UPGRADING THE CONTROL SYSTEM OF RIKEN RI BEAM FACTORY FOR NEW INJECTOR

M. Komiyama#, M. Fujimaki, N. Fukunishi, RIKEN Nishina Center, Wako, Saitama, Japan
A. Uchiyama, SHI Accelerator Service, Ltd., Shinagawa, Tokyo, Japan
J. Odagiri, KEK, Tsukuba, Ibaraki, Japan

Abstract

To boost up the intensity of the uranium beam accelerated in the RIKEN RI Beam Factory (RIBF), a new 28 GHz superconducting ECR ion source was constructed in 2008. The standalone commissioning of the ion source has started in early 2009. In order to control the ion source as a part of the RIBF accelerator complex, we introduced F3RP61-2L as Input/Output Controller (IOC) and integrated them into the existing EPICS-based RIBF control system. F3RP61-2L is a new CPU module running Linux, which functions with the I/O modules of FA-M3 PLC on the PLC-bus. It is expected to make our control system simpler and easier to maintain. We will report the details of the control system of the new ion source and its integration into the whole RIBF control system.

OVERVIEW OF RIBF CONTROL SYSTEM

The RIBF has an accelerator complex consisting of one heavy-ion linac (RILAC) [1] and five heavy-ion cyclotrons including the world's first superconducting ring cyclotron (SRC) [2]. The injector system of the RIBF includes the RILAC, an AVF cyclotron and the RIKEN Ring Cyclotron (RRC) which have been used more than twenty years. Three newly-constructed cyclotrons (fRC, IRC, SRC) were commissioned in 2006 and started a beam service to users in early 2007. Most parts of the RIBF components are controlled using EPICS [3]. Many kinds of controllers are in use to control them, such as two kinds of our in-house controllers based on CAMAC and network interface, a control board based on VME and some kinds of PLCs. They are controlled and monitored by front-end controllers called IOC through Ethernet connections. In our system, almost all EPICS driver/device supports for controllers above mentioned are executed on Linux-based IOCs. To control the in-house controller based on CAMAC, we are using the network-based crate controller (CC/NET), which is a commercial product of Toyo Corporation [4] [5]. Since it is a single board computer based on Linux, we can execute EPICS base software on it. Therefore, the CC/NET itself is one of IOCs. On the other hand, both the network-based in-house controller (Network-DIM, N-DIM) [6] and PLCs don't have such kind of OS to execute EPICS base software on themselves. Therefore, in order to control them in EPICS, they should be connected with another EPICS IOC through Ethernet connections to convert the communication protocols between EPICS Channel Access and PLCs or the N-DIM. For the RIBF control, a lot of Linux-based small single board computers are used as IOCs, and they execute software called netDev on them. The netDev was developed by ourselves in collaboration with the KEK control group in 2006 [7]. As an exception, only a type of control board based on VME is controlled and monitored by a device/driver support developed based on vxWorks. As a VME board, we are using NIO board which is a commercial product of Hitachi Zosen Corporation.

The in-house CAMAC based controllers control approximately 370 magnet power supplies, 100 beam diagnostic devices and vacuum systems. CAMAC system is applied to the components in the RRC, AVF cyclotron and their beam transport lines. On the other hand, the N-DIMs control approximately 250 beam diagnostic devices and vacuum systems. They are mainly applied to the devices in the three new ring cyclotrons, in their beam transport lines and around RILAC. Since the RILAC is the oldest accelerator in the RIBF, a step-by-step upgrade of the old control system is necessary for stable operation. PLCs control the vacuum systems for cyclotrons and some beam diagnostic devices. There are many PLCs in the RIBF, however, EPICS controls and monitors only about 12 of them. Other PLCs have their own control systems and they are independent from EPICS system. At last, NIO boards control approximately 420 power supplies for the magnets in the three new ring cyclotrons, in their beam transport lines and around RILAC. Table 1 shows the summary of interface controllers used in the RIBF control system.

ADVANTAGE OF SYSTEM WITH EMBEDDED EPICS

The RIBF control system has been operated without serious troubles for these three years and a lot of convenient functions have been introduced step by step. On the other hand, we have evaluated the use of F3RP61-2L as an IOC which controls various kinds of PLC modules. F3RP61-2L is a new PLC-CPU module running a soft real-time Linux produced by Yokogawa Electric Corporation and installation of EPICS on it has been developed by collaboration between the KEK control group and us.

misaki@riken.jp

Table 1: Interface Controllers Used in the RIBF Control System

	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								
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)
Motion 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/ PLC(Melsec)	DIM/ PLC(Melsec)	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

* DIM: in-house controller based on CAMAC

It functions with a sequence CPU, a base module, a power source module, and various I/O modules of the FA-M3, which are the commercial PLC series of Yokogawa Electric Corporation. It was commercially released in 2008, and we succeeded in building EPICS base programs on it in June 2008 [8]. As mentioned in the last paragraph, PLC has been used in the RIBF control system before F3RP61-2L is released, and its control logic was constructed with the ladder program on a sequence CPU. They are controlled from a high-level application such as GUI through Ethernet connection with IOC. As an advantage of introducing F3RP61-2L to the control system instead of the stably-operated existing PLC-CPU is that the control system becomes simple. It is expected that it becomes easier to fix a trouble when it occurs because the number of computers are reduced in the control system. Concretely, F3RP61-2L works as an IOC itself in the EPICS system and it does not require additional IOC machine to communicate with high-level applications. In other words, it becomes possible that F3RP61-2L as EPICS IOC directly accesses each I/O modules of PLC through the PLC bus, not through Ethernet. As a result, there are two advantages: one is that developing driver/device support becomes very simple, and the other is that we will not be bothered by the problem of originating from the network communication such as delay of receiving messages or an interruption of communication.

CONTROL SYSTEM FOR NEW INJECTOR OF RIBF

In 2008, the RIBF succeeded in providing heavy ion beams of ^{48}Ca and ^{238}U with 170 particle-nano-ampare (pnA) and 0.4 pnA, respectively, at an energy of 345 MeV/u. In order to increase the intensity of the uranium beam, a superconducting ECR [9] ion source and a new linac injector (RILAC2) [10] are now under construction. The new ion source is designed to use a microwave source of 28 GHz. Except for the microwave source of 28 GHz, the construction of the ion source was completed and installed in upstream position of the existing RILAC in early 2009. The ion source was installed on a high-voltage terminal, where the beam from the source will be directly injected into the RILAC by skipping the RFQ pre-injector. Commissioning and performance tests of the ion source have been started in FY2008 using the existing microwave source of 18 GHz and a newly-constructed medium-energy beam-transport (MEBT) line between the end of the high-voltage terminal and the RILAC.

Considering the advantages of using F3RP61-2L in the system, we adopted it for the control system of the new injection system including the new ion source. It is the first time for us to install the F3RP61-2L system into the RIBF control system.

A new control system using F3RP61-2L applied to the new ion source controls following devices; the power supplies for the solenoid and hexapole coils, the RF source, the high-voltage power supply for the extraction electrode, the controller of gas feeding system, the negatively biased disk, the high temperature oven for solid material. In addition, it also monitors the leakage of water at the stage of the ion source. The components installed in MEBT are also controlled by EPICS, however, they are controlled by the same kind of controllers used in RIBF. Therefore, we applied the same kind of programs as used in the RIBF control system to them.

Fig. 1 shows the control system for the new ion source using F3RP61-2L. We need to separate the PLC unit in two because of the difference of the ground potential level between them. The negatively biased disk and the high temperature oven were placed besides of the plasma chamber whose voltage was kept 20 kV higher than the high-voltage terminal where the ion source itself was installed. Therefore, we placed a PLC unit with CPU module and some I/O modules and an optical link module just beside the ion source, and the other PLC unit with only some I/O modules and an optical link module was placed besides the plasma chamber. The communication between the both units is done through an optical fiber.

Figure 1: The control system for the new ion source using F3RP61-2L.

For the control of the new ion source, we are using only basic I/O module of PLC such as DI module, DO module, AI module and AO module. The control logic for each component was written in EPICS sequencer instead of traditional ladder programs as before.

For GUI development, we adopted the edm instead of the medm for the first time. Both the edm and the medm are applications for developing GUI, which are supported by EPICS collaboration. The advantage of using the edm for the control system of the new ion source is that its build-in XY plot tool is convenient in illustrating charge-stage distribution produced by the ion source.

PRESENT STATUS AND PLANED SCHEDULE

Since we installed only basic I/O modules in the control system of the new ion source, it was not difficult to construct the control system. The performance test of the new ion source started in early 2009 by a local control and the remote control test of the ion source started in June, 2009.

In July and September 2009, the acceleration tests using the ^{136}Xe beams were performed, in which ions extracted from the new ion source were injected into the RILAC through the MEBT. In these two tests, we found that the control system using F3RP61-2L was working quite stably. In addition, we also found that the performance in speed and functions was sufficient for the control system of the superconducting ECR ion source.

In October 2009, the first acceleration test using ^{238}U from the new ion source to RIBF is scheduled. In this test, a uranium beam generated in the new ion source will be injected into the RIBF cyclotrons, and the expected beam intensity extracted from the SRC is 5 pnA. We are now preparing a lot of EPICS sequencers and monitor programs for the success of the test.

In addition to the new superconducting ion source mentioned above, we have another superconducting ECR ion source. The ions extracted from this ion source are injected into the AVF cyclotron, which is another injector to the RRC. The control system for the ion source also employs F3RP61-2L. In this case, some special PLC modules with various functions on themselves, such as a position control module and a serial communication module were installed. However, since basic control logics are common in both ion sources, basic I/O modules of FA-M3 are also installed in the system. Control tests for this ion source continue in order to realize steady operation of both ion sources.

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