STATUS OF THE CSNS CONTROL SYSTEM

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Abstract

The China Spallation Neutron Source (CSNS) is a high current proton accelerator which will officially start construction in September of 2011 in China. The CSNS control system has finished the preliminary design including devices interface determined and high level application.

This paper introduces control system design and 他和 progress of some prototypes as well as schedule and personnel plan.

INTRODUCTION

The CSNS[1] will be a 100KW accelerator based facility which is comprised of five major sections as shown in Fig. 1: a front end consisting of a 50 Kev H^- ion source followed by a 3MeV RFQ; a 80 MeV linac; a 1.6 GeV RCS; a 100 kw spallation neutron target which can be expanded to 500kw.

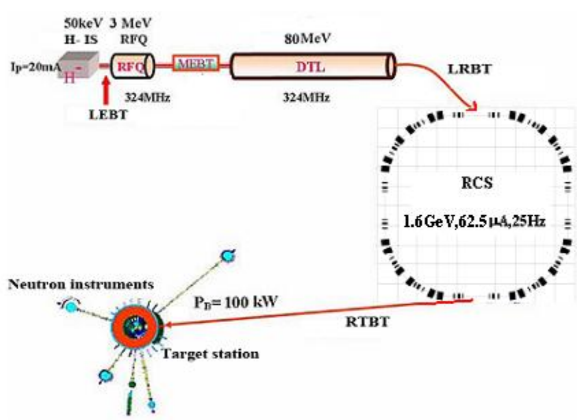

Figure 1: The Schematic Layout of the CSNS Facility.

The beam loss must be strictly controlled due to high current proton. On one hand, the radiation produced by the beam must be minimized for hands-on maintenance, on another hand, the damage to the equipments/devices due to radiation and thermal effect should be avoided since this facility has a strong radiation. So, the machine protection is very important.

CONTROL SYSTEM DESIGN

The defined scope for the control system is: that it will be a site wide monitoring and control system for the accelerator, target and conventional facilities. It will include all hardware and software of the following aspects as shown in the Fig. 2: computer system, networking, front-end controllers and hardware interface, machine protection system, as well as timing system.

The control system will not include any control or data acquisition for the target and the experimental stations. It further will not include the personnel protection system, which is a separate system that will be monitored by the control system. The control system will exchange data to conventional utility through the Ethernet. The overall task of the control system is to control and monitor thousand of the equipments/devices covering linac, LRBT, RCS and RTBT. In another word, the control system mainly provides the connections between operators/programs and accelerator equipments. Besides, it provides synchronization operation and equipments protection from the linac, RCS and the target.

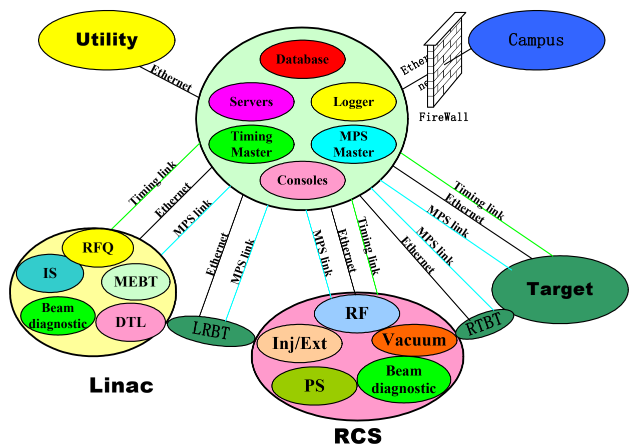

Figure 2: The Layout of the Control System Distribution.

Architecture of HW/SW

The control system will adopt the standard two layer architecture[2] with PC/Linux workstation as the Client. The EPICS IOCs are VME IOCs, one CPCI IOC, Embedded IPC IOCs and Embedded PLC IOCs for subsystem as shown in the Fig. 3. There will be no field bus to a third layer, but extensive use will be made of serial interfaces from layer two to the equipments. EPICS 3.14.10 and VxWorks 5.5/Linux 2.6 will be used for EPICS development environment. The interface from the control system to the equipment will be through different IOCs. The equipments interface has been determined.

Front End Interface

The Front-end include an ion source, LEBT,RFQ and MEBT. The ion source control system is typically a single component of the control system. It includes 5 parts: power supplies, vacuum, temperature measurement, water cooling and timing. All are required to be controlled locally in the tunnel and remotely at the central control room. The power supplies will work in the high voltage environment. So, they require high reliability and availability of the control system.

The prototype of the ion source control system was finished in 2009. All the devices had been controlled using YOKOGAWA FA-M3 PLC. One PC/Linux as EPICS IOC exchange data with the PLC CUP via Ethernet. The PLC CPU communicates with PLC I/O

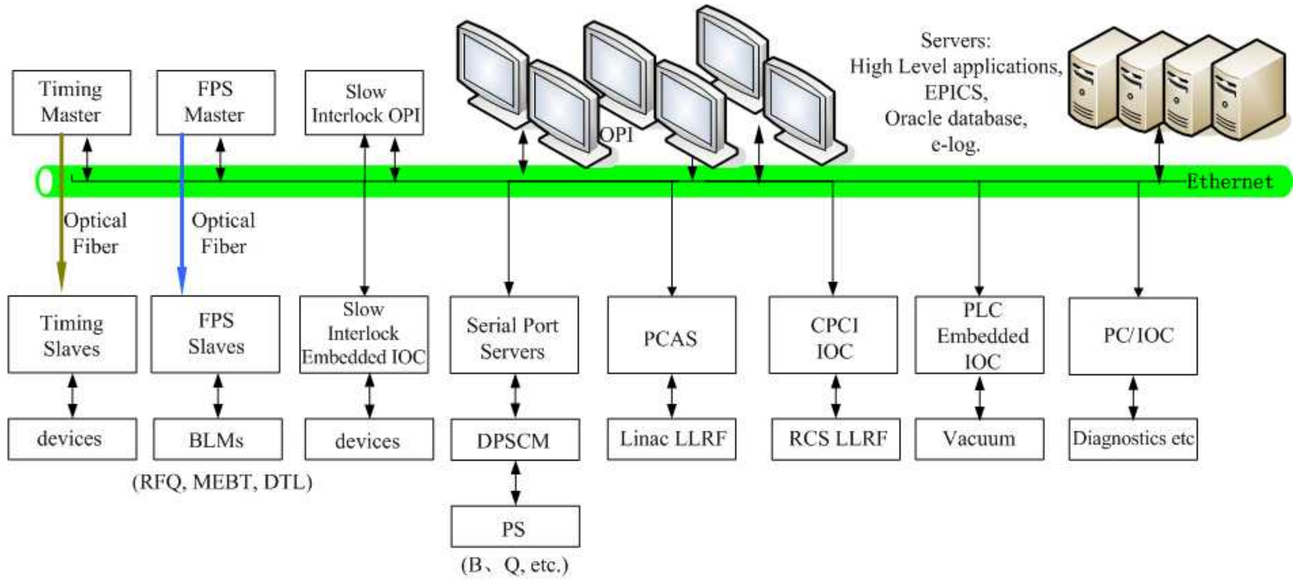

Figure 3: The Control System Architecture.

modules through the FA-Bus optical fiber. There is no extra electrical isolation between the ground and the high voltage platform. Some lessons are learn by the prototype like ground isolation, temperature modulation from relay switching on/off to PID control, more detailed specifications of the devices interface, processing of high voltage ramping and so on. In next step, the embedded IOC will be used to replace combination of the SoftIOC and the PLC/CPU as shown in the Fig. 4.

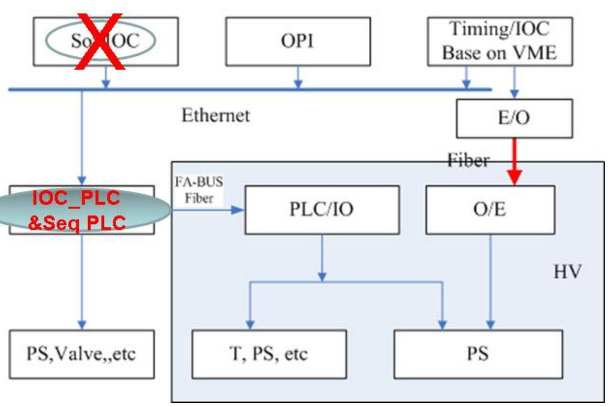

Figure 4: Ion Source Control System.

Power Supply Interface

There will be about 300 various magnet power supplies that are distributed in the linac, LRBT, RCS and RTBT. All the power supplies will be digital power supplies using a digital power supply module (DPSCM) developed by the power supply group. The DPSCM is an intelligent power supply controller with only serial port supporting Modbus RTU/RS232 and can implement logic control to the digital power supplies. Most work will be done within the DPSCM and power supplies. Since the ring is a rapid cycling synchrotron (RCS), the dipole and quadrupole power supplies with white circuit will provide 25 Hz sine waveform output to the magnets. Most magnet PS are DC power supplies, the RCS power supplies are DC plus AC power supplies with 25Hz sine waveform. Although these PS are different, the control interface to the different PS will be standardized. The requirements from the physics are very simple, for e.g. DC setpoint setting and reaback, AC amplitude/phase setting and readback. The DPSCM works fine for the RCS dipole/quadrupole power supply now.

After many times discussion between the control group and power supply control, the interface to the DPSCM has been determined using the serial port with Modbus RTU/RS232. The control group used a MOXA serial device DA682/Linux to connect the serial port of the DPSCM as shown in the Fig. 5. The communication between DA682 and the DPSCM is using Modbus RTU/RS232. We have developed Modbus RTU/RS232 driver and device support as well as database on DA682. In one word, this device is used as IOC to communicate with the DPSCM through the serial port with Modbus RTU/RS232 protocol. The prototype has been tested with the DPSCM with one power supply on site. The testing result showed that the software communication is ok and the speed can meet the requirement.

Vacuum Control Interface

The vacuum control system needs to monitor and control 128 ion pump power supply controllers, 45 vacuum gauge controllers and 27 gate valves in linac, LRBT and RCS,RTBT. The YOKOGAWA PLCs has been chosen for Ion pump and gate valve ON/OFF control and status monitoring. The MOXA serial device has been chosen for monitoring the gauges and pump power supply controllers via RS232/RS485.

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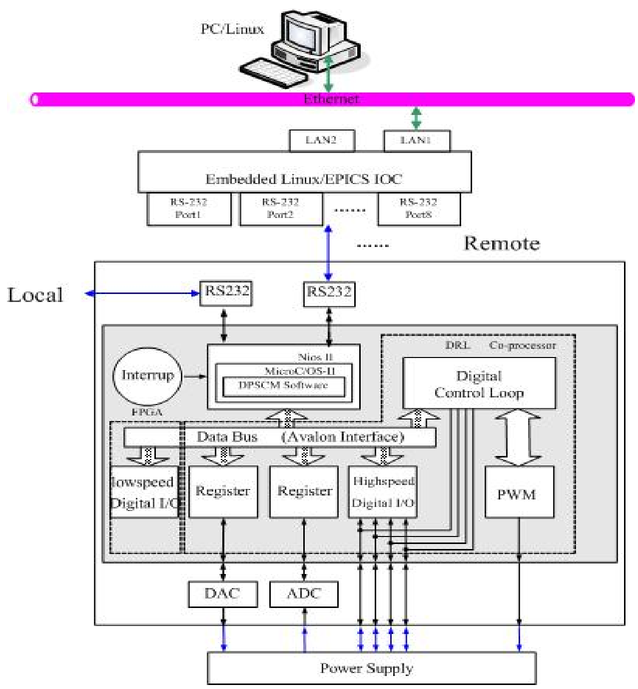

Figure 5: Power Supply Control System.

Injection and Extraction PS Interface

There are 8 injection power supplies and 8 kick pulse power supplies. YOKOGAWA WE7000 measurement has been used for the injection power supply prototype. The prototype test has been done in 12/2009. The control system is requested to monitor the PFN charge voltage and the kicker pulse current. The ZTEC oscilloscope (1GS/S, 300MHz, 12 bits, 2 Ch) with a built-in EPICS system is selected to get the charge voltage and pulse current. The ON/OFF control of the high voltage charge power supply will be implemented by YOKOGAWA PLC.

LLRF Interface

The Linac LLRF consists of a VXI crate and customized I/O module and a PC through RS422. It has been done by Linac RF group. The control system uses PCAS to communicate the API of the LLRF for changing local variable into EPICS PVs. The RCS LLRF will be implemented using customized CPCI I/O modules by RCS RF group. The control system needs to develop EPICS driver and database to interface with VxWorks driver supported by the company.

Machine Protection System

The machine protection system (MPS) has been redesigned during the preliminary stage referring to the MPS of the SNS[3] and J-Parc[4]. The design philosophy of the MPS is as follows:

- The devices local interlock done within the devices and send interlock signals to the MPS
- Hardware interlock,software recording as assitant
- Physical I/O redundancy for fatal faults in the key region/system
- Yokogawa PLC for equipment protection
- Customized Master and Slave for fast protection
- With a failsafe and rich self-diagnostic
- When a fault occur, MPS can shut down ionsource extraction high voltage and RFQ high voltage as well as perform post mortem analysis automatically

The MPS consists of two parts:

- Equipment protection for collecting signals and detecting internal faults from the equipments in Linac,RCS,Target and PPS. When any equipment fault occurs, it performs alarm handler and stop beam to avoid damage due to thermal effects
- Fast protection for interfacing BLM, once beam loss exceeds loss limit, shut down ion source and drop RFQ voltage to zero to avoid damage due to radiation and thermal effects

Besides, the MPS is also responsible for displaying status of the equipments and allowing automatic recovery from beam faults.

The equipment interlock consists of one central PLC and several PLC stations to collect signals and propagate the state signals of Linac,RCS and Target through the FL_Net to the central PLC. The FL_Net can accomplish data scanning within 200μs. The response time from a fault signal of the equipment to action can be within 20ms. How the FPS work is shown in the Fig. 6. Once the beam loss exceeds the loss limit, FPS will shut down ion source and drop RFQ voltage to zero within 20 μs to avoid damage due to radiation and thermal effects. The FPS consists of one Master and several slaves Fast responses are handled in FPGA (Xilinx Spartan 6) either locally or over bi-directional FPS optical communication. FPS unit monitors digital signals from BLMs. The ion source and RFQ are interfaced to MPS Master digital outputs. When any inputs on MPS unit changes, the output on MPS Master is triggered. The response time from MPS unit to MPS Master at 1 km distance is below 20 μs.

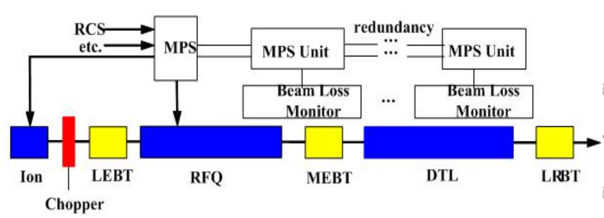

Figure 6: FPS working principle.

Timing System

Timing system is designed to provide triggers and clocks to the following systems: Front end, linac RF, injection, beam instrumentation, magnet power supply, RCS RF, extraction, spectrameter and target. The timing system consists of one EVG and several EVR stations. Detailed discussions with the above systems have been done, while there are still some points need to be studied further. Prototype using EVG/EVR has been setup. The specification of the EVG/EVR has been tested. The interface with the MPS has been studied and preliminary simulation has been done. Timing details about extraction have been studied and discussed with corresponding systems. A dedicated hardware for the extraction timing has been designed.

Consoles

The consoles will be workstations and for cost reasons these are likely to be PCs running Linux. There are also some requirements to provide some PCs running windows for Win32 based applications. The accelerator, target and conventional facilities will be operated and monitored from the central control room, although there will be local control rooms available for device commissioning and troubleshooting.

Central Servers

There will be several central servers at the central control room. They are likely to be PC servers running Linux. They will provide development, applications, relational database, network, data archiver and viewer, alarm management, error logging, logging services and IOC booting.

Applications

The device application requirements can be met through the standard EPICS tools, control panels through EDM, alarm management through Alarm Handler, archiving through Channel Archiver together with Oracle database. Since web browsers have become an easy way to view and manipulate the control data, the CSNS control group is also planning to developed web-based control panel. Because the similarities between the CSNS and the U.S.SNS, the high level application framework will adopt XAL[5], used at SNS. XAL has been used for SNS commissioning and operation for over five years. Some XAL work in CSNS has been done including database framework of the CSNS accelerator by using standardized rules and interfaces. We have imported most of the equipments data of the CSNS Linac accelerator and two beam transfer lines. A virtual accelerator has been successfully setup. The control system will be responsible for providing high level application platform.

Network

A preliminary control system network design is based on 100Mbit switched Ethernet with a Gigabit switched Ethernet backbone. The network infrastructure will connect the control system computer to each of the local control and instrumentation areas with single and multi mode fibre. There will be a firewall between the control network and campus network. The control network will use a central core switch in the central control room and edge switches at each local control and instrumentation areas. The control network will be separate into several subnets. EPICS CA gateway will be used for the different IOC PV access and effective management of traffic and security.

CONSTRUCTION

The detailed program of work for construction phase of the project is currently being planned. The control system development will take 2 years. Some subsystem installation with the equipment installation will start in the end of 2012. The whole control system installation will be complete in 2/2016. The whole control system online commissioning will take 3 months. We are expecting to put it into operation in 5/2016. The CSNS control group is not only responsible for the CSNS control system construction, but also for the BEPCII control system maintenance. The CSNS control system would have a minimum resource requirement to get a basic system up and running.

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