THE CONTROL SYSTEM BASED ON EPICS FOR THE EXPERIMENTAL TARGET PROTOTYPE

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Abstract

Building a high power spallation target is one of the critical issues in Accelerator Driven System (ADS). The control system which was built based on the real-time distributed control software of experimental physics and industrial control system (EPICS) was attempted for the experimental target prototype. There are several sub-systems in the target system, e.g. the elevating system, the vacuum system, the heat-exchanging system. As an IOC, each sub-system was finally integrated into the control system of the target by different drivers and methods because different hardware devices were used for each sub-system. The "SLS s7 driver" which was developed based on the Ethernet Interface was used for the communication between the Siemens PLCs and the Human Machine Interface (HMI). The interfaces between Labview and EPICS were used for the National Instruments (NI) DAQs systems. In addition, the driver developed by ourselves was used for devices with serial ports, e.g. RS-232 or RS-485/422. The control system was finally proved stable and could basically meet the elementary requirements of the spallation target system.

INTRODUCTION

In an Accelerator Driven System (ADS), a heavy metal spallation target locates at the centre of a sub-critical core. A beam of high intensity protons emitted from an accelerator bombard on the target, generating neutrons to drive the sub-critical reactor. Building a high power spallation target is one of the critical issues in an ADS [1]. In China initiative Accelerator Driven System (CiADS), a new concept for a high-power spallation target: the gravity-driven dense granular target (DGT) was proposed.

An experimental target prototype has been constructed and tested for some important issues. The layout of the prototype is shown as Fig.1. The helium loop which is an auxiliary system is separate and not shown in Fig.1. Three loops: Loop 1, Loop2 and Loop 3, as shown in Fig.1, were designed for different functions and experiments. The target design is one of the challenging and key technologies. So, the Loop 1 was designed mainly for testing the performance of the spallation target. At the same time, the feasibility of the mass flow-meters and sieve sorter was also tested. The Loop 2 was designed for testing the feasibility of the heat-exchanger. A proton beam was not considered at the first stage of the target design, so, a middle frequency heating device was used in the Loop 2 to heat the grains before they flow into the heat-exchanger. The Loop 3 acts only as a recovery system. A four-way valve was fixed at the entries of the three loops to control which loop to be used for experiment. Many important issues would be tested and studied as the experimental target prototype running, e.g. flowing character of the grains in the target container, heat conductivity of the grains, the feasibility of the method which is used for measuring the rate of the flow.

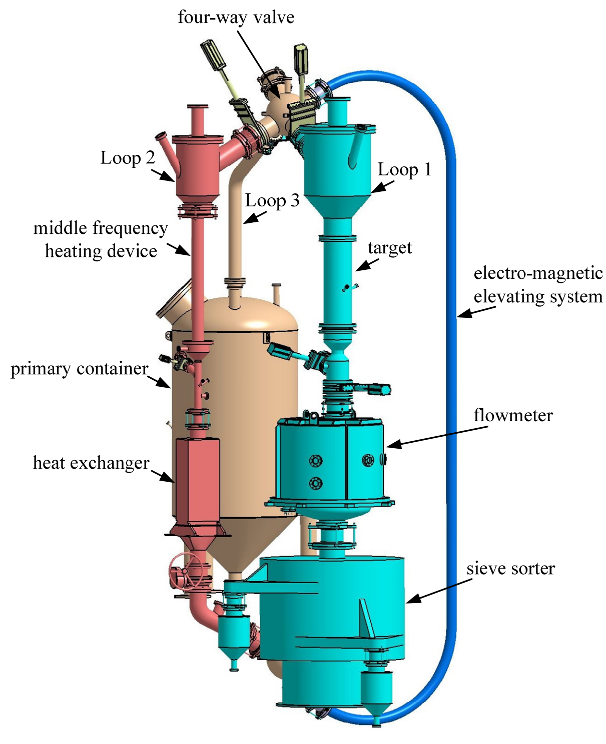

Figure 1: Layout of the prototype.

The architecture of the control system is also one of the important issues to be tested and studied. The control system of the accelerator has been designed and constructed based on EPICS [2, 3]. It will be easy to couple together if the control system of the target system is also constructed based on EPICS. However, considering the software toolkits of EPICS is open-source, the stability of the control system constructed based on EPICS is the most worried and concerned problem due to the extreme high safety requirements of the target system. Constructing the control system based on EPICS for the target system aimed to initially testify the stability of it.

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THE ARCHITECTURE OF EPICS

EPICS is a set of Open Source software tools, 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 [4]. It consists of a set of software components and tools that application developers can use to create control systems. The basic components are operator interface (OPI), input/output controller (IOC) and local area network (LAN) [5]. The architecture of EPICS is shown as Fig. 2.

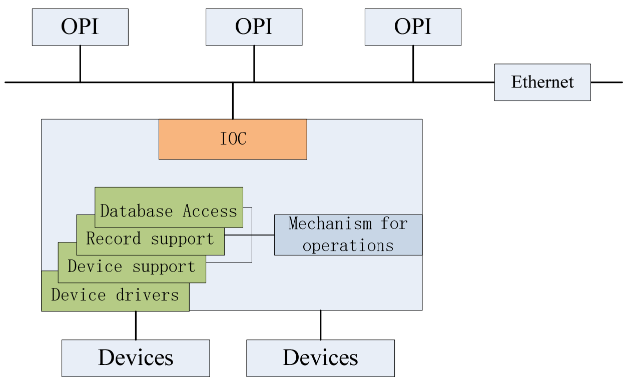

Figure 2: Layout of EPICS.

The OPIs working as clients read (or receive) and write (or send) data with IOCs (working as servers) through the Ethernet. The platforms OPIs running on usually are Windows, Linux and VxWorks. An IOC works as a server which responses the request sent by an OPI. It is the heart of the EPICS and has a complex mechanism to control the data flow.

THE CONTROL SYSTEM FOR THE PROTOTYPE

The Architecture of the Control System for the Prototype

There are various devices used in the control system of the target system for various physical demands. Some physical quantities are slow-response, e.g. temperature. However, some others are fast-response, e.g. neutron flux. Controllers have been very advanced now and usually have at least one Ethernet interface. In consideration of the feasibility and simplicity of integrating the devices with EPICS, the Siemens PLCs were finally used for most of the measuring and controlling of the physical quantities. And the NI products were used for those physical quantities that demand high precision and high sampling rate even though some of them could not be measured because proton beam was not considered during the design of the experimental target prototype.

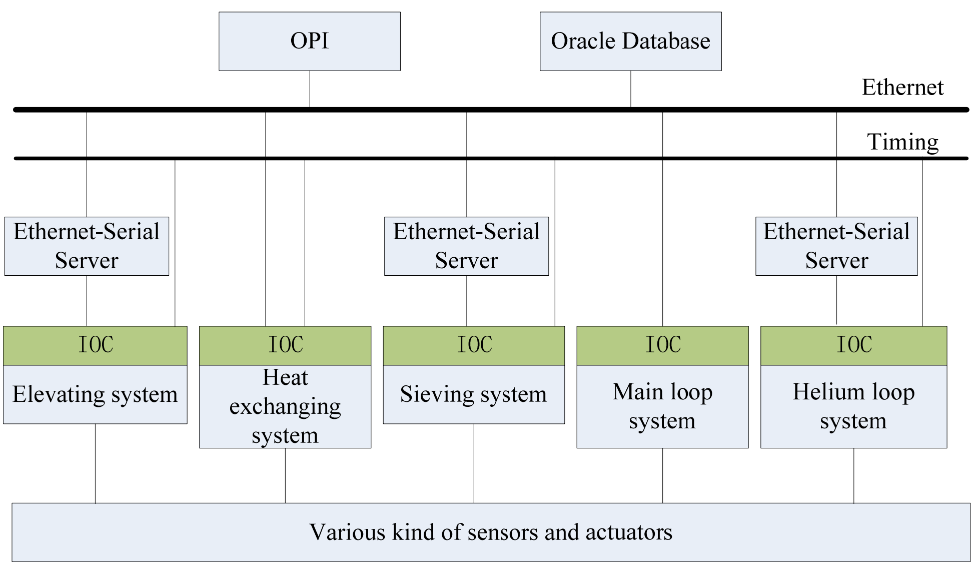

Figure 3: Architecture of the control system.

The architecture of the target control system is shown as Fig.3. As Fig.1 shows, the target system contains several sub-systems and each one has their own control system. So, they all were considered as an IOC when integrated with EPICS. The OPI was developed by Labview rather than CSS because the Labview can meet the requirements of the design now. All the data was recorded in an oracle database, so, an operator or scientist could look up and analysis the data any time. The security and efficiency of the Ethernet which was built as a ring were not taken into consideration only for simplicity now and will be studied in the next step. In addition, a timing system was also designed and constructed for each sub-system, assuring that the data would be sampled by each controller at the same time and be better analysed in the future. All the sensors and actuators were directly connected to the data acquisition cards or modules of the control system.

The Integration of the Siemens PLCs with EPICS

Siemens PLCs were used as the controllers of the subsystems of Elevating system, Sieving system and Helium-loop system. The “SLS s7 driver” was used as the driver for the corresponding IOCs after some minor revisions for our own requirements [6]. The revisions involve the driver support, device support, record support and the script files under the principles of EPICS. Ethernet-Serial Server was used because the Siemens PLCs only configured a serial (RS485) module rather than an Ethernet communication module.

Some actuators used for the protection of the target system should be controlled by the well programmed algorithms that had been designed and downloaded in the PLCs initially because it is difficult for the serial or Ethernet interfaces to meet the requirements of some fast protection system. The severity of the potential accidents during the operation of the target system will be evaluated and some protections triggered by hardware directly will be also studied and tested in the next step for the high requirements of some critical accidents.

The Integration of the NI DAQs with EPICS

The NI DAQs were used as the controllers of the Heat exchanging system and Main-loop system. The programming language is Labview which is systems engineering software for applications that require test, measurement, and control with rapid access to hardware and data insights. It offers a graphical programming approach for visualizing every aspect of the application, including hardware configuration, measurement data, and debugging [7]. The Labview reads and writes data by bounding the Network published shared variables with the PVs (Process Variable) [8].

Figure 4: A photo of the target system.

In this work, the variables which were related to the other sub-systems were communicated by building a CA Client and CA Server. As mentioned above, the type of all the variables are Network Published Shared variables. A simple test was also performed for the performance of the communication between the sub-systems.

The PID algorithm was used to control the valve of the cooling water and achieve the control of the temperature at the outlet of the heat-exchanger. The hysteresis only using a PID controller is obvious. So, another PD controller with the temperature at the inlet of the heat-exchanger as the input signal was added to avoiding the hysteresis. Finally, it noticeably improved the algorithm and worked well during the experiment. The other physical quantities which were also needed to be controlled automatically and accurately were not finished in this work now due to some objective reasons and will be studied and developed in the next step. The Fig. 4 is a photo of the target system.

CONCLUSION

The experimental target prototype consists of several sub-systems which perform different tasks as the target system running. The development process of the control system for the experimental target prototype is as follows. Firstly, the framework of the control system was constructed and tested based on EPICS which is a distributed control system. Each sub-system was considered as a separate IOC. Different drivers and methods were taken for integrating them with EPICS. Then, the function of data acquisition and control for each sub-systems was finished and the variables needed by other sub-systems were published on the Ethernet as PVs. At the same time, all the variables were recorded into a database ensuring the subsequent analysis. Finally, the algorithm designed for a specific physical quantity was used for the control system. It was finally proved stable and could basically meet the elementary requirements of the spallation target system in ADS.

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