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CONTROL SYSTEM UPGRADE FOR THE FFAG ACCELERATOR COMPLEX AT KURNS

Y. Kuriyama*, Y. Fuwa, Y. Ishi, Y. Mori, H. Okita, T. Uesugi
Institute for Integrated Radiation and Nuclear Science, Kyoto University, Osaka, Japan

Abstract

Fixed field alternating gradient (FFAG) accelerator complex has been operated as a proton driver for the experiment of accelerator driven system (ADS) at Institute for Integrated Radiation and Nuclear Science, Kyoto University (KURNS). PLC based control system has been developed and the operator interface has been connected to PLC via network. Originally, a LabVIEW based operational interface was chosen to construct the system because of its easiness. However we met an upgrade problem, and a new control system based on EPICS instead of LabVIEW was introduced in 2010. In the spring of 2018, the replacement from LabVIEW to EPICS has been almost completed except for the beam interlock system and the LINAC control system provided by LINAC production company (AccSys). Also, the EPICS archiving tool (Archiver Appliance) has been invoked and operated at the end of 2017. This presentation reports the details of the current control system and also the upgraded GPIB control and storage system.

INTRODUCTION

FFAG accelerator complex has been operated as a proton driver for the ADS experiment [1]. The construction of this complex had been started since the fiscal year of 2002 and with this complex, the world first ADS experiment was carried out in March, 2009 [2].

The KUNRS complex consists with two ion sources, H^- linac and four FFAG rings. Figure 1 shows the schematic view of KURNS complex.

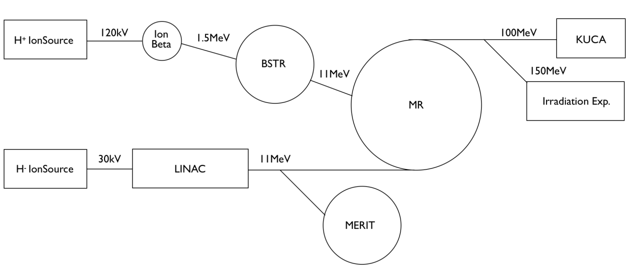

Figure 1: Schematic View of the KURNS Complex.

To control this complex, PLC based control system had been developed. Originally, operator interface had been developed based on a LabVIEW [3]. Since 2010, the aim for the sophistication and stability, we introduced EPICS control system [4]. The immigration from LabVIEW to EPICS had been almost completed in the spring of 2018 except for the beam interlock system and Linac control system.

* kuriyama@rri.kyoto-u.ac.jp

OVERVIEW OF CONTROL SYSTEM

In the KURNS complex, PLC-based systems have been adopted since the beginning of construction. The operator communicates with the PLC via the network, and the control target device such as the electromagnet power supply is operated by receiving a command from the PLC.

About 20 PLC-CPU modules and 20 Linux PCs, 5 Windows PCs and 2 board computers and 2 servers are used. Also, 20~35 network cameras are used for an equipment monitoring and beam profile observation.

These control devices are connected by an independent network for the accelerator control. Figure 2 shows a diagram of control system.

Since all the devices are connected to the same network, high network load is becoming a problem.

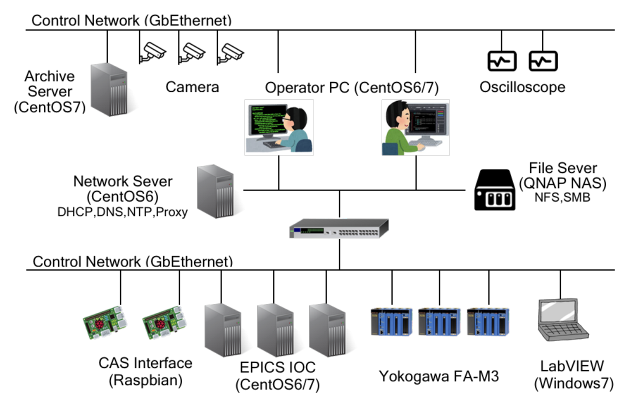

Figure 2: Schematic View of the Control System.

For the device control system, EPICS-based ones and GPIB controlled ones are mixed. EPICS-IOC consists of Yokogawa's PLC FA-M3 and CentOS6 or CentOS7 PC. The number of EPICS-IOC is about 15.

From the point of necessary processing capacity, it is possible to aggregate them into several units. Since accelerator components are often replaced at the KUNRS complex, EPICS IOCs are prepared for each section such as ring and beam line to cope with this. It realizes the flexibility of control system.

RENEWAL OF STORAGE SYSTEM

During the past 10 years, KURNS control system had changed file server three times. One is Linux-based file server and two are mac os based file servers.

Since the period of use was exceeded five years in December 2017, we began to consider updating the file server. Requirements for the new file server are

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- Supported Protocol : NFS v3, SMB 2.0,
- Redundancy : RAID 6,
- Backup : External Storage, Snapshot,
- Ease of replacement : Hot-swappable, General Drive Bay (SATA).

In order to satisfy the above requirements, we decided to shift to a NAS dedicated machine instead of a x86 based PC.

The adopted hardwear is TS-431P2-4G manufactured by QNAP [5]. It has Arm-based CPU, 4 GB memory, and 4 storage bays. The specifications of new file server are summarized in the Table 1.

Table 1: Specifications of the New File Server

Model	QNAP TS-431P2-4G
OS	QTS 4.3.4
CPU	1.7 GHz Quad Core (Arm Cortex-A15)
Memory	4 GB (DDR3) × 1
Storage	3 TB × 4 (RAID6)
LAN	GbE × 2 (Link Aggregation)

We continue to use previous file server as read-only storage for some time and evaluate the durability and reliability of the new file server.

INTRODUCTION OF EPICS ARCHIVING SYSTEM

Until now, we used homemade shell scripts to preserve various parameters. The timing of preservation is left to the judgment of the operator. Therefore, it was not possible to save parameters during non-operation.

In order to deal with this problem, we started experimental use of the EPICS Archiver Appliance [6] from December 2017. Approximately 140 PVs were recorded at the shortest period of 0.1 second. The ArchiveViewer [7] is used to display the acquired data. Figure 3 shows vacuum data taken from January 1, 2018 to February 1, 2018.

Figure 3: Vacuum Data from 1 Jan. 2018 to 1 Feb. 2018 taken by "The EPICS Archiver Appliance". The Viewer is "ArchiveViewer".

Since the EPICS Archiver Appliance was stable over 3 months, we started to use full-scale usage from April 2018.

We prepared exclusive PC and EPICS archive server had started to record about 310 PVs. The hardware specification of the EPICS archive server are summarized in the Table 2 and software specifications are summarized in the Table 3.

Table 2: Hardware Specifications of EPICS Archive Server

CPU	4 GHz Quad Core (i7 6700K) × 1
Memory	16 GB (DDR4 PC4-17000) × 4
Storage	1 TB SSD × 1
	6 TB NAS (RAID6)

Table 3: Software Version of EPICS Archive Server

OS	CentOS7
Archiver Appliance	22 June 2017
Java	Oracle Java SE Dev. Kit 8
Tomcat	7.0.86
Apache	2.4

The data acquired by this archiver is directly stored in the NAS. Currently, the event rate is 65/s and the data consumption is 0.1 GB/Day. Since there is sufficient margin in performance, we plan to increase the number of PVs to store.

MIGRATION OF GPIB CONTROL ENVIRONMENT

In the KURNS control system, GPIB is used to control old type power supply and stepping motor controller. Control programs for the GPIB devices were made using the Glade [8] version 2 for GUI creation under the CentOS5 environment.

As the CentOS5 support period expired in March 2017, the immigration of the GPIB control environment became necessary.

In the KUNRS control system, GPIB-USB-HS [9] manufactured by National Instruments has been used as a standard device for connection between the device controlled by the GPIB and the PC. But the device driver of GPIB-USB-HS provided by manufactured is only compatible with CentOS5 or older.

In order to use the CentOS6 or later version, it was necessary to change the device driver. Therefore, we decided to use the device driver Linux GPIB Package [10] which is being developed as open source. In addition, since this device driver was able to cooperate with Python, we decided to use Tkinter as a GUI creation tools, which is Python's standard library.

Before the migration, when relocating programs between PCs, there was a need to recompile. After migration, recompile doesn't need and portability improved with Python. Table 4 shows the results before and after the immigration of the GPIB control environment.

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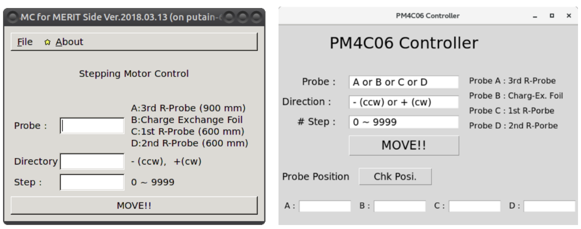
Table 4: Migration of GPIB Control Environment

	Before Migration	After Migration
Hardware	NI GPIB-USB-HS	NI GPIB-USB-HS NI GPIB-USB-HS+
OS	CentOS5	CentOS7
Dev. Driver	NI-488.2	Linux GPIB Package
App. Lang.	C (GTK)	Python (Tkinter)

Figure 4 shows two operator interfaces of stepping motor controller, one is created using GTK and another is using Python(Tkinter).



(a) GTK based OPI. (b) Python (Tkinter) based OPI.

Figure 4: Examples of Operator Interface for the device controlled via GPIB.

NEXT PLANS

Integration of GPIB Control to EPICS

GPIB controlled devices are independent control, not in cooperation with EPICS. For this reason, different operation systems are mixed in control, which is a cause of complicating the operation of the accelerator. In order to solve this problem, we are preparing a bridge program including GPIB control which behaves as EPICS IOC.

Integration of Beam Diagnosis to EPICS

Since problems arise in the accessibility of data acquired by the beam diagnosis device, we would like to implement bulk management using EPICS archive server. We are developing data acquisition system integrated with EPICS.

Update of Linac Control System

We introduced a linear accelerator to the KURNS complex system in 2008. It has been over 10 years since the introduction, and in 2015, we had experienced serious hardware problems with RFQ.

The PC used for control has not been updated since its introduction and failed at startup and sudden shutdown occurred. Although early replacement is necessary, there is no source code of control software in the manufacture. And there is no device driver of the input/output board (for communication with the linear accelerator power supply unit) for the latest OS.

Since there are many uncertain factors regarding the updating work of the control PC, the manufacture cannot estimate the cost of renewal. However, for the continuous operation of the KURNS complex, the replacement of linac control system cannot be avoid.

SUMMARY

The KURNS complex has also exceeded 10 years since the start of construction. During this 10 years, the structure of the accelerator continues to change, and the control system is also changing to cope with the change.

For the purpose of the sophistication and stability, replacement of LabVIEW-based control system to EPICS is almost completed and for the data protection, file servers were replaced fourth times and EPICS archive server is introduced. And beam diagnosis system and GPIB control system are also moving to EPICS environment.

At present, the update plan of the control system of the linear accelerator has not been determined but this is a most urgent task of control group.

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