrade and revise work needs to be carried out to address the high quality requirements.

REFERENCES

[1] S. Wang *et al.*, "Introduction to the overall physics design of CSNS accelerators", Chinese Phys., vol. 33, pp. 1-3, 2009.

[2] https://epics.anl.gov/

[3] http://controlsystemstudio.org/

[4] http://slacmshankar.github.io/epicsarchiver_docs/index.html

[5] http://epics.web.psi.ch/software/streamdevice/

[6] http://essrf.sinap.cas.cn/technology/timing_system/Electronics/201506/t20150605_294797.html