CONTROL SYSTEM UPGRADE FOR SUPERKEKB INJECTOR LINAC

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Abstract

The KEKB project has successfully ended 13 years operation in the June of 2010. The construction of SuperKEKB main ring has almost completed for aiming at the peak luminosity of 8 x 10^{35} $cm^{-2}s^{-1}$. The injector linac upgrade is also going on for increasing the intensity of bunched charge with keeping the small emittance. The key upgrade issues are the stable operation of a new positron capture system, a low emittance photo-cathode rf electron source, and the establishment of low emittance preservation. The injector linac beam commissioning started in the October of 2013. The control system performance determines the beam operation efficiency of injector linac, and it eventually has a strong impact on the experimental results of physics. In this decade, the linac control system has been gradually transferred from the in-house system to the Experimental Physics and Industrial Control System based one for the high availability of beam operation. In this paper, we present the detail of SuperKEKB injector linac control system.

INTRODUCTION

The linac beam control system is based on a standard client and server model with three layers. It comprises a client, a server, and a local controller layers. At the beginning stage of KEKB operation, the original linac control system has been developed by using the in-house software libraries based on the remote procedure call (RPC). The client user interfaces have been implemented by a command line interface based on shell script and a graphical user interface based on Tcl/Tk scripting language. Around a decade ago, the middle phase of KEKB operation, the linac control system has been upgraded to a new framework based-on the Experimental Physics and Industrial Control System (EPICS) [1] to improve the affinity between the linac and KEKB main ring control systems. These improvements make it possible to conduct the correlation analysis of linac and main ring parameters in much easy way. Such analysis can strongly help to find a source of injection rate deterioration and any other troubles.

After introducing the EPICS framework, the new client side user interfaces have been implemented by Python scripting language since its rich library modules and functionalities can accelerate the software development process. For the simultaneous top-up injection of KEKB and PF rings, an event based timing system has been installed to enable the pulse-to-pulse beam modulation [2].

OUTLINE OF CONTROL SYSTEM

Computer environment

In the beginning phase of KEKB project, the six Compaq Alpha servers based on the Tru64 UNIX operating system were utilized as the server computers. All server programs were basically run on them. Two of them were connected to the RAID disk drive via SCSI bus interface, and they can work as the active/standby redundant NFS servers for aiming at the high availability operation. Since the Tru64 UNIX was obsoleted, all server machines have been gradually replaced by the Linux-based servers. Eventually, we made decision to use the Linux base system without cluster functionality after the evaluation of several different types of high availability cluster system based on Linux. For keeping the high availability of server machines without cluster scheme, the blade server system was installed as the high reliability server. Currently, fifteen Linux based blade servers are utilized as the server computers with CentOS 5.11 x86_64. Both of server and client side control software are running on the server machines. CentOS 6.7 and 7.1 running on two blade servers are currently tested by using VMware vCenter of the virtual computing technology.

The Tektronix X terminals and touch panel displays based on PC9801/DOS machines have been originally utilized as the operator terminals. These terminals were replaced by the Linux based PCs and Windows based PCs with the X server application software of ASTEC-X and

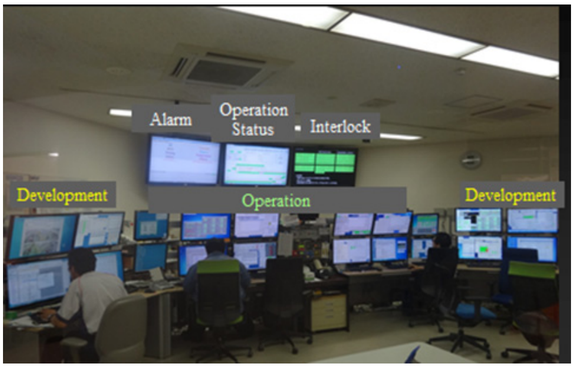

Figure 1: Photograph of the KEK electron/positron injector linac main control room.

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Reflection X. Figure 1 shows a photograph of the linac main control room. Three large liquid crystal displays (LCDs) with 55” show the alarm, operation, and interlock statuses. Sixteen LCDs with 27” are used for running the beam operation software and its development.

Network environment

In the previous linac control network system, Cisco Catalyst 4506 and 3750 have been utilized as the master network core and slave switches, respectively, for enabling the active/standby failover. Each of them was independently connected to 45 edge switches of Catalyst 2950 via single or multi-mode optical fibers with 100 Mbps bandwidth. For the network connection between the edge switches and the local controllers like a programmable logic controller (PLC), the optical fiber is used for avoiding the noise generated by the klystron modulators.

Toward SuperKEKB operation, the core switch system was replaced by 6 of Cisco Catalyst 3750X. They can work as the active/active redundant system based on the virtual switching system technology. We replaced also the edge switch by Catalyst 2960S, and the network connection speed was improved up to 1 Gbps bandwidth. In addition, the wireless network was installed into the beam line tunnel for improving maintainability.

Local controller

For the injector linac control system, many kinds of different local controllers are utilized for the injector linac component control as listed in Table 1. The ladder PLCs control the magnet power supplies, vacuum pumps, and safety related signals. About one hundred seventy CAMAC and VME based timing delay cards have been replaced by the 25 event timing cards based on VME64x bus for the pulse-to-pulse beam modulation. The reduction of number of timing modules improves the system availability. The PLCs used for the klystron modulator control have been gradually replaced by the new embedded controller of Armadillo. The EPICS Input/Output controller (IOC) can run on it. The Windows based digital oscilloscope as the BPM readout system will be replaced by a new one based on VME card soon. Its measurement precision is around 3 μm [3].

Table 1: List of the network attached local controllers used for the linac control system.

Devices	Accelerator components (# of components)	# of local controllers
VME64x	Event based timing system (MRF EVG-230, EVR-230RF)	25
PLC	Magnet (363) Vacuum (333) Klystron (5) Charge interlock	59 26 5 3
Network attached power supply	Magnet (105)	105
Linux based PLC	Profile monitor (100)	30
Embedded Linux	Klystron (66)	66
Data logger	Temperature (690)	28
Oscilloscope	BPM (90)	23
NIM modules	Timing watchdog (15)	15
Total		385

EPICS ENVIRONMENT

Overview

In the linac control system, the EPICS IOCs were originally implemented with the base R3.14.9 for wrapping the existing in-house control system. Table 2 shows the total number of IOCs for each subsystem. The EPICS process variables (PVs) are just communicating with the existing system based on RPC when the software access any PVs. Toward higher reliability, the server applications were remodeled for the direct communication between the IOCs and local controllers by EPICS base R3.14.12. All EPICS IOCs are running inside the vncserver sessions as shown in Fig. 2.

Table 2: Number of EPICS IOCs used for each subsystem.

Subsystem	# of ICOs
Safety	2
Monitor	48
RF	57
Magnet	19
Vacuum	1
Operation	3
Timing	21
Temperature	2
Total	153

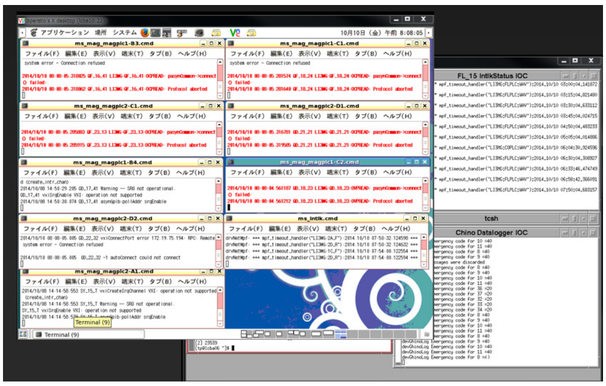

Figure 2: All EPICS IOCs are running in the vncservers.

Alarm

The independent in-house alarm applications were originally developed and utilized for each subsystems. For the comprehensive alarm management, we adopted the EPICS Control System Studio (CSS) [4] alarm 3.0.0 together with PostgreSQL 9.1.4 as a backend database engine. Around 1000 PVs are currently registered to the CSS alarm. The graphical user interface (GUI) showing the alarm status was developed by the Python scripting language. The panel shows the both of summary and detailed information of alarm status. The more detailed historical list of alarmed PVs can be also displayed in the other windows. Since the total number of registered PVs will be increased toward SuperKEKB operation, we are evaluating the speed performance and the robustness of CSS alarm with the large number of PVs.

Archiver

In the original linac control system, we developed the simple archiver tool recording the parameters into a text file together with the dedicated viewer software. After the implementation of an EPICS based control system, the EPICS channel archiver and CSS archiver 3.2.2 together with PostgreSQL 9.1.4/9.3.3 have been utilized. The total number of PVs registered to each archiver is currently 44063. The daily disk space usages are approximately 2 GB and 4.5 GB for channel and CSS archiver, respectively.

The web based data browser is utilized for the CSS archiver though the standard java based viewer is used for the channel archiver. The web based one was developed with Flex 4.6, PHP 5.3.6, and Amfphp 1.9. It can provide the easy access to archiver data from the any client devices including mobile one. It has the functions of correlation plot, multiple vertical axes, PV name search, and autocomplete for the quick parameter analysis.

The data retrieve speed of CSS archiver is slower than that of channel archiver. For improving these issues, the pg_reorg option was added into PostgreSQL database. It can reduce the CSS archiver database size by 33%, and improve the data retrieving time to a certain extent. For the further improvement of data retrieving speed, another scheme using the NoSQL type database of Casandra as a backend is now being evaluated.

OPERATION SOFTWARE

Outline

The original linac operator interface was developed by the Tcl/Tk scripting language and command line interface. For the rapid application development, the main software development language was transferred to Python scripting language. The communication between the operation software and EPICS PVs can be established via PythonCA module developed for the KEKB project.

Operation status display and electronic logbook

The real-time linac operation status is given through the Web-based application which can be run on the multiple operating system without installing specific software. This web application was implemented by using WebSocket together with Node.js and Socket.IO library. WebSocket can reduce the CPU load on the server machines in comparison with the other technologies like Ajax or Comet since its protocol can provide a full-duplex communication channels over a single TCP connection. This application shows the information of present beam repetition, high power klystron status, radiation monitor status, and so on as shown in Fig. 3.

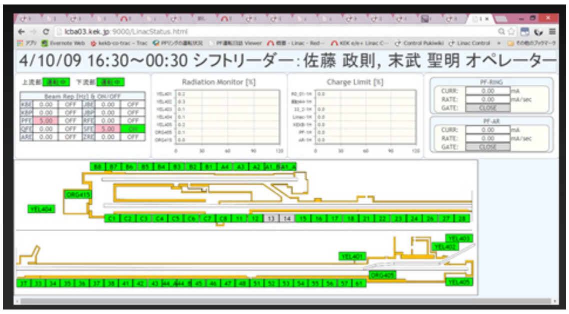

Figure 3: Web-based linac operation status.

The electronic operation logbook system (OPELOG) can enable the rapid operation information sharing between the accelerator operation team and hardware group. We developed an OPELOG system with Flex 4.6, PHP 5.3.6, Amfphp 1.9, and PostgreSQL 9.4.0. It comprises the summary and detailed information screen for each operation shift. OPELOG can automatically record the all routine operation state transition like the status change of beam repetition and klystron failure. In addition, a snapshot of operation GUI image can be easily imported into the detailed information screen. Moreover, OPELOG has the quick search function of past log by a key word combination set during a specific time period. It can be a strong help to find a solution of similar trouble occurred in the past.

CONCLUSION

Towards SuperKEKB project, the injector linac upgrade and commissioning are now on going for aiming at the 4 ring simultaneous top-up operation. Since the middle phase of KEKB operation, the linac beam control system has been gradually transferred from the in-house system based on RPC to the EPICS based one. Many operation software are developed by the Python scripting language. The data retrieving speed performance of archiver and the rapid development of advanced commissioning tools are recent main issues.

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