EMBEDDED EPICS CONTROLLER FOR KEKB PULSED QUADRUPOLE MAGNET POWER SUPPLY

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Abstract

The pulsed quadrupole magnets have been installed in KEKB for the betatron tune adjustment. These magnets need to be controlled by the existing EPICS-based control system of the KEKB accelerator. It is preferable to choose a front-end controller which allows us to develop and maintain the software in a highly efficient manner to cope with limited human resources. In order to satisfy this requirement, a new type of Input / Output Controller (IOC), which runs Linux on a CPU module of FA-M3 Programmable Logic Controller (PLC), has been adopted. The CPU functions with the I/O modules of FA-M3 on the PLC-bus. We found that replacing ladder programs with EPICS sequencer makes the development and maintenance of the software for the IOC considerably efficient. This paper describes the details of the new IOC and its experiences in KEKB operation including long term stability.

INTRODUCTION

KEKB is an asymmetric collider comprised of two storage rings, one for 3.5-GeV positrons (LER) and the other for 8-GeV electrons (HER). In order to correct the betatron tune, the pulsed quadrupole magnets were designed and installed for the rings [1]. The magnets were excited on every revolution in order to correct the tune shift of the first 700nsec at the head of bunch train in LER, and correct the tune shift of non-collision bunch for betatron tune monitor in HER. They have been successfully operated. The DC charging power supplies for the magnets are installed in the klystron gallery which is accessible during an accelerator operation.

In KEKB control system, it was a common practice to use a PLC as a dedicated embedded controller, which was under supervision of a VME IOC running VxWorks. The PLC and the IOC were connected by Ethernet for the communication. The IOC/PLC-based control has been operated stably for years. However, for the pulsed quadrupole magnet power supply control, we adopted a new PLC's CPU, F3RP61-2L, running Linux for easier maintenance of the application programs. By executing EPICS iocCore directly on the CPU, we can integrate the PLC/IOC-based control into one F3RP61-2L-based IOC. In this scheme, ladder programs are no longer required since the local control logic can be implemented by using the EPICS sequencer software running on the IOC.

EMBEDDED EPICS CONTROLLER

As shown in Table 1, F3RP61-2L manufactured by Yokogawa Electric Corporation has enough capability to execute iocCore to function as an embedded IOC. The remarkable feature of F3RP61-2L is that it supports Linux as its operating system. It allows us quicker development and easier maintenance of the application software.

Table 1: Main Specifications of F3RP61-2L

Item	Specification
CPU	PowerPC (MPC8347E)
OS	Linux (kernel 2.6.24.3-based)
Memory	FLASH ROM 64MB DDR2 SDRAM 128MB SRAM 512KB User SRAM 4MB
Interfaces	Ethernet (100BASE-TX) 2ch RS-232C IEEE1394a CF JTAG PCI

Encouraged by the satisfactory result of feasibility tests executed in corporation with RIKEN RI-beam factory control group in the April of 2008, we decided to adopt F3RP61-2L for the pulsed quadrupole magnet power supply control as the first example of this new type of IOC in the real accelerator control [2].

HARDWARE CONFIGURATION

An existing FA-M3 PLC unit was reused to control the magnet power supplies with replacing only CPU module with F3RP61-2L. All the other I/O modules were remained unchanged. Table 2 lists the modules of the PLC unit after the replacement and Fig. 1 shows the PLC unit in operation for the magnet power supply control.

Table 2: Module Configuration

Module	Model	Note
CPU	F3RP61-2L	Linux-based
DO	F3YC08-0N	8ch relay output
DI	F3XD16-3F	16ch digital input
AD	F3AD04-0V	4ch analogue input
DA	F3DA02-0N	2ch analogue output
Power Supply	F3PU10-0N	
Base (Backplane)	F3BU06-0N	

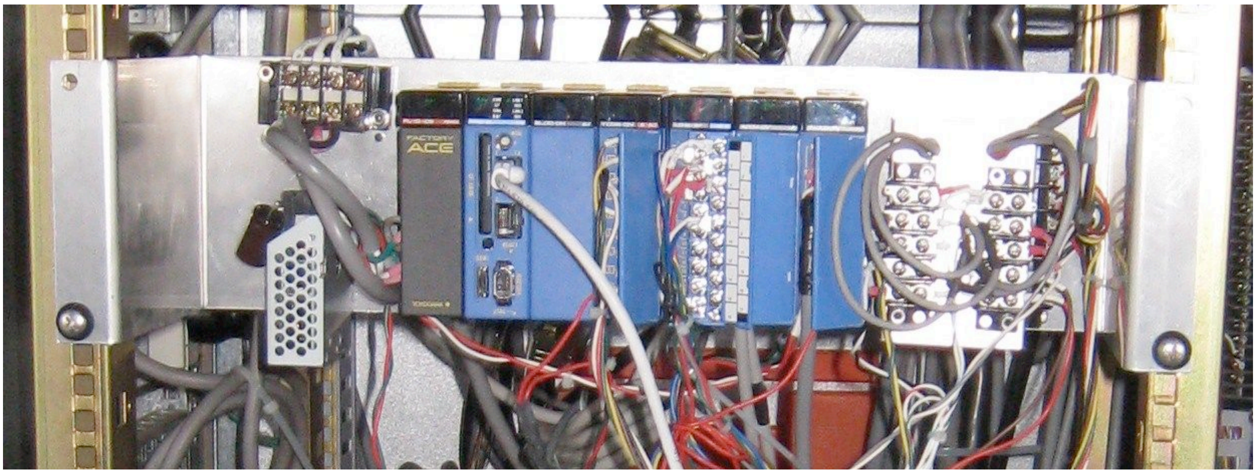

Figure 1: F3RP61 in operation for the pulsed quadrupole magnet power supply

More capable power supply module was recommended for the use of F3RP61-2L since it consumes more power than ordinary PLC's CPUs of FA-M3. We, however, have not experienced any problems with the configuration so far.

The whole control subsystem of the pulsed quadrupole magnet power supplies is shown in Fig. 2.

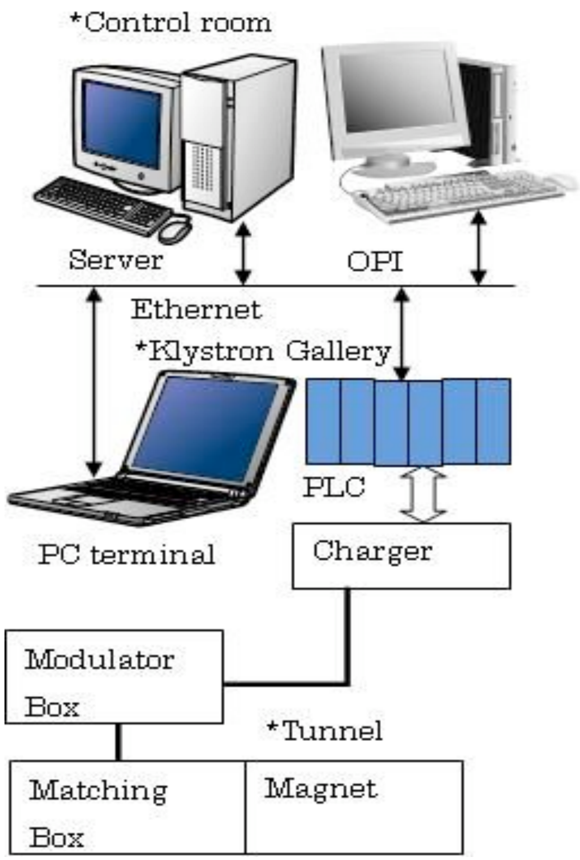

Figure 2: Configuration of pulsed quadrupole magnet power supply control system

SOFTWARE CONFIGURATION

This section describes the configuration of the software on the target as well as the host machine used to develop the application.

Target Software Configuration

The Board Support Package (BSP) of the F3RP61-2L CPU includes the kernel modified and pre-built for the CPU, a driver kernel module for accessing the I/O modules of the FA-M3 PLC, busyBox as the user level commands and other libraries to develop application programs.

Many different options are available in configuring the software on the target, i.e., the F3RP61-2L-based IOC. In order to make the F3RP61-2L-based IOC as a standalone system, we installed Linux system on the CF card in the CPU. On the other hand, we left the cross-compiled binaries of EPICS programs on the host computer considering the ease of application development and their version control. To let the F3RP61-based IOC download the executable file of iocCore upon the boot up, the Linux on the CF was configured so that it mounts the file system of the host computer.

Development Environment

In order to develop application programs for F3RP61-2L, a Linux/x86-based host computer is required. Once the build tool chain for cross development included in the BSP were installed on the host computer, all we needed to build iocCore was to arrange a few files under the "base/configure" to specify the path to the build tool chain in the Makefiles. All the source code of iocCore was able to be compiled without any modifications [2]. The EPICS application development environment was created with the standard Perl script (makeBaseApp.pl) in the EPICS base.

Device Support

By running iocCore directly on the F3RP61-2L CPU, device support can be implemented just by wrapping

Application Program Interfaces (APIs) of the kernel level drivers included in the BSP. In contrast to the case where an external IOC communicates with an ordinary PLC's CPU over the network, the device support becomes simple synchronous type rather than complicated asynchronous one. The device support had already been developed and available for the implementation of the quadrupole magnet power supply control system. The device support currently supports Analogue Input / Output, Long Input / Output, Binary Input / Output, and Multi-bit Binary Input / Output type records.

APPLICATION DEVELOPMENT

The important point of the pulsed quadrupole magnet power supply control is to replace ladder programs with EPICS sequencer programs written in State Notation Language (SNL) [3, 4, 5, 6]. With the notion of a finite state machine and the clear and simple syntax to wait events, SNL allows us to implement control logic in an easier-to-read and easier-to-write manner compared to ladder programs. The feature of SNL especially matters in the pulsed quadrupole magnet power supply control because it requires conditional ramping, which means that the output power must be gradually increased above a threshold voltage, can be increased at a stroke below the threshold voltage, and can be decreased at a stroke in any cases.

Another remarkable point of the control is that the logic to interlock the power supply, which is usually implemented by ladder programs on an ordinary PLC's CPU, is also implemented by using the EPICS sequencer program [7]. Owing to the stability of the F3RP61-2L-based CPU, we have not experienced any problems on the design so far.

The stability of the embedded EPICS IOC partly comes from, besides the reliability of F3RP61-2L and iocCore themselves, the fact that it is a dedicated controller for the power supply control with limited range of function. It was not difficult to increase the coverage in testing the EPICS application programs since the number of records is rather limited and the EPICS sequencer is simple enough to test all of the possible paths of the execution. Thus, the overall system of the IOC becomes reliable.

SETUP FOR OPERATION

In order to operate the developed F3RP61-2L-based IOCs for the real operation of the pulsed quadrupole magnet power supplies, we added two more functions onto them. One is the NTP client for the time management. The other is procServ, which is supported by EPICS community, to run iocCore in background and allows the operators to login to the IOCs. It enables boot-up and operation message logging as well.

OPERATIONAL EXPERIENCE

Since the September of 2008 when the F3RP61-based IOCs were put in operation for pulsed quadrupole magnet power supply control, they had been operated successfully without any problems for more than a year, excluding the machine shutdown period, which proved the reliability of this embedded EPICS configuration on PLC.

CONCLUSIONS

The control system of the pulsed quadrupole magnet power supplies of KEKB was implemented on the F3RP61-based IOCs for easier maintenance of the application programs. The ladder programs to control the power supplies were replaced with EPICS sequencer programs, which is easier to develop and maintain. More than a year of the operational experience proved the stability of the F3RP61-based IOCs.

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