STATUS OF CONTROL SYSTEM FOR RIKEN RI-BEAM FACTORY

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Abstract

The control system of the RIKEN RI-Beam Factory (RIBF) is constructed using EPICS. We had set up all controllers for accelerators and their beam transport lines, EPICS Input/Output Controllers (IOC) and application programs for the beam commissioning of the RIBF, and extracted the first beam from the world's first superconducting ring cyclotron (SRC) on December 28 2006. In this paper, we will report an overview of RIBF and its control system including some latest improvements of it.

OVERVIEW OF RIBF

The RIBF has been constructed as a next-generation RI beam facility including the RIKEN Accelerator Research Facility (RARF) since April 1997. The RARF has an accelerator complex consisting of the K540-MeV ring cyclotron, the RIKEN Ring cyclotron (RRC) as a main accelerator and its two different types of injectors, frequency-variable RIKEN heavy-ion linac (RILAC) and K70-MeV AVF Cyclotron (AVF). It started beam service to users in 1990. A new high-power heavy-ion booster system consisting of three ring cyclotrons with K-values of 570 MeV (fixed frequency Ring Cyclotron, fRC), 980 MeV (Intermediate stage Ring Cyclotron, IRC) and 2600 MeV (SRC), respectively, boosts energies of the output beams from the RRC injected from the RILAC. It will be capable of providing RI beams of all elements, energies and intensities of which will reach 440 MeV/nucleon for light ions and 350 MeV/nucleon for very heavy ions like Uranium. It will greatly exceed the current world standards. These primary heavy-ion beams will be converted into intense RI beams via the projectile fragmentation of stable isotopes or the in-flight fission of uranium isotopes by a superconducting fragment separator, BigRIPS. The primary-beam intensity is targeted to be 1 pμA. The combination of the SRC and BigRIPS will greatly expand our knowledge of nuclear world into presently inaccessible region on the nuclear chart [1].

The RIBF building was completed in May 2005. After a various test of each components, we started a beam commissioning in July 2006. On December 28 2006, the first beam, a 345 MeV/nucleon $^{27}Al^{10+}$ beam, was extracted from the SRC. And on March 27, we successfully identified a large variety of RI beams produced via the first in-flight fission of the 345 MeV/nucleon $^{238}U^{86+}$ beam. Now some upgrade plans are under investigation to raise an extracted beam intensity from the SRC up to 1 pμA.

OVERVIEW OF RIBF CONTROL SYSTEM

Controller

Figure 1 shows groups of accelerators and their interface devices in the RIBF control system. Except some stand-alone systems, such as a system for an ion source or RF, most parts are controlled using EPICS. It can be grouped into five by controllers; (1) DIM (CAMAC), (2) GP-IB, (3) NIO, (4) N-DIM and (5) PLC. The first one, DIM stands for a Device Interface Module, which was originally developed by RIKEN about twenty-five years ago in order to assist the main computer in its tasks. It executes a local sequence control, local surveillance, function generation and testing. It is used with our original CAMAC module, the Communication Interface Module (CIM).

	RILAC	AVF/RRC	BT	fRC	BT (in Nishina bldg.)	BT (in RIBF bldg.)	IRC	SRC	Injection Line for Big-RIPS	Big-RIPS
Ion Source	Hard wire /WE 7000	WE 7000								
RF	PLC (CVM1)	PLC(Melsec) /DIM		PLC (CS1)			PLC (CS1)	PLC (CS1)		
Magnet Power Supply	GP-IB/NIO/DIM	DIM	DIM/NIO	DIM/NIO	NIO/DIM	NIO	NIO	NIO	NIO	NIO
Beam Diagnostics	DIM/N-DIM	DIM	DIM/N-DIM	N-DIM/DIM	N-DIM	N-DIM	N-DIM	N-DIM	N-DIM	PLC(FA-M3)
Driving Controller	DIM	PLC (FA-M3) /N-DIM/DIM	DIM	PLC (FA-M3) /N-DIM/DIM	PLC (Melsec)	N-DIM	PLC (CS1) /N-DIM	PLC (Melsec) /N-DIM		PLC(FA-M3)
Vacuum	N-DIM	PLC (CS1)	DIM/N-DIM	PLC(FA-M3)	N-DIM	N-DIM	PLC (CS1)	PLC (Melsec)	N-DIM	PLC(FA-M3)
Beam Interlock	Hard wire /PLC (Melsec)	DIM	DIM	PLC (Melsec)						
Cooling	Local Control	Local Control	Local Control	Local Control	Local Control	PLC (Melsec)				

: controlled by existing EPICS system
: monitored by existing EPICS system

* NIO: Network-I/O (NDS)

Figure 1: Interface devices used in RARF and RIBF control system

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It executes a message transfer between the VME and DIM and information is transferred serially between these two modules through a pair of plastic optical fiber cables. The CIM/DIM system is used in two ways in our system; one is based on a CAMAC HWY loop using a U-Port Adopter and the other is using with a network-based crate controller and controlled by Ethernet directly. As a network-based crate controller, we employed the Pipeline CAMAC Controller with PC104plus Single Board Computer, CC/NET [2] [3]. We originally have controlled the CIM/DIM system by the first method, however, it is difficult to maintain the first system because some components of a U-Port Adopter are no more available. Thus, a few years ago, we introduced the CC/NET to replace our old CAMAC-CIM/DIM system based on a CAMAC HWY loop with Ethernet [4]. Most of magnet power supplies and beam diagnostic devices such as a beam profile monitor or a Faraday cup of RARF are controlled by them. The second one, GP-IB controls the oldest magnets and RF power supplies of RILAC. The third one, NIO stands for Network-IO [5], which is used to control new types of magnet power supplies. Almost all power supplies for magnets that were set up at downstream beam transport lines and cyclotrons of RRC and a part of RILAC are controlled by NIO. The forth one, N-DIM stands for a Network-DIM, which was also developed by RIKEN to substitute for the CAMAC system [4]. We did not expand our CAMAC system to RIBF control because of its difficulty of maintenance in the future. The most important feature of N-DIM is that it is a network-based intelligent controller. Since N-DIM was designed to have same connector parts as DIM, we can replace DIM with N-DIM easily, and after that, it can be controlled by CC/NET directly without using CIM. It makes our old CAMAC system simple. N-DIM and PLC control all beam diagnostic devices and vacuum control system of a part of RILAC and downstream beam transport lines and cyclotrons of RRC. Table 1 shows the current number of interface devices used in the RIBF control system. It includes the number of devices from RILAC to SRC, excluding an injection beam line for Big-RIPS. Table 2 shows the current number of main components of RIBF.

Table 1: Current number of interface devices

DIM (PS)	80
DIM (BD)	100
GP-IB (GMACS)	4
GP-IB (IDX)	5
NIO	420
N-DIM (PF)	90
N-DIM (RP)	12
N-DIM (FC)	60
N-DIM (VAC)	70
PLC (Omron)	3
PLC (Melsec)	4
PLC (FA-M3)	3

Table 2: Current number of RIBF components

Power Supply	908
Beam Profile Monitor	138
Beam Differential Probe	9
Faraday Cup	92

System Status

Figure 2 shows the structure of RIBF control system. The RIBF has two control rooms; one is in the Linac building to control RILAC, and the other is in the Nishina building to control all cyclotrons and downstream beam transport lines of RILAC. A file server based on an HP-UX system and Force VME computers placed in the Nishina building are the oldest devices in our system. We introduced the file server in 2001 and the VME computers in 1999 as main computers of RARF control. EPICS R.3.13.8 was mounted on the system. The file server had functioned very stably; however, a very serious accident on two disks after the summer maintenance of RARF occurred in 2006. We changed the two disks and recovered the programs hardly. Now, we are attempting at replacing the system with another system because of its age and high-cost maintenance.

For replacing the system of the HP-UX server and the Force VME computers, we introduced one Linux server for application programs, including GUI, graphic formulas and data taking, and two types of system, namely, a system consisting of the Linux server and Motorola VME computers, and a Linux server and CC/NET. The former controls magnet power supplies (NIO) only. Although we mounted an upgraded EPICS base on the former (R.3.14.7), almost all current and device support programs can be used in the new system with a small change. The latter server functions as a file server of CC/NET and GP-IB control. There are seven CAMAC crates in the RARF control system, and we have already replaced a crate controller for RILAC control and one of them for a RARF control except RILAC with CC/NET. We have a plan to replace the remaining five crates as soon as possible. After successfully replacing crate controllers, we will remove the HP-UX server and the Force VME computers from the control system.

Furthermore, there is one more Linux server in our system. It works as a file server for a Linux client PC which functions as an IOC for N-DIM and PLC control. We employed an embedded single board computer, a wireless router application platform (WRAP) [6] as an IOC. As shown in figure 1, there are eight IOCs in our system. The reason is that we set up one IOC to each subnet and each building meeting the demand. The network system of RIBF control is stand-alone one and it was designed to have five sub networks. The first one is used for the VME, its server computers, PCs for an operator interface and high-level control computers that work for data archiving and alarm systems among others. The second one is used for N-DIM for a Faraday cup control and vacuum control.

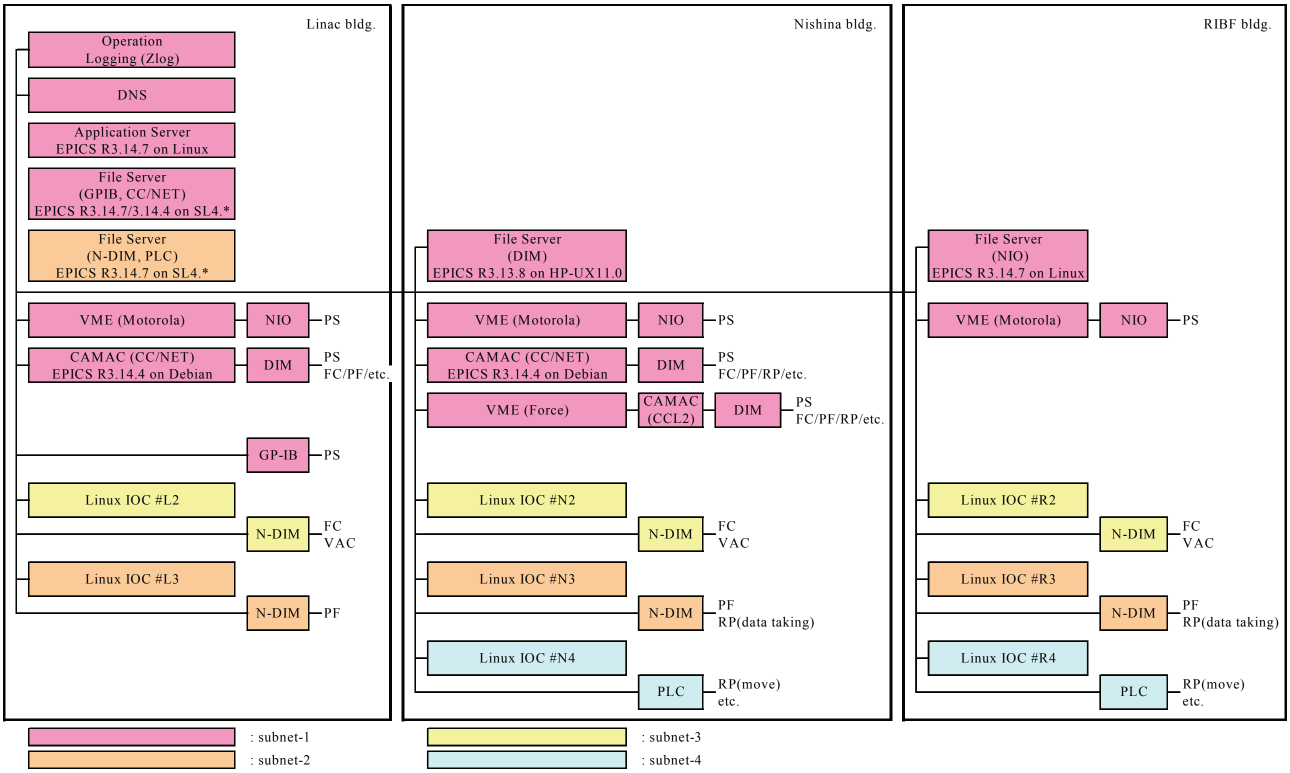

Figure 2: Structure of RARF and RIBF control system

The third one is used for the N-DIM for a beam profile monitor and a beam differential probe. The forth one is used for PLC, and the last one is used for the maintenance of the network system itself. To share common programs with all IOCs, each board computer requires to obtain necessary files from the file server by NFS to run as an IOC, for example, EPICS base, device supports and runtime databases.

We control GP-IB devices using EPICS device support programs supported by EPICS collaboration. On the other hand, NIO, CC/NET, DIM, N-DIM and PLC are controlled using device support programs developed by ourselves originally. In particular, device support programs for CC/NET, N-DIM and PLC were developed with the control group of KEK [7]; thus, we are using and supporting the same programs among RIKEN, KEK and J-PARC control systems.

Beam Interlock System

In RARF, we have been using a beam interlock system which is based on CAMAC-CIM/DIM system for more than 20 years. For constructing a beam interlock system for RIBF, we newly introduced a new system using PLC in addition to the current system. The development of a prototype of the system started in 2001. Main features of the system are as follows;

- The system is constructed using five Melsec PLCs and connected to each other with optical fiber cables.
- The beam is stopped by the beam chopper at the exit of the ion source of RILAC within 10 msec. after the system receives a digital or analog interlock signal.
- We can set an interlock signal pattern depending on the type of beam or operation mode at one time by downloading a file by PC to PLC as well as by setting each signal manually.

Three beam interlock system using PLC are under operation in RIBF. The first one watches RILAC area, the second one watches RRC and fRC area, and last one watches IRC and SRC area.

SUMMALY

To date, the RIBF control system has functioned well without any serious troubles. As an upgrade plan of it, we are now investigating a program to make short a beam tuning time. Since RIBF has one Linac and four cyclotrons, it is one of the most demanded works to save a man power and power cost.

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