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Control system for the CSNS ion source test stand

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Abstract A penning plasma surface H^- ion source test stand for the CSNS has just been constructed at the IHEP. In order to achieve a safe and reliable system, nearly all devices of the ion source are designed to have the capability of both local and remote operation function. The control system consists of PLCs and EPICS real-time software tools separately serving device control and monitoring, PLC integration and OPI support. This paper summarizes the hardware and software implementation satisfying the requirements of the ion source control system.

Key words CSNS, H^- ion source, EPICS, PLC, control system

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1 Introduction

The China Spallation Neutron Source (CSNS) is an accelerator-based high power project currently under research and development (R&D) in China [1]. Its accelerator is composed of an 81 MeV H^- linear accelerator (Linac) as the injector and a 1.6 GeV Rapid Cycling Proton Synchrotron (RCS) [1]. The H^- ion source is one of the significant parts of the linac. A reliable, stable and good performance H^- ion source is the precondition of a successful linac, accelerator and the CSNS.

An ion source test stand for the CSNS has been developed at the Institute of High Energy Physics (IHEP). It is undergoing design, application and continuous improvement. The test stand consists of many instruments, such as several sets of power supplies (PS), a turbo molecular pump and a gate valve. All these hardware instruments need to be controlled and/or monitored. The control system has been developed by utilizing Programmable Logic Controllers (PLCs) and Experimental Physics and Industrial Control System (EPICS) software toolkits [2–4]. In this article, the design and development of the ion source control based on PLC and EPICS distributed real-time software tools are presented.

2 The ion source components and their control system architecture

The ion source control system is a local and two-level control system, and it will be linked with the remote control system via Ethernet in the future [5]. It is composed of the front-end controller, the field control equipment (device interface) and the Ethernet network. A schematic of the control system structure is shown in Fig. 1.

The communication between the PLC and the PC employs the TCP/IP protocol based Ethernet, by installing driver support for Ethernet on EPICS [6]. And it promises a high speed network for transmitting critical signals of the ion source system and providing real-time control and monitoring.

In order to realize the integration of extendable systems, and to set up a friendly operator interface, the EPICS software is adopted and installed in the PC. The PC working as the front-end controller is the top-level control. The operator interface (OPI), channel access (CA) and soft input/output controller (IOC), based on the EPICS software toolkits [7], form the upper layer of the control system. The soft IOC on the upper control layer functions as a hardware controller running the device interface modules (i.e. the PLCs). CA connects the client in the OPI with

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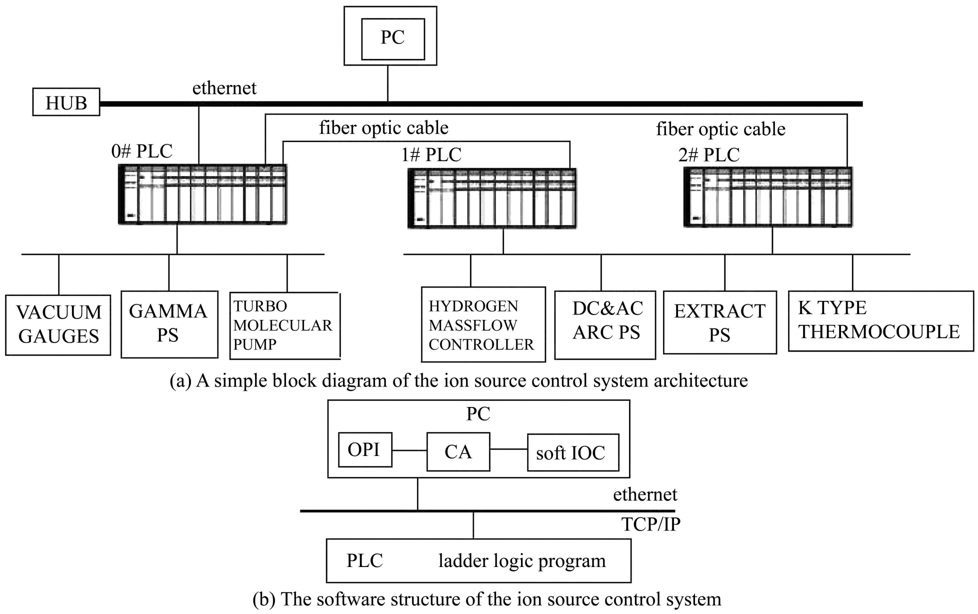
the server in the IOC, and brings the OPI transparent access to the IOC database. This software architecture allows the user both to implement the control and monitoring through the graphical user interface developed by an EDM toolkit based on EPICS, and to create the state notation program with state notation language (SNL) in the IOC. Fig. 1 shows a schematic of the ion source control system and Fig. 2 shows parts of the graphical user interfaces. In Fig. 1, only some of the devices controlled and monitored are shown as an example, i.e. the vacuum gauges, the gamma power supply (PS) for accelerate, the turbo molecular pump, the mass flow controller, the direct current and alternating current PS for generating arcs, the extraction PS for extracting beam and the K type thermocouples.



(a) A simple block diagram of the ion source control system architecture

(b) The software structure of the ion source control system

Fig. 1. The ion source control system architecture.

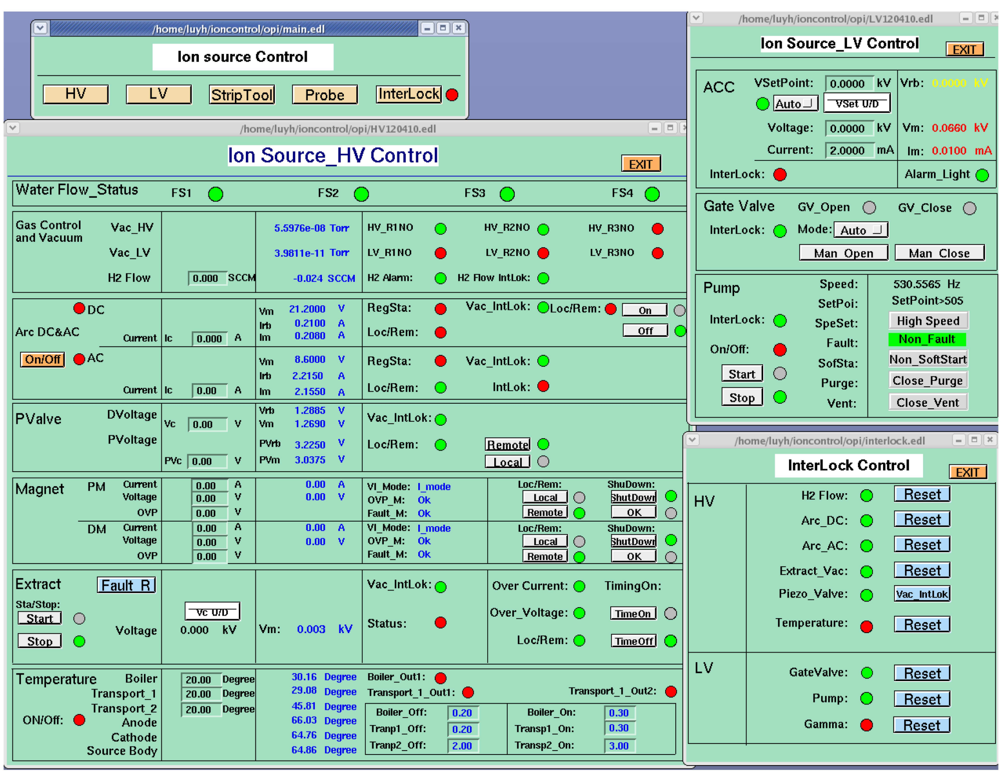


Fig. 2. The graphical user interface of the control system.

The YOKOGAWA PLCs as the device interfaces are adopted to carry out most of the control functions with the ladder logic program. As shown in Fig. 1, the data exchanges between number 0 PLCs and number 1 and 2 PLCs are accomplished through duplex fiber-optic cables connected with fiber FA-bus modules because number 1 and 2 PLCs are on the high potential while number 0 PLCs are on the grounded potential. The field devices are connected to the PLCs directly or via isolation modules by using multi core cables. The principle functions of the PLCs include the receiving, processing and transmission of digital and analog data and interlocks. The CPU module of the PLC processes the signals and transmits them to the associated input/output modules to achieve real-time monitoring and control of the field devices.

The GUIs are organized in two major layers, i.e., 1) the CSNS ion source main window and 2) the detail windows. As shown in Fig. 2, the main window includes five detail windows. They are HV, LV, Interlock, Strip tool and Probe windows. A detail window always contains one or several blocks, and each block is basically associated with one controlled instrument of the system. The contents on the front panel of the physical instrument are included in the block as much as possible, i.e., each signal to be monitored and/or controlled is in the block. Therefore, a detail window controls and monitors one or several subsystems of the ion source control system. In each window, there are pushbuttons to pop up the other detail windows.

3 Interlocks and software implementations with sequencer

3.1 Interlocks in PLC

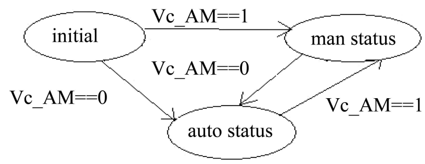
In order to assure the safety of people and the key devices, lots of interlocks need to be taken into account. The interlocks are achieved through the ladder logic program, monitored with the red/green lights and controlled with button control in the GUI. As shown in Fig. 2, most of the instruments are of vacuum interlock, but only a few of them are for personal safety protection. For example, as a typical device, the gamma power supply (PS) is of both vacuum interlock and personal safety protection. The gamma PS will stop working when 1) the vacuum pressure drops to a specified limit (10^{-3} Torr), observed from the vacuum gauge; 2) there is power supply loss; 3) the door of the high platform cabin is open; 4) too big a voltage change step results in over-current protection; 5) there is an interlock instruction from the operator. Certainly, all of the associated interlocks must be enabled in advance if an operator wants to switch on the gamma PS and apply high voltage to the high platform.

For safety purposes, some software interlocks are also set, and self-locking is added to the interlock in the ladder logic program. In the interlock OPI, there exist only the "RESET" buttons to operate for fear of the error operations to make manual interlock.

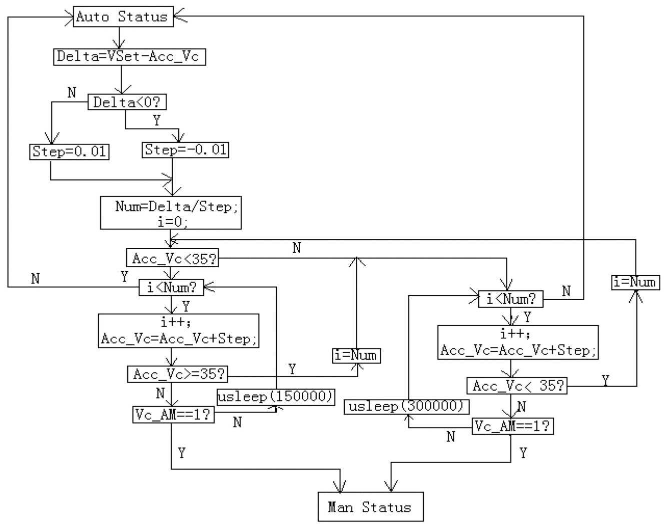
3.2 The software implementations with sequencer

As mentioned in Section 2, the EPICS software architecture allows the user to create the state notation program in the IOC. Under EPICS, a more complicated state transition program with the SNL can be developed to achieve more software functions. The state notation program is firstly compiled by the state notation complier, downloaded to the IOC, managed by the software sequencer provided by EPICS, and then run in real-time with the IOC database. The state transition program is used for the manual interlock of the DC&AC Arc PS, the interlock of the gamma PS, the heating device control, the control of gamma PS voltage change steps, and so on. Fig. 3 shows the utilization of the SNL in controlling the voltage ramping process of the gamma PS.

The gamma PS is applied to a capacitor with a capacitance of 2 μf, so the voltage change of the gamma PS is a process of charging and discharging of the capacitor. Once the current of charging and discharging is larger than the maximum output current limit of the PS, the PS will automatically switch to over-current protection. The state transition program is adopted to implement the automatic change of the PS voltage and to control the change steps. Since the output current is smaller at a lower voltage due to the current-limit resistance, the voltage of 35 kV is taken as the boundary of low and high voltages in the design of the program. As shown in Fig. 3(b), the change steps are designed equally while the applying time for the process of charging and discharging of the capacitor is designed differently.



(a) The state transition diagram of the gamma voltage control.



(b) The program structure of the automatic voltage ramping of the gamma PS.

Fig. 3. The gamma voltage control diagram.

4 Conclusions

The CSNS ion source control system of the test stand has been finished. Control and monitoring of the system have been demonstrated. The ion source control system is under commissioning. The EPICS based OPI is being improved to provide operations more friendly and clearly. Further efforts of developing and improving the EPICS software will be made to satisfy the new requirements from the ion source as the commissioning continues, such as the use of Alarm Handler software to realize the sound alarms for some critical interlocks and so on.

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