EPICS CONTROL SYSTEM FOR THE FFAG COMPLEX AT KURRI*

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Abstract

In Kyoto University Research Reactor Institute, a fixed-field alternating gradient (FFAG) proton accelerator complex, which is composed of three FFAG rings, had been constructed to make an experimental study of accelerator driven sub-critical reactor (ADSR) system with spallation neutrons produced by the accelerator.

The world first ADSR experiment was carried out in March of 2009. In order to increase the beam intensity of the proton FFAG accelerator, a new injection system with H^- linac has been constructed in 2011. To deal with these developments, a control system of these accelerators should be easy to develop and maintain.

The initial control system was based on LabVIEW and the development had been started seven years ago. Thus it is necessary to update the components of the control system, for example operating system of the computer. The initial control system had also some minor stability problems and it was difficult for non-expert of LabVIEW to modify control program. Therefore, the EPICS toolkit has been started to use as the accelerator control system in 2009.

INTRODUCTION

Kumatori Accelerator Driven Reactor Test (KART) project has been started at Kyoto University Research Reactor Institute (KURRI) since the fiscal year of 2002 [1]. The main purpose of this project is to study the feasibility of accelerator driven subcritical system (ADS).

In KART project, the FFAG accelerator complex was developed as a proton driver for ADS. This complex was composed of three FFAG rings: injector, booster and main-ring (MR) [2], respectively. Figure 1 is a picture of this complex.

With this complex, 100 MeV - 0.1 nA proton beam was achieved with 30 Hz repetition and the world first ADS experiment was carried out in March, 2009 [3].

To increase the beam intensity of this complex for the ADS experiment, new injection scheme with H^- ions was developed [4] and the construction of this new injection system was completed in 2011. Using this new injection scheme, this complex achieved 100 MeV - 10 nA with 20 Hz repetition in 2012. And acceleration up 150 MeV has been achieved with 1 nA in 2012.

The present FFAG accelerator complex with this new injection system is composed of

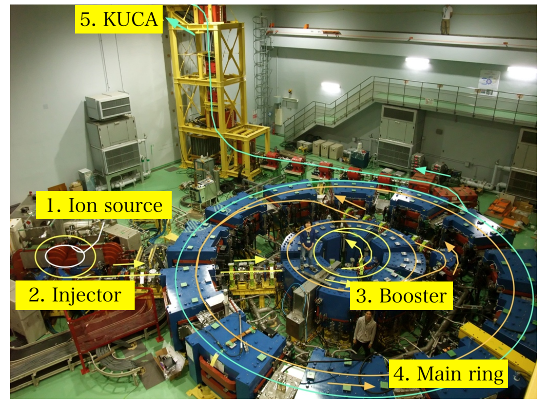

Figure 1: The initial FFAG accelerator complex in KURRI.

- Negative hydrogen (H^-) ion source.
- 11MeV Linac.
- Beam transport to MR from Linac (HEBT).
- 150MeV FFAG MR.
- Beam transport to KUCA from MR (MCBT).

Figure 2 shows the present status of this complex.

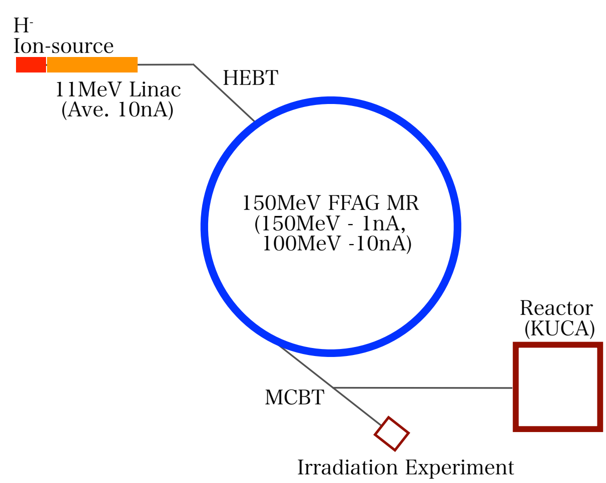

Figure 2: The present FFAG accelerator complex in KURRI.

INITIAL CONTROL SYSTEM

The control system for this complex must accept such developments and changes. The initial control system was based on programmable logic controllers (PLC), FA-M3R series which manufactured by Yokogawa Electric Corporation, and LabVIEW, manufactured by National Instru-

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ments, on Windows XP [5]. This control system was served for an actual beam commissioning and ADS experiment with high reliability.

Difficulties and Problems in Our Case

We must replace old software, such as Windows XP, to up-to-date one because of the end of support period. But our control programs developed with LabVIEW 7 or 8 have no compatibility with the present version of LabVIEW. In addition, all the members in charge of the control system left our group in 2008. Therefore, it was decided that we do not modify these control programs for the compatibility of newer version of LabVIEW and the introduction of EPICS to our control system has been started since 2009.

THE STATUS OF CONTROL SYSTEM

The update of control system has been done gradually. Consequently, LabVIEW based control programs are still used. Figure 3 shows computers and networks which are used for the operation of this complex.

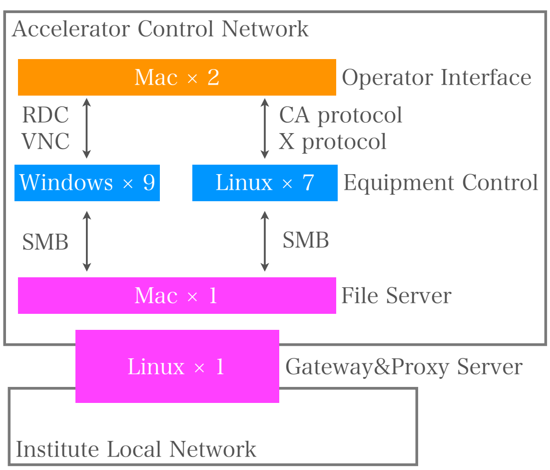

Figure 3: Computers and networks of our control system.

Network and Servers

As shown in Fig.3, independent network has been built for the purpose of reducing security risk and there are two servers, one is a file server and another one provides several network services. The file server, of which operating system is Mac os x server, provides all files which are required by the operation of this complex using SMB protocol. And another server, of which operating system is Linux, provides the following network services:

- Network Time Protocol (NTP).
- Dynamic Host Configuration Protocol (DHCP).
- Domain Name System (DNS).
- Proxy.
- Gateway.

Windows Computers

The number of Windows computers is nine and they provide the following functions:

- Beam interlock system interface.
- Negative hydrogen ion source control interface.
- Linac control.
- MR vacuum control interface.
- Access control for the radiation controlled area.
- Camera server.

Except the last item, these functions are based on ladder programs on PLCs and operator interfaces were developed with LabVIEW or Visual Basic 6.

Linux Computers

The number of Linux computers is eight and one of them provides network services and the rest provide the following functions:

- EPICS IOC.
- Waveform generator control.
- Stepping motor control.
- MR defocus magnet control.

For the last three items, GPIB-USB converter and its driver software, manufactured by National Instruments, is used and operator interfaces are developed using GTK. In Fig.4, the MR defocusing magnet control interface developed with GTK is shown.

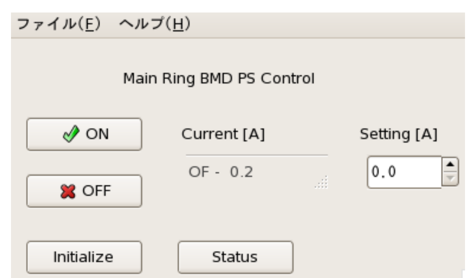

Figure 4: Operator Interface developed with GTK for the MR defocusing magnet control.

In case of our EPICS control system, PLC is used just as device interface. The details of this will describe in the next section.

Mac Computers

The number of Mac computers is three and one of them is file server and the rest provide the following interfaces to the operator:

- EPICS OPI (EDM, MEDM).
- X.
- RDC.
- VNC.

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Timing System

The present repetition of this complex is 20 Hz and maximum is 120 Hz in design. The master clock for the machine operation synchronizes with commercial power supply line (60 Hz) and we use 20 Hz which is made by dividing 60 Hz. From this master clock, six trigger signals are made and delayed independently using function generators manufactured by NF Corporation. These trigger signals are used for the following devices:

- Arc pulser of the H^- ion source.
- Beam chopper.
- Linac.
- Waveform generator for the acceleration cavity in the MR.
- Extraction kickers of two in the MR.
- Pulse septum magnet in the MR.

And also NIM delay modules are used for the precise timing control.

EPICS CONTROL SYSTEM

The first EPICS based control system was developed for the beam transport line, MCBT in 2009. Next year, in 2010, EPICS based control system was developed for the new beam transport line, HEBT. The hardware components of the EPICS control system is not changed from the initial one. In Fig.5, comparison of standard design between initial control system and present one is shown. In the present

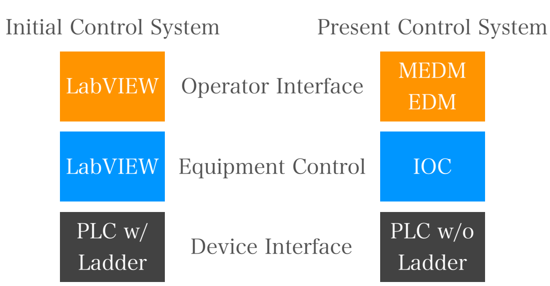

Figure 5: Comparison of standard design between initial control system and present one

standard design of the control system, ladder program of PLC has not been used and instead of LabVIEW, EPICS has been used.

Operator Interface

Operator interface has been developed with EDM and MEDM. Two computers, of which operating system is Mac os x, has been used as an operator interface. In operator's computer, EDM and MEDM have been running natively and communicate with EPICS IOCs through network. Figure 6 is a screen shot of main operation window for the operator.

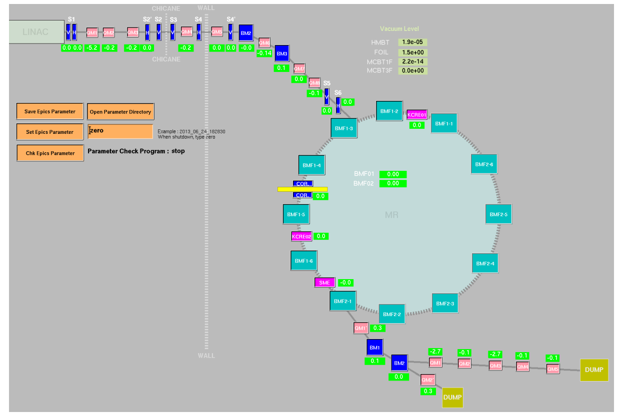

Figure 6: Main operation interface of this FFAG complex based on EDM.

Equipment Control

We use Linux IOCs as an equipment controller. Linux IOCs communicate with PLCs through network. As a PLC driver, we use a NetDev [6] software. Currently, the number of IOCs is three and these IOCs provide the following functions:

- HEBT control.
- MR control.
- MCBT control.
- Beam profile monitor control.
- Beam current monitor control.
- Beam intensity interlock system.
- Vacuum control.

Device Interface

PLCs, Yokogawa FA-M3R series, are used as a device interface in our EPICS control system. PLCs group of nine have been used and each PLC group have several sub-units. For the communication between PLC sub-units, independent optical fiber network has been used.

SUMMARY AND FUTURE PLANS

Introduction of the EPICS to our control system has been started in 2009. To replace initial LabVIEW based control system, this introduction was decided This introduction has been succeeded and the update is on going. In the future, all control will be unified to EPICS based control system. Except Linac control, the control system required by the machine operation will be replaced within a year.

Virtual EPICS IOCs

Currently, we use Linux computers of four as a EPICS IOCs and each computer has been used for the several separate purposes. For the purpose of easy development and maintenance, it is useful to prepare separate EPICS IOC for each functions. But the increase of the number of computers increase amount of work for the management. Therefore, we are planning to use virtualization technology to separate EPICS IOCs [7].

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Beam Profile Monitor System with the EPICS Control System

In order to improve the beam quality, we are planning to combine beam profile monitor system to the EPICS control system. This beam profile monitor is now under construction. After this construction, basic beam parameters, such as twiss parameter, will be able to obtain easily.

New Access Control for the Radiation Controlled Area

Already, we has developed EPICS based system for the access control of the radiation controlled area and this system has been started to use in 2013. Figure 7 shows this EPICS based access control system. In the near future, this system will be combined to our beam interlock system.

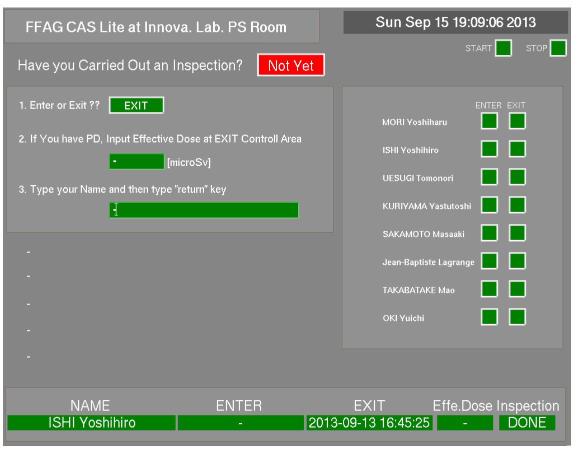

Figure 7: Access control for the radiation controlled area.

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