RECENT IMPROVEMENTS TO THE RIKEN RI BEAM FACTORY CONTROL SYSTEM

M. Komiyama†, N. Fukunishi, A. Uchiyama, RIKEN Nishina Center, Wako, Saitama, Japan
M. Hamanaka, T. Nakamura, SHI Accelerator Service, Ltd., Shinagawa, Tokyo, Japan

Abstract

The RIKEN Radioactive Isotope Beam Factory (RIBF) is a cyclotron-based heavy-ion accelerator facility that provides the world's most intense beams of unstable nuclei for nuclear physics studies. A major part of the components of the RIBF accelerator complex is controlled by the Experimental Physics and Industrial Control System (EPICS). Here, we present recent improvements to the EPICS-based RIBF control system. First, the alarm system was improved to support stable beam delivery during a long-term experiment. We introduced the Best Ever Alarm System Toolkit (BEAST) based on the Control System Studio (CSS) platform to our control system and started to monitor the vacuum systems and magnet power supplies in order to detect hardware issues or anomalous behaviors of the accelerator components. Second, the data-logging and setting software system was renewed for nearly 900 magnet power supply units. These power supplies are controlled by several different types of controllers and the configuration of the magnet power supplies has become very complicated because of several recently performed extensions and updates of the RIBF accelerator complex. Hence, we have developed new control programs in order to simplify the recording and setting of the data relevant to the operation of all the magnet power supplies.

INTRODUCTION

The RIKEN Radioactive Isotope Beam Factory (RIBF) is a cyclotron-based accelerator facility for nuclear science investigations. It consists of two heavy-ion linac injectors and five heavy-ion cyclotrons, one of which is the world's first superconducting ring cyclotron (SRC). Several acceleration modes can be achieved by changing the combination of accelerators used, and one of them is chosen according to the beam condition required by users [1]. A major part of the components of the RIBF accelerator complex, such as magnet power supplies, beam diagnostic devices, and vacuum systems is controlled by the Experimental Physics and Industrial Control System (EPICS) [2]. On the other hand, the radio frequency (RF) systems used in the RIBF accelerator complex are controlled by different dedicated systems [3]. However, all the essential operation data sets of the EPICS and other control systems are integrated into the EPICS-based control system. In addition, two types of interlock systems, which are independent of the control system, are constructed in the RIBF facility. One is a radiation safety interlock system for human protection [4], and the other is a beam interlock system (BIS) that protects the hardware of the RIBF accelerator complex from unacceptable beam losses caused by the mis-operation of high-power heavy-ion beams [5]. Figure 1 shows an overview of the RIBF control system.

† misaki@riken.jp

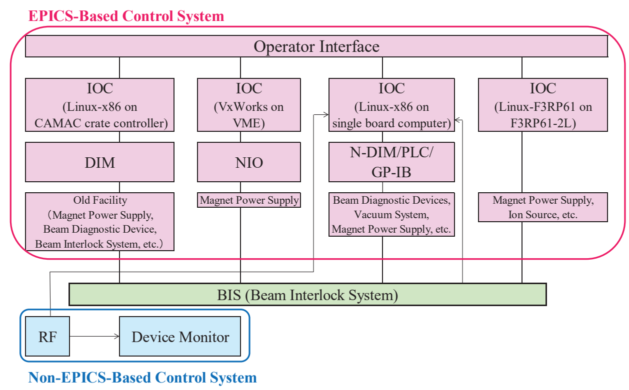

Figure 1: Overview of the RIBF control system.

IMPROVEMENT OF THE ALARM SYSTEM

At the RIBF accelerator facility, various types of heavy-ions are accelerated for various types of experiments. The most operationally difficult example is a 345-MeV/nucleon ^{238}U in which we use one injector linac and four ring cyclotrons in a cascade. Operators of the RIBF accelerator are required to control a large number of accelerators components safely during beam tuning and to maintain their fine tuning during experiments lasting for long periods (typically one month). In this case, the operators should adjust and monitor 600 magnet power supply units and monitor the status of 60 units used for systems such as vacuum pumps and gate valves of the accelerators and the beam transport lines. In addition, when a trouble occurs during an experiment, the operator is required to determine the cause of the trouble and, if possible, remove it immediately. Therefore, disorders of the components, which may cause an accident, should be detected as soon as possible, especially for high-intensity operations of the RIBF accelerator complex performed routinely owing to recent performance updates. However, the existing alarm system, the Alarm Handler of the EPICS only covers some components of the ion source. Hence, we have started to upgrade the existing alarm system.

We newly installed a distributed alarm system, the Best Ever Alarm System Toolkit (BEAST) [6] under the Control System Studio (CSS) [7] that is an Eclipse-based collection of tools to monitor and operate large scale control systems. In the RIBF control system, we have

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already used an another CSS package, the Best OPI, Yet (BOY) [8] as a display manager in addition to the Motif Editor and Display Manager (MEDM) [9] and the Extensible Display Manager (EDM) [10] by taking merits of each system into account. The BEAST was chosen taking future extension of the CSS at the RIBF control system instead of upgrading the existing Alarm Handler [11].

As the first step of the alarm system upgrade, the vacuum status of the entire RIBF accelerator complex, including the status of vacuum pumps, gate valves, and vacuum pressures, is registered in the BEAST. The BEAST outputs a warning signal when the opening-closing status of a valve changes, a vacuum pump stops, or a sizable change of vacuum pressure is detected. The criterion for a sizeable change in the vacuum pressure is a difference of more than twice the average vacuum pressure over the past 10 readings. The vacuum signals have been monitored by an EPICS Input Output Controller (IOC) at an interval ranging from 0.1 s to 1 s depending on their location. In addition, the difference between the set and the read-back value of the excitation currents of all the magnet power supplies of the RIBF accelerator complex is registered in the BEAST. The BEAST outputs a warning signal when the ratio of the read-back current values to the set value is different by 50% (minor alarm) and 90% (major alarm). The accuracy of the read-back value is insufficient for especially old magnet power supplies, and the small difference between them is not effective for a warning signal. The current value of the magnet power supplies is monitored by EPICS IOC at 10-s intervals.

We registered approximately 700 signals in the BEAST and its test operation has been started in April 2016. We were concerned that we registered too many signals before starting its operation; however, the system runs correctly without showing any delayed responses due to overload. Toward more efficient operation, we are now considering how to set the optimal alarm criterion patterns for each experiment in the BEAST. Since there are 65 beam operation patterns with different combinations of the ion sources, accelerators, and experimental vaults, it is necessary to activate signals relevant to running experiments.

RENEWAL OF DATA-LOGGING AND SETTING SOFTWARE SYSTEM FOR MAGNET POWER SUPPLY

In an experiment, several hundreds of magnet power supplies are used. In order to control such a number of magnet power supplies smoothly and avoid missing any, the operators usually use batch control programs when they control them as a group, such as at the start of beam tuning, the end of beam tuning or the end of an experiment. At the beginning of beam tuning, a batch control program of the system sets values of excitation currents to all the magnet power supplies used for the experiment, instead of one by one from the GUI for each magnet power supply. Furthermore, the current values used at the experiment are recorded by another batch control program of the system at any time. Since the number of the magnet power supplies and types of their controllers have increased with each update step of the RIBF accelerator complex, both kinds of control programs were developed for each type of controller of the magnet power supplies. According to the type of controller, they are summarized into five groups. The name of each controller and number of magnet power supplies to be controlled are as follows:

1. Network-I/O (NIO) [3], which is a commercially available control system manufactured by Hitachi Zosen Corporation. Approximately 470 units.
2. Device Interface Module (DIM) [12], which is an in-house controller based on the computer automated measurement and control (CAMAC) system developed in 1984. Approximately 350 units.
3. Modules of programmable logic controllers (PLCs) [13]. Approximately 30 units.
4. General-purpose interface bus (GP-IB) controllers. Approximately 20 units.
5. Network-DIM (N-DIM) [14], which is an in-house controller developed as a successor to DIM in 2004. Approximately 30 units.

The batch control programs are started from the GUI for a magnet power supply. When the GUI button for recording the values of excitation currents of the magnet power supplies is clicked, the batch programs for each type of controller start collecting the data of current values from the EPICS Process variables on the EPICS IOC and store them into the files dedicated to each type of controller and location of the magnet under a date directory, which is automatically created daily on the file server. On the other hand, when the GUI button for setting the current value to the magnet power supplies is clicked, the batch programs for each type of controller set the data with reference to the data files for each type of controller in a dedicated directory set by the operator. The data file is edited based on the logged data of a same type of experiment performed in the past, or a result of calculation. In recent years, according to the several updates of the magnet power supplies associated with the facility updates, the configuration of the magnet power supply in the stored data files has changed. To accommodate these changes, we developed patch programs to modify the log files as needed. However, the types of patch programs have increased gradually, and the setting procedure of magnet power supplies has become very complex. For example, when the controller of a magnet power supply is changed and we subsequently use a file stored before the controller change, it is necessary to remove the magnet power supply data from the setting file, and the magnet power supply data must be set separately and individually. Consequently, mistakes in operation, such as failure to set data or to record data, have become more likely to occur. Therefore, we renewed the management system of the magnet power supplies this year.

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The new data-logging and setting software system is designed to manage the data of the magnet power supplies using a relational database instead of a text file, and we developed a web-based software system for managing the relational database. In the RIBF control system, we have been using the Oracle database for the management of the static parameters of the accelerator components, such as magnet power supplies, and the information of the beam operation patterns. However, to separate the management of the operational data and the accelerator parameters, we have newly introduced the PostgreSQL database dedicated for this purpose. In the PostgreSQL database, we have created two kinds of tables: one is a table for providing information on the RIBF accelerator complex, such as the list of beam operation patterns, magnets, and their arrangement order from the upstream in each beam operation pattern and the type of controller of each magnet power supply, and the other is a table to store the collected current data from the magnet power supply. The former tables are used as a reference at the time of recording and setting of the current value, and they are modified automatically by reference to the Oracle database to avoid dual management.

The algorithm for recording data of the new system is as follows:

1. The operator inputs the ID number of the beam operation pattern (hereafter, the ID) used at the running experiment and clicks the save button on the MEDM-based GUI for recording the current data into a database table.
2. The new batch control program starts to refer to the table of magnet list tagged by the ID and picks up the included magnet information, such as name and the controller type of its power supply, taking the set and read-back current data of the selected magnet power supplies from the appropriate EPICS IOC. The new program is designed to take the data from all the controller types.
3. The program writes the data into a table created with a tag of date and time, the type of beam, and the ID. The table is automatically created by the web-based system. The result of whether the save succeeded is shown on the MEDM-based GUI every time.

On the other hand, the algorithm for setting the current data to each magnet power supply by the group is as follows:

1. The operator edits the current data into a setting format by using the web-based system shown in Fig. 2.
2. The operator starts the new batch control program for setting through the MEDM-based GUI.
3. The program checks the on-off status and the polarity setting of the magnet power supplies in comparison with the configuration data. It turns on the magnet power supplies or changes the polarity setting as necessary, and sets each current value to each magnet power supply. The program is designed to set the data for all the controller types.

At the first step, we often use the past data stored in the database in addition to setting the calculation results. In order to be able to call the past data, a huge amount of data saved in the text files in the file server were imported into PostgreSQL.

The most significant advantage of the new system is that the batch control programs for data-logging and data-setting are integrated, and we can check the current setting status of the magnet power supplies in the list from the upstream of the beam course, regardless of the type of controller. Furthermore, even if the controller is replaced with the different existing types of controllers in the future, it is able to use the data and the program without having to edit the configuration of the data recorded in the past. Progress and results of the current setting are monitored on the web-based system at present. Thus far, since the setting result was only displayed in character on the window of the terminal running the program, the new system is advantageous even in this respect.

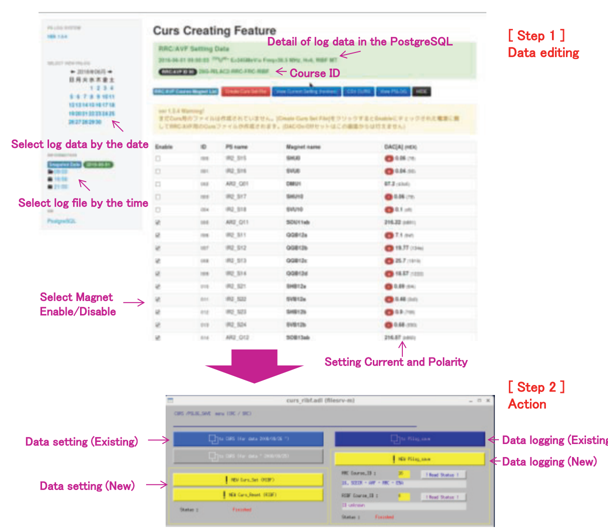

Figure 2: Web-based system for editing the values of excitation currents of all the magnet power supplies used for an experiment and MEDM-based GUI for setting.

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