# Improvement of the RIBF control system

M. Komiyama,[*1] A. Uchiyama,[*1] M. Fujimaki,[*1] K. Kumagai,[*1] N. Fukunishi,[*1]
M. Hamanaka,[*2] T. Nakamura,[*2] and S. Fukuzawa[*2]

We report on two aspect of the RIBF control system; one is the maintenance of the aging components in the system to maintain stable operation of the accelerators and the other is safe operation of the accelerators based on the improvement of their performance.

The Network-I/O (NIO) system is one of the control systems for magnet power supplies in the RIBF accelerator complex,[1)] which is a commercially available system manufactured by Hitachi Zosen Corporation. The NIO system consists of three types of controllers: the NIO-S board, the NIO-C board, and the branch board. The NIO-S board is a slave board attached directly to the magnet power supply and controls it based on the signals received from an upper-level control system through the NIO-C board. The NIO-C board works as a master board for the NIO-S boards and is designed to operate in the VME computing machines. The NIO-C and NIO-S boards are connected using an optical fiber cable through a branch board. Since one NIO-S board can control only one magnet power supply, there are about 500 NIO-S boards, and this corresponds to 60% of the total magnet power supply used in the RIBF accelerator complex. The existing NIO system has been working stably; however, the production of the present NIO-S and NIO-C boards was terminated because some parts used for communication were not available. Therefore, we decided to develop fully compatible successors to the existing NIO-S and NIO-C boards, and first, a successor of the NIO-S board was developed in 2013.[2)] However, a problem was found during the performance tests; some types of magnet power supplies could not be controlled by the successor because the widths of some output pulses produced were slightly different from those produced by the existing board. After the pulse width of the successor was adjusted to match with that of the existing NIO-S board, we confirmed a normal operation of the successor in 2015. The development of a successor for the NIO-C board has also been started since 2014. The specifications required for the successor of this board are essentially the same as that for the existing one; however we decided to design the new board to run in a control system constructed by PLC modules instead of the VME computing environment currently used, in order to achieve cost reduction and functional scalability. The successor of the NIO-C board is based on FA-M3, manufactured by Yokogawa Electric Corporation, [3)] according to recent trends in the control systems of RIBF accelerators based on EPICS. One of the advantages of adopting FA-M3 is that a simple control system can be set up because a Linux-based PLC-CPU (F3RP61) is available in the FA-M3 system and F3RP61 can work not as only a device controller but also as an EPICS Input/Output Controller (IOC).[4)] This means that additional hardware to serve as an EPICS IOC is not required for F3RP61. Following the development of the hardware for the successor in 2014, its software was developed in 2015. The successor of the NIO-C board is not only equivalent to the existing one in terms of functionality some new functions have also been added to control any NIO-S board from an NIO-C board by using its serial port. In the existing NIO system, there are only two ways to control an NIO-S board: one is by entering a command from the VME computer and the other is by entering a command directly from a serial port of an NIO-S board. Therefore, the new function is expected to help identify the cause of the problem at the time of its occurrence.

The second aspect is the contribution towards a safe operation of the accelerators. Following an annual increase in the beam intensities supplied from the RIBF accelerators, various functions have been added to the control system and the beam interlock system (BIS) [5)] to operate the accelerators safely. As a part of the improvements, we connected the interlock signals indicating failure of old magnet power supplies for the AVF cyclotron and RRC and their beam transport lines to the BIS in 2015 by modifying a part of the magnet power supplies to take out the interlock signals. As a result, signals from almost all magnet power supplies in RIBF are connected to the BIS except for the magnets installed in the junction building and the vault of ion sources for AVF cyclotron. Furthermore, current signals detected by the beam spill monitors installed in the fRC were also connected to the BIS in 2015. With this improvement, the amount of beam loss in all cyclotrons except the AVF cyclotron can be monitored by the BIS, and it has become possible to prevent damages to the hardware of the RIBF accelerator complex from significant beam losses for high-power heavy-ion beams. For a further increase on the beam intensities supplied from the RIBF accelerators in the near future, we will expand the number and type of signals managed by the BIS appropriately.

*1 RIKEN Nishina Center
*2 SHI Accelerator Service Ltd.

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