THE CONTROL SYSTEM DEDICATED FOR BEAM LINE OF PROTON RADIOGRAPHY TEST-STAND ON A 100 MeV CYCLOTRON CYCIAE-100*

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Abstract

This paper outlines the design of the control system for beam line ofproton radiography on 100 MeV cyclotron CYCIAE-100. The project proposed by the China Institute of Atomic Energy (CIAE). For high intensity operation, a dedicated controls system and stabilized operation environment are preferable. In order to satisfy the requirements of this proton radiography control system, we have built a complex control system which contains PLC controller, MOXA controller, IOC and EPICS system. In this paper, the designing, constructing and commissioning of the proton radiography control system will be described.

INTRODUCTION

CYCIAE-100 100MeV H- compact cyclotron is the main component of HI-13 tandem upgrade project. It can provide the proton beam of 70-100 MeV with beam current of 200-500 μA. CYCIAE-100 consists of some subsystem such as main magnet system, RF system, main vacuum system, beam detection system, control system and so on. The control system is an important subsystem which main function is to carry out the devices of CYCIAE-100 automation control.The first beam of CYCIAE-100 was extracted on July 4, 2015 [1]. In previous work, we have completed the main magnet system and vacuum system. With the improve of system stability, in June of 2016, 1135 μAbeam was got on the internal target.

Nowadays, proton radiography is a main tool for providing a development direction for advanced hydrotesting research. For x-ray radiography, its advantages are simplicity and relatively low cost of the facilities, the main element of which is an electron accelerator. But x-ray with high penetrating power passing through an object engender photon showers which result in background noise in the recorded image. In thick objects, the photon noise can completely conceal the useful image. Proton radiography does not have these problems. In terms of penetrating power, protons significantly surpass x-rays. In 2014, the low energy proton radiography system utilizes a 11MeV proton beam to radiograph thin static objects, which developed at CAEP [2].

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OVERALL DESIGN

Proton radiography requires a particular magnetic lens system to provide a point-to-point imaging from the object to the image. The design detail is described in Ref. [3]. For the above reason, the beam precise control must to take into account at the beginning of the control system design. In the beam line of proton radiography there are many subsystems, such as magnet power system, vacuum system, water cooling system, beam detection system and stripping probe system. Considering for a lot of signals to be control, we use the SIMEMENS S7 series Programmable Logic Controller (PLC) controller which CPU model are S7-400, S7-300 and ET-200. Because of the SIMEMENS S7 series have exceptional stability. The MOXA controller is used to receive analog feedback signals. The Experimental Physics and Industrial Control System (EPICS) [4] is the like a bridge connects the Input/Output Controller (IOC) and the Operator Interface (IOC) which stored in the INSPUR server. The structure of proton radiography control system is shown in Figure 1.

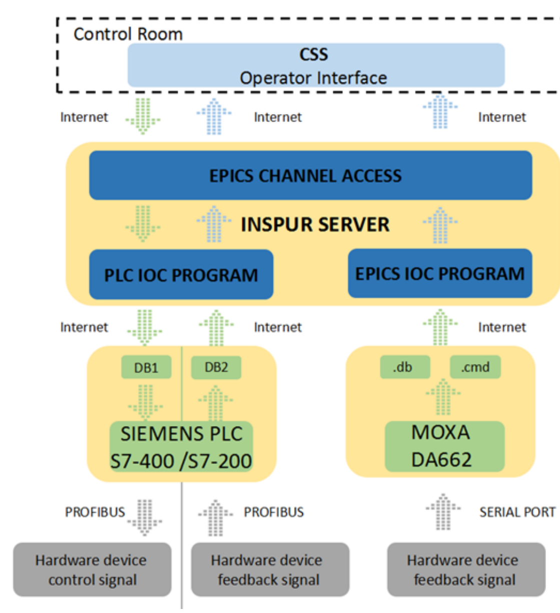

Figure 1: The structure of proton radiography control system.

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INPUT/OUTPUT CONTROLLER DESIGN

We use SIMEMENS S7 series, CPU model for S7-400/S7-300 and ET-200. Communication between PLC and ET-200 adopts PROFIBUS. In this Beam Control System, there are three main categories of PLC program function block. They respectively are interlock system for control devices power, special blocks for communication between devices and general function block for complete logic control. DB is the communication module of PLC. It is evident from Figure 1 that DB1 gives the control commands to the devices and DB2 accept the feedback signal form the devices. For chose the PLC, there are two reasons. Firstly, it is known that stability is the fundamental requirement in the control system. SIEMENS PLC S7-400 can provide a stable platform. Because of the CPU can work interchangeably. Secondly, S7-400 uses a modular design. It contains a variety of modules, for example SM modules、CP modules、FM modules. All these modules can be directly connected to the beam diagnostics devices. It can collect a lot of feedback signals of the device. During the control process, PLC can provide a rich programming models. This allows us to perform complex logic control.

We also use MOXA controller. MOXA is a kind of multi-serial port embedded computer. Communication protocol is used RS232/RS485. This device is connected to a power device and vacuum gauges. It has the advantage of multi-channel feedback signals can be collected on a single device. Figure 2 and Figure 3 show the connection of these devices.

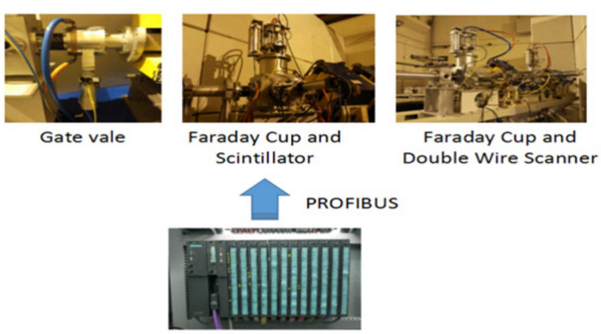

Figure 2: The connection of the PLC.

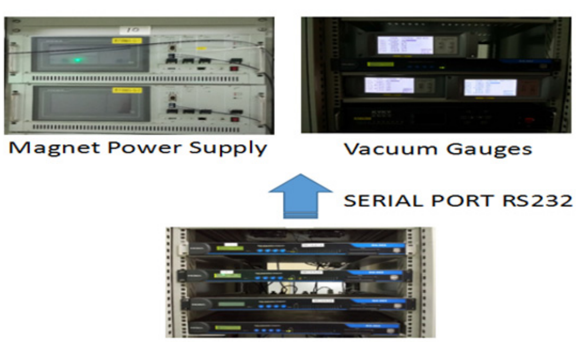

Figure 3: The connection of the MOXA.

Unlike other beam line of CYCIAE-100. In order to maintain the accuracy of the beam, there are more beam diagnostics devices and vacuum gauges in the beam line of proton radiography. In particular, those analog signals from vacuum gauges will complicate the control logic. To keep the code of PLC simple, we use the Visual EPICS Database Configuration Tool (Visual DTC). Visual DCT is an EPICS configuration tool completely written in Java and therefore supported is various systems. The Visual DCT program is shown in the Figure 4. The 'ai' block is a feedback signal which type is word from the MOXA controller. The 'bo' block is a control signal which type is bite from the PLC. The function of Visual DCT is not only to communicate the MOXA controller and the PLC but also can change the type of the signal. Therefore, we can save saved a lot of work to writing the program in PLC.

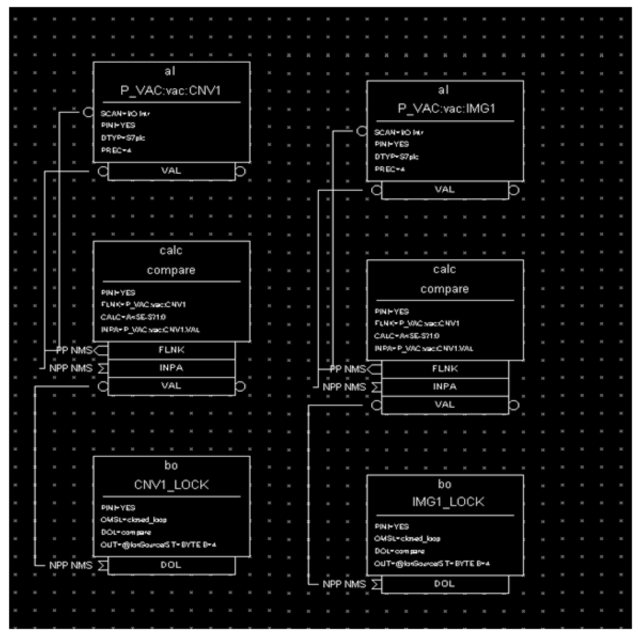

Figure 4: The program of the Visual DCT.

EPICS is a set of Open Source softwaretools, libraries and applications developed collaboratively and used worldwide to create distributed soft real-time control systems for scientific instruments such as a particle accelerators, telescopes and other large scientific experiments. In EPICS, the control algorithms are stored in independent databases which are not combined until the system is loaded onto the IOC. All the databases and the IOC program is stored on the INSPUR server. EPICS runs on processors which use a real-time kernel, therefore the rate at which EPICS database records are processed is deterministic. All these characteristics are important for the beam line control system delivers.

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Channel access (CA), the 'backbone' of EPICS, hides all details of TCP/IP network from both devices and servers. It connects all devices with all servers. CA also creates a very solid 'firewall' of independence between all devices and server code, so they can run on different processors, and even be from different versions of EPICS. Using a host tool, the database is described in terms of function-block objects called 'records'. About 50 record types exist for performing such chores as analog input and output; binary input and output and other tasks. For supports not only Windows OS, but also other operating system like Linux OS or MAC OS. The Linux OS was installed on the INSPUR server because of its stability. The IOC program of PLC and MOXA controller are stored separately in the database of server. It consists of two parts, one is the file of records which describes the properties of the signals, the other is the file of initiator program. During control process, operator can login the server remotely and loading the initiator program files. When the IOC program is running, the signals will be send to the OPI from the devices of beam line.

OPERATOR INTERFACE DESIGN

Control System Studio (CSS) [5] is an Eclipse-based collection of tools to monitor and operate large scale control systems. It is dedicated to supplying tools for control system, data integration and data visualization to enable users to achieve their objectives. BOY is an Operator Interface (OPI) development and runtime environment. PV Manager is the library that talks to the control system. Simple PV Layer is a layer that provides a simpler and abstract interface to talk to PV Manager. BOY only needs to talk the Simple PV interface. At OPI is a graphical user interface that displays live control system data to operators and allow them to input data to the control system. The OPI of our Beam Line of Proton Radiography control system (Figure 5) clearly shows all the devices running status. All digital signals and analogue signals through the EPICS to OPI. All the operations are completed in OPI. We use the vividly image instead of the simple switch button. This makes the interface more attractive.

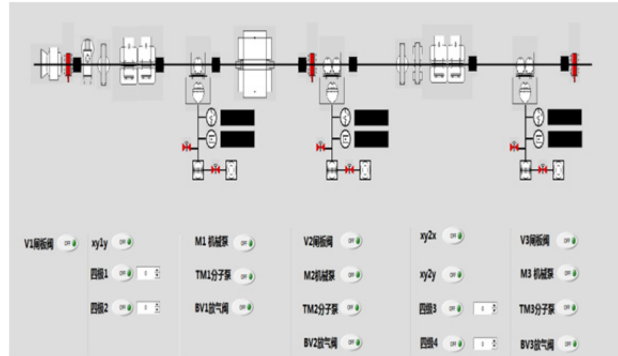

Figure 5: The OPI of the beam line control system.

CSS/BOY supports not only EPICS, but also other frameworks like DOOCS or TINE. Moreover, it can run on all the most common operating systems such as Windows, Unix and Mac X OS. This makes the whole control system has strong portability.

CONCLUSION

The design work for Control System Dedicated for Beam Line of Proton Radiography on 100 MeV Cyclotron CYCIAE-100 has shown in this paper. Results indicate that the designed parameters and the control system are reasonable and could meet the requirements for basic beam line of proton radiography. In the next step, the Alarm System and Data Base system will be built by using CSS.

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