The Initial Design of Process Control System Based on EPICS for HL-2A & HL-2 M*)

Fan XIA, Li PAN, Li ZHAO, Wei PAN, Xiao SONG, Xinyi LI, Chuan WANG, Jintao LAN, Liaoyuan CHEN and Kazuo NAKAMURA[1)]

Southwestern Institute of Physics, Chengdu, 610041, China

[1)]*Research Institute for Applied Mechanics, Kyushu University, Fukuoka 816-8580, Japan*

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In addition to the real time plasma magnetic and kinetic control, process control is also very important for the operation of a Tokamak. Process control aims at the normal control of the plant systems including information sharing, schema of the Tokamak operation, and alarm handling. A new tokamak named "HL-2M" will be built during the next four years and many conceptual designs for the operation of the new device might be validated on HL-2A, which is currently running at SWIP Chengdu, China. For those purposes, we select the EPICS as the basis for the process control system of HL-2A. Some user interface, data management, and development tools are adopted such as control system studio (CSS), MS SQL Server, Matlab, LabVIEW, VC++, and Java. In this study, we will describe the initial design of the whole HL-2A/HL-2M process control system and its related achievements in HL-2A.

Keywords: EPICS, process control, HL-2A

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1. Introduction

HL-2A is a divertor tokamak with noncircular plasma cross-section; it can operate single-null or double-null plasma discharges [1]. A new tokamak named "HL-2M" [2] will be built during the next four years at the SWIP Chengdu, China. The objective of HL-2M is to elucidate important research issues such as the mechanism of plasma confinement and transport, physics of high energy particles, MHD stability, and interaction between the first wall and plasma in physics and engineering related to the ITER project and the future fusion reactor. The control system of HL-2M will be rebuilt based on the current control system of HL-2A. Several conceptual designs for the operation of the new device might be validated on HL-2A.

There are more than ten subsystems involved in the process control system of HL2A. For historical reasons, except for the hardwired links, the process control communication mechanism between the subsystems in HL-2A is designed individually and it typically makes use of a dedicated TCP/IP based protocol over the Local Area Network (LAN). As each subsystem has its own internal protocol, many "information islands" have been built. This situation becomes a critical problem because of the excessive number of private protocols that need handling During an actual operation some subsystem operators need detailed process control information from other subsystems and need to find the appropriate subsystem operators. Therefore, it is necessary to establish a mechanism to share the process control information via a uniform interface within the experiment zone. Considering the solution adopted by ITER CODAC [3], this situation could possibly be optimized by using the EPICS as the basis for the whole process system.

In this study, we will focus on the initial design for the process control system for HL-2A/HL-2M, and we will also describe some related achievements. In section 2, the advantages of the EPICS will be briefly described. In section 3, we will introduce the architecture of the system and the technology that is applied to construct the system. In section 4, based on the system, we will introduce the scheduling and configuration of the experiment during the gap between two shots and automatic analysis of engineering and physics phenomenon during and after one shot.

2. EPICS Framework and Its Protocol

Experimental Physics and Industrial Control System (EPICS) [4] is a set of open source software tools, libraries, and applications that are developed collaboratively and are used worldwide to create distributed soft real-time control systems for scientific instruments including some current tokamaks [5]. The EPICS is a control system framework, which is a client/server model based on a transfer protocol named Channel Access (CA). CA works with data sets called process variables (PVs). A channel is established when a client connects to the server using PVs.

For most of the dedicated communication protocols for process control applied in HL-2A: first, the clients must

author's e-mail: xiafan@swip.ac.cn

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know the IP address of the servers Second, a TCP or UDP connection should be established for further information exchange. However, under the framework of the EPICS, the process becomes different. The CA client only needs to know the name of the process variable and should not bother about the details of the specific server that maintains the value of the process variable. Moreover, a mechanism is used to automatically establish the connection between the CA client and the CA server. The connection mechanism works as follows:

1) The CA client sends name search requests either to unicast IP addresses if it knows the server or to broadcast IP addresses if it does not know the server.
2) If a reachable CA server can serve one or more specified process variables, it sends back a response containing the CA server's IP address and port number to the CA client.
3) The CA client and CA server can establish a TCP connection, which can be reused. This means that several PVs on the same server use the same TCP connection.

Next, an authorized CA client can easily get the needed information and can modify the information via the process variables.

Such a communication mechanism and the EPICS information exchange method will provide convenient means for communication between the subsystems involved in the process control in HL-2A, if all subsystems use the unified interface CA protocol under the EPICS framework.

3. System Architecture

The system architecture is shown in Fig. 1. There are two different LANs in the current process control system. First is the experiment LAN, which is isolated from the internet and strictly controlled to ensure network security for the experiment. Most of the workstations involved in the process control are arranged here. Second is the normal LAN, which is used for normal analysis. The CA protocol is the main protocol for the process control running on the two LANs.

The process control information of over ten subsystems can be put onto the EPICS platform including the power supply system, networking monitor system, fueling system, vacuum system, diagnostic system, heating system, plasma control system, cooling system, flywheel generator system, wall cleaning system, and interlock system.

3.1 The interface to EPICS

To maintain a smooth operation, we hold to the principle that only the smallest possible changes should be made to the original subsystem to ensure that the function causes no problems elsewhere. In this case, we put a converter, which is a software arranged on an independent workstation or on a corresponding subsystem site, according to actual conditions between every subsystem and the EPICS platform. The converter can convert the private data of the subsystem to the related process variables on the EPICS platform and vice versa. The schematic diagram is shown in Fig. 2.

Because of historical reasons, there is no unified operating system and development environment to develop the related process control software. Fortunately, the EPICS society provided enough language interfaces including C, C#, Java, Matlab, LabVIEW, and Python. Furthermore, anyone can take any measure to exchange the subsystem data with the EPICS platform. Indeed, most of these interfaces are used to develop the converters for the subsystems.

For example, Siemens PLCs are widely used in interlock systems and some subsystems in HL-2A. STEP7 and Wincc, produced by Siemens [6], are installed on most of the PLCs. The OPC protocol provided by the Wincc OPC server under the Windows Operating system is selected to export the data of the PLCs to the EPICS platform. Then, a

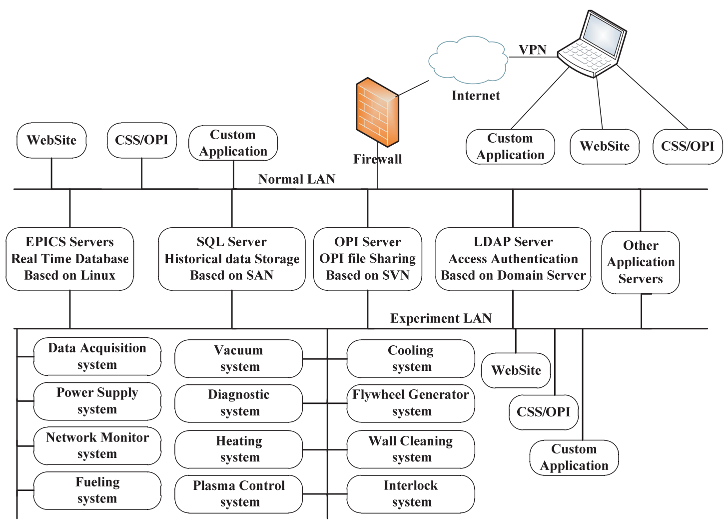

Fig. 1 the architecture of the EPICS system.

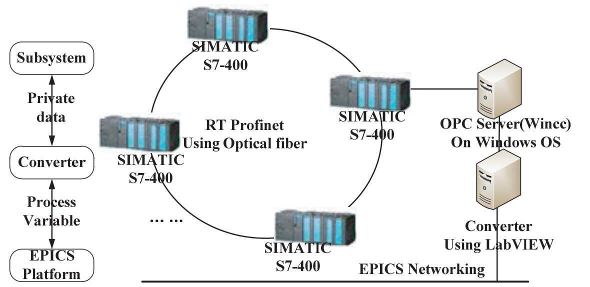

Fig. 2 the converter and the PLC-EPICS interface.

converter, which runs on an independent workstation, connecting with the Wincc OPC server and the EPICS platform via a LAN is established to convert the control information format. On the workstation, LabVIEW is used for its convenient VI to access the OPC server and the CA Lab [7] interface between LabVIEW and the EPICS is adopted. The schematic diagram is shown in Fig. 2.

3.2 Servers and clients for process control

There are many servers to implement the various functions. EPICS servers where soft Input/Output Controllers (IOCs) [4] are running under a Linux Operating system, act as the centralized location of the process control information. An MS SQL server, which is based on Storage Area Network (SAN), act as the historical data storage location and it provides functions such as historical inquiry and process variables browsing. The Operator Interface (OPI) server, which is based on subversion (SVN) for the OPI files, is synchronized to get the latest version of the OPI files developed by the subsystem owner or someone responsible for dedicated applications. Finally, the LDAP server which is based on the current domain server, provides the access authentication using the EPICS access security mechanism.

With regard to the client applications, everyone can develop his or her own application under the framework of the EPICS system. Furthermore, two standard applications are available. First isthe control system studio (CSS) [8] and second is the website integrated with the current information system in HL-2A.

3.3 Remote participation

After sending the appropriate data to the EPICS live database, not only the engineers and researchers in the local control rooms can view/analyze the data in soft real time using LAN, but also researchers all over the world can access the data using a wide area network (WAN) with virtual private network (VPN) technology. The end user can utilize the same client applications as they used in the local control rooms without any modification such as the CSS, website, and custom applications.

In this case, the authorized end user can learn the current experimental status and modify the related parameters,

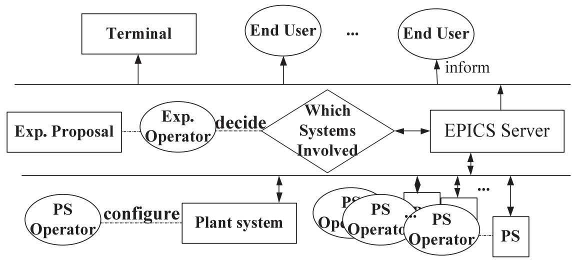

Fig. 3 scheduling and configuration of the discharge.

even when he is absent from the experimental site.

4. Initial Design of Applications

On the basis of the above process control system, two initial application designs will be described in this section. First, the scheduling and configuration process before discharge and second, the automatic analysis process during and post discharge.

4.1 Scheduling and configuration

The scheduling of the plasma discharge and the configuration of the subsystems can be improved by using the EPICS platform. The schematic diagram is shown in Fig. 3.

First, according to the experiment proposal issued by the physicists, engineers and the current status of the subsystems gleaned from the EPICS platform, the experiment operator publishes the pertinent information concerning the next discharge onto the EPICS platform. This might include the experiment goal, global engineering parameters, and the needed subsystems. Then, the subsystem operators will give the corresponding status signal such as ready, stand by, running, error, and in maintenance according to the information on the EPICS platform. Simultaneously, the operators also publish the related subsystem parameters onto the EPICS platform.

Compared to the original control process, the current design has many advantages. First, all subsystems can be considered, however, only those subsystems that are controlled by or connected with the PLC are involved in the original control process.

Second, many engineers and researchers are very concerned about the status or configuration parameters of some subsystems such as the NBI power, time duration of the heating, and configuration of the power supply. In the new design, end users can get this information automatically from the EPICS platform without asking other employees, as was the case in the original process.

Third, it is not necessary for end users to learn how to use the dedicated software of some subsystems in order to read the related information and parameters, as previously observed. They only need to know the names of the appropriate process variables and put them together into an OPI file using CSS.

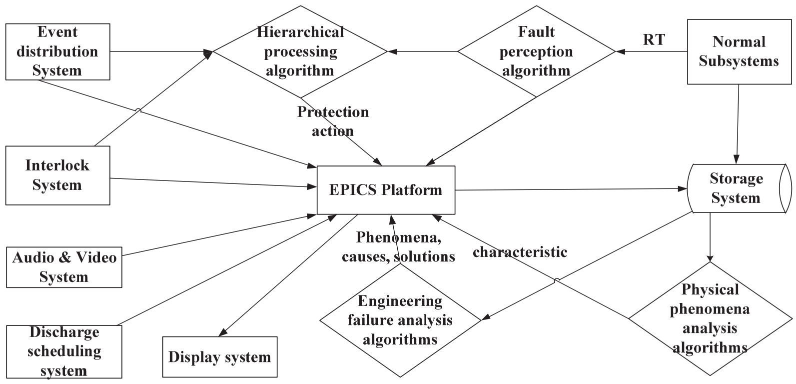

Fig. 4 design of the automatic analysis during and post discharge.

4.2 Automatic analysis during and post discharge

Under normal circumstances, we do some analysis after discharge, especially when something goes wrong during the last experiment. From this experience, we conclude that some analyses occur routinely. An example is the common engineering risk and failure analysis.

With enough information and related algorithms present in the system, it is possible to automate these routine analysis procedures during and post discharge analysis procedures. Automatic analysis procedures during and post discharge will make the process control of the tokamak more intelligent. The design is shown in Fig. 4.

With the information gathered from all the subsystems and the automatic analysis during discharge, the EPICS platform can give a composite warning and status in soft real time. The faulty perception algorithm and the hierarchical processing algorithm will perform the related analysis in real time.

Historical data and knowledge provided by many subsystems are archived in a storage system. For example, the EPICS platform provides the evolution data of the process variables, the discharge scheduling system provides the experiment goal and the configuration and parameters of all subsystems. Furthermore, the data acquisition system provides the detailed data of every signal and the interlock system provides the protection actions, and the Audio & Video networking based on IP technology provides the intuitive information of the last experiment such as photos, videos, and audios. In this case, the storage system is the base for automatic analysis post discharge, which can be much more complicated than during discharge.

Once the automatic analysis procedures are finished, the results will be put into display systems such as monitors and projectors. The data collected from them can be put onto the EPICS platform immediately so that everybody can learn from it.

5. Conclusion and Future Research

We selected EPICS as the basis of the process control system for HL-2A/HL-2M because of its excellent characteristics There are nearly 2000 process variables available in the current HL-2A experiment. Based on the EPICS platform, two applications were initially designed. Moreover, the scheduling and configuration has been implemented in the current HL-2A experiment.

The process control system will be improved by integrating the abovementioned system into the current IT system and by developing more applications.

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