INTEGRATION OF STANDALONE CONTROL SYSTEMS INTO EPICS-BASED SYSTEM AT RIKEN RIBF

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Abstract

The RIKEN RI Beam Factory (RIBF) was constructed as an extension of our old accelerator facility, the RIKEN Accelerator Research Facility (RARF). The major part of the accelerator components newly developed have been integrated into the Experimental Physics and Industrial Control System (EPICS), but several old standalone control systems were carried over and some new components adopted their own standalone control systems. These non-integrated systems are grouped into two major categories. The first is hard-wired control systems and the other is based on a two-layer remote-control system without a middle layer. From the view point of efficient accelerator operation, the entire control system should be integrated. For this reason, we have replaced hard-wired devices with EPICS-compatible devices, namely, the N-DIM (originally designed by the Nishina Center), and the FA-M3 (Yokogawa Electric Corporation, Tokyo, Japan) controllers. Additionally, to access data in a two-layer system from EPICS, we have introduced a MySQL-based system as the middle layer, and have developed a feature to connect the database through the CA protocol. Thus, we could successfully integrate the system, and it is now possible to acquire all the data through EPICS.

INTRODUCTION

The RIKEN RI Beam Factory (RIBF) accelerator facility consists of five cyclotrons, including a superconducting ring cyclotron, and two linear accelerators, which act as injectors [1]. For the RIBF, we constructed a distributed control system based on EPICS for almost of the accelerator components, including the magnet power supplies, beam diagnostic instruments, and vacuum control systems [2]. On the other hand, some of the accelerator components are controlled by non-EPICS-based small control systems because the RIBF project is also utilized some components of the RIKEN Accelerator Research Facility (RARF) [3], constructed as part of a previous project. In addition, two-layer control systems, which consist of controllers and client PCs, have also been adopted since the start of the RIBF project because they require only a relatively short development time.

From the viewpoint of accelerator operation, the control systems should be integrated because the operational efficiency of the accelerator depends on the interfaces of the control systems being unified. However, due to manpower and time constraints, it would be difficult to integrate all the non-EPICS-based system in a single step. In this study, we report the methods that could be adopted to introduce EPICS-compatible controllers, as well as the data integration methods for non-EPICS-based small control systems.

STANDALONE SYSTEMS

Before the present study, the non-integrated systems remained are the control system for the 18-GHz electron cyclotron resonance ion source (18-GHz ECRIS) [4], that for the hyper electron cyclotron resonance ion source (Hyper ECRIS) [5], the beam Faraday cup control in RILAC [6], the radio-frequency (RF) systems, the temperature-measuring system, as well as several two-layer systems. We examined a mean of integration into EPICS suitable for each component one by one. Cross-operations are required for some of these standalone control systems because of management requirements.

INTEGRATION METHODS

18-GHz ECRIS

Hard-wired controllers had been used for the 18-GHz ECRIS control system since its commissioning in 1995. These old controllers should be modernized as soon as possible because the 18-GHz ECRIS is used very actively for both RIBF and standalone experiments in RILAC, the latter including superheavy element search experiments. We decided to use a Yokogawa F3RP61-2L programmable controller, in which EPICS is embedded [7], because this configuration has already been implemented in the RIBF control system. The control system for the 18-GHz ECRIS was completed in 2015 [8].

Beam Faraday Cup in RILAC

In the same way as in the case of the 18-GHz ECRIS control system, the RILAC beam Faraday cup control was based on hard-wired devices. We replaced the hard-wired devices with a N-DIM [9], and an EPICS input/output controller (IOC), which consists of single-board computers running Linux x86 [10] to provide a channel access (CA) service for the N-DIMs.

Hyper ECRIS

Hyper ECRIS, developed and operated by the Center for Nuclear Study, University of Tokyo (CNS), is used to provide a variety of metal ion beams for injection in the RIBF [6]. The control system was constructed as a standalone system with a closed network, for which the main controller was a MELSEC-A series programmable logic controller (PLC). Hyper ECRIS is usually controlled by using a Microsoft Windows-based client PC, located in the ion source room. Therefore, this client PC in the ion source room had to be accessed remotely by the accelerator operators from the RIBF control room via remote

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desktop protocol whenever beam tuning of Hyper ECRIS was required.

On the other hand, an unintegrated control system between Hyper ECRIS and the RIBF accelerator causes inefficient operation. However, the control system could not be replaced with one based on EPICS for the benefit of the RIBF accelerator operation, because Hyper ECRIS is managed by CNS. For this reason, the conventional control method was left as is, and integration to the EPICS system was supplemented by introducing an EPICS IOC as a gateway between the RIBF control network and the closed network of the Hyper ECRIS control system (see Fig. 1). In the present study, we developed EPICS device support for a MELSEC-A series PLC by using NetDev [11], developed by KEK. Thus, we could construct unified operator interfaces by utilizing CSS/BOY [12].

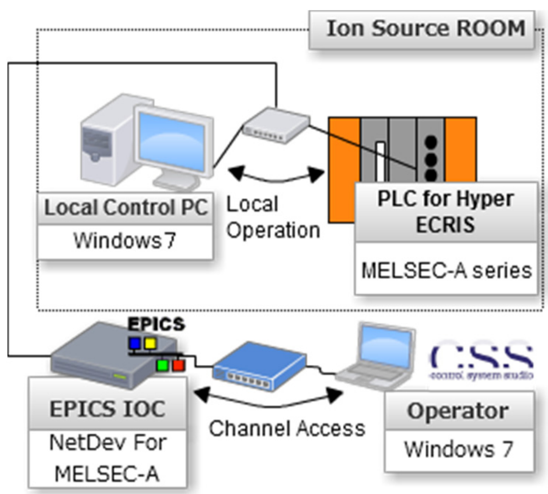

Figure 1: Hyper ECRIS control system. Both the conventional method and EPICS are used.

RF Controls

For the linear accelerator and the cyclotrons, the RF control systems are implemented as a two-layer system consisting of a client, based on Wonderware InTouch [13], and OMRON programmable logic controllers (PLC). Since the accelerator operators are familiar with the InTouch interface, it would not be beneficial to replace the GUIs to send output control commands to the PLCs. On the other hand, there is a need to monitor the RF data along with the other EPICS-based data, such as vacuum pressures, by creating charts and graphs. Therefore, the two-layer systems were left as they were for the accelerator operation, but we inserted a middle layer, based on EPICS, to monitor the data. In this case, the EPICS device support software is realized by the features provided by NetDev [11].

Other Two-layer Systems

When a new instrument is introduced, the control system may not be compatible with EPICS because human resources are required to develop the EPICS device support software. National Instrument LabVIEW is a suitable platform for the rapid prototyping of a system. In RIBF, LabVIEW-based systems with a two-layer structure are utilized for the gas stripper control [14], the monitoring of the beam phase and intensity [15], measurement of beam energy system [16], and so on. In addition, commercial systems are also implemented to monitor the temperature. To attain data integration, we considered an approach for handling and sharing the data for the system described above.

MYSQL-BASED DATABASE AS MIDDLE LAYER

Since there is a need to store and analyze the data for a system with a two-layer structure, we introduced MyDAQ2, developed by SPring-8, as a common DAQ system for small non-EPICS-based systems [17]. The MyDAQ2 system can store data into a MySQL-based database by sending an ASCII command with the socket and allow viewing of the stored data via a Web application [18]. One of the good features of MyDAQ2 is that it is possible to develop easily a program to store data from other client systems. In addition, by utilizing a JavaScript chart library, we have realized a chart feature with a much higher level of performance than the original MyDAQ2 chart feature which used gnuplot. Thus, the administrator can store data from the LabVIEW-based and commercial systems via MyDAQ2.

We constructed a prototype system capable of handling the data stored in a MySQL-based database by using EPICS CA. First, the system searches for a table name, and EPICS software records are created automatically per the table name. Then, the clients regularly connect to the MySQL-based database via a socket, after which the polling access program obtains the latest values and copies them to premade EPICS software records. For example, the "*MyDAQ2:ABC:c1*" software record is created in column *c1* in table *ABC*. Using this prototype system, it is possible to obtain the data stored in most of the non-EPICS-based systems via EPICS CA.

Given the success of this prototype, we implemented not only a simple system to copy a value to the EPICS software record, but also a method to handle the MyDAQ2 data through EPICS device support software. The architecture of MyDAQ2 is compatible with the Message And Database Oriented Control Architecture (MADOCA) [19]. As such, it sends the ASCII command with the socket connection to the server, and then receives a response. For this reason, we have developed device support software utilizing StreamDevice [20], because StreamDevice offers the advantage of data processing with ASCII through a socket connection. An example of a protocol file for the MyDAQ2 device support software is shown below.

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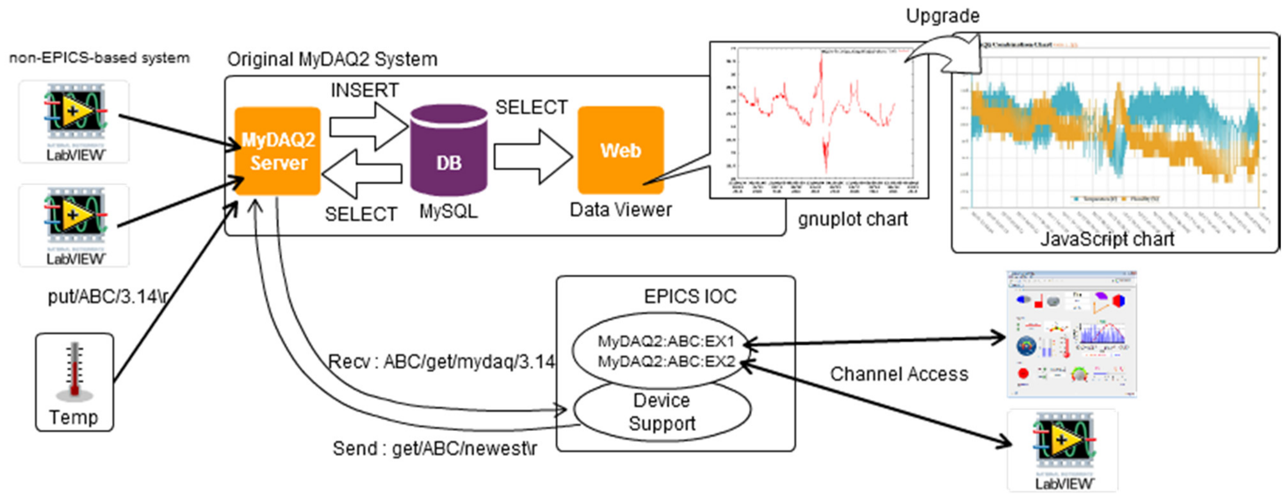

Figure 2: EPICS IOC for MyDAQ2. Newly stored data can be obtained from the MySQL-based database by using the device support software.

```
getMyDAQ2data{
    Separator = "_";
    out "get/\$1/newest";
    in "\$1/get/mydaq/%E";
}
```

The system is illustrated in Figure 2. Simply by inserting data into MyDAQ2, data in the CA protocol can be flexibly acquired, even if the system is a non-EPICS-based system.

SUMMARY

Basically, a RIBF control system is based on EPICS. However, non-EPICS-based systems, configured as standalone systems, have been utilized for some components. Using embedded EPICS technology, hard-wired control systems have been replaced and integrated into the EPICS-based system by using Yokogawa F3RP61-2L and FA-M3 modules.

By using NetDev, Hyper ECRIS and RF system can also be controlled with EPICS while maintaining a conventional two-layer structure. Additionally, we introduced a MyDAQ2 system to enable us sharing data used in LabVIEW-based systems, commercial monitoring systems, and so on. Since all the data for a non-EPICS-based system are stored into a MySQL-based database via MyDAQ2, the data can be accessed via the CA protocol by developing EPICS device support for MyDAQ2.

In our study, the control system integration was successfully completed and we can now handle the data of almost all the RIBF components in an integrated way.

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