PROTORYPE CONTROL SYSTEM OF THE 60-MEV PROTORN LINAC FOR THE J-PARC PROJECT

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Abstract

J-PARC, a high-intensity proton accelerator facility, started construction in 2001, and expects an anticipated first beam in the summer of 2007. The initial 60-MeV of the proton linac has been under construction at KEK. Early studies with proton beams have already started. A prototype control system based on the EPICS toolkit has been developed and evaluated in beam studies.

1 INTRODUCTION

J-PARC (Japan Proton Accelerator Research Complex) is a high-intensity proton accelerator facility, which consists of a 400-MeV linear accelerator, a 3-GeV RCS (Rapid Cycle Synchrotron), and a 50-GeV MR (Main Ring) [1, 2]. This is a joint project between JAERI [1] (in Tokai) and KEK (in Tsukuba). Although the construction site is Tokai, the initial 60-MeV part of the linac has been under construction at the Tsukuba site. Early studies with proton beams already started in 2002 [3]. The 60-MeV linac will be moved to Tokai at the end of fiscal year 2004.

EPICS (Experimental Physics and Industrial Control System) is a software toolkit used to develop a distributed real-time control system for large accelerators. It is now widely used in many accelerator institutes [4]. We decided to use EPICS to control the J-PARC accelerators [5, 7].

A prototype control system based on EPICS has been developed at KEK for the 60-MeV linac. The advantages are as follows: (a) to evaluate newly developed interfaces and software with real accelerator beams, (b) to provide staff members chances to use an EPICS-based control system in the early phase of the project, and (c) to support the commissioning activities at the 60-MeV linac.

2 EPICS AT THE 60-MEV LINAC

2.1 Network-based interfaces

The J-PARC control staff members in KEK have been interested in network-based interfaces [6]. In the 60-MeV linac control, we have used the following network-based interfaces: (a) a Programmable Logic Controller (PLC) with an Ethernet module, (b) an embedded controller for a power-supply (hereafter EMB [8]), and (c) a measurement station WE7000 (see 2.3). The development status of EPICS drivers is summarized in Table 1.

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Table 1: EPICS drivers for network-based interfaces.

Interface	EPICS device.support	Memo and update
PLC and EMB	(Feb01) Test version	PLC (Yokogawa FA-M3) used until Apr.03
	(Feb03) NetDev [9]	both PLC (Yokogawa FA-M3) and EMB
	(Apr03) update (May03) update	PLC (Mitsubishi Melsec-Q) EPICS3.14+Linux
WE 7000	(Mar02) 1st version [10]	WE7111 (100MS Oscillo.) WE7121 (10MHz Func.G.) WE7271 (100kS Digitizer)
	(May03) update (Jul03) bug-fix	add station-bus commands WF –>Calc conversion

2.2 PLC and EMB

In the KEK 60-MeV linac, PLC (Yokogawa FA-M3) is widely used as a front-end interface. The first EPICS driver for the PLC was developed in 2001 [6]. This test version had been used for monitoring the ion-source until April, 2003, and was then replaced by a new driver, NetDev (see below).

The EMB controller was developed as a dedicated network-based controller for the DTL/SDTL-Q power-supplies. A remote host can read and/or write EMB's registers over the network by exchanging simple messages [8].

The EPICS driver, NetDev, was developed for various network-based interfaces with a simple communication protocol: Yokogawa's PLC (FA-M3), EMB, and Mitsubishi's PLC (Melsec-Q). Descriptions are given in [9].

2.3 WE7000

In the J-PARC accelerators, the remote observation of waveforms is indispensable. A commercial product, Yokogawa WE7000 [13], is a module-type measurement station. We expected that the oscilloscope/digitizer modules of WE7000 can be used as low-cost network-based waveform monitors.

In fiscal year 2001, we developed three EPICS drivers of the WE7000 modules: a 100 MS/s oscilloscope (WE7111), a 100 kS/s digitizer (WE7271), and a 10MHz function generator (WE7121), followed by small updates and bug-fixes during the shutdown period of 2003.

Evaluations of the 100 MS/s oscilloscope module

(WE7111) were carried out. The data-acquisition time of a one 5kB-size waveform is about 33 ms, and 23 ms per 5 kB when eight waveforms are transferred at once [10].

3 CONTROL FOR THE 60-MEV LINAC

3.1 Computers and Networks

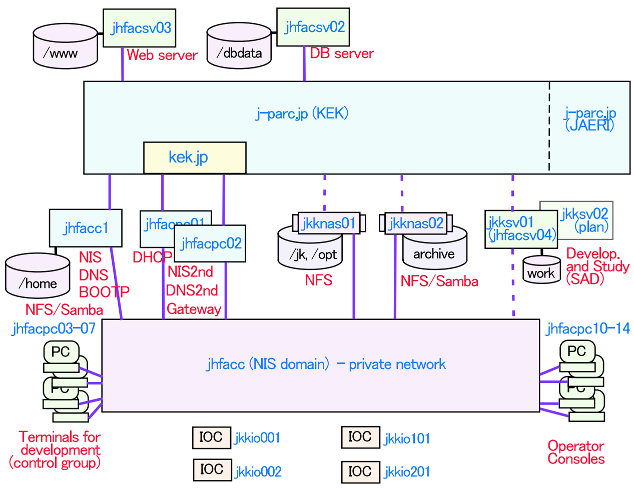

Figure 1: Computers and Networks.

The computer system is shown in Fig.1. It consists of: (a) 4 VME-bus computers (shown as IOCs in Fig.1), (b) a HP-UX server (jhfacc1) as the main development server, (c) 2 BSD-based servers (jhfacpc01,02) for supplemental functions of the main server, (d) 5 Linux-based personal computers for operator's consoles, and (e) 7 personal computers (Linux, BSD, Windows) for development.

In 2003, we introduced the following: (f) 2 NAS (network attached storage, each 180GB) systems to share program sources and archive data, and (g) a Linux server (jkksv01, now in test) for development and beam studies. These computers are connected with a private network (jhfacc) dedicated to control of the 60-MeV linac.

In addition, we have a web server (jhfacsv03) and a database server (jhfacsv02), which are connected with the laboratory network (j-parc.jp). The server computers have two networks (both private and laboratory networks). The relationships are also shown in Fig.1.

3.2 Control and Beam Commissioning

The development of a prototype control system started in 2001. The main purpose was to study and evaluate an EPICS-based control system. By the end of 2002, we succeeded to control the pre-injector part of the linac.

Due to historical reasons, the control of each linac device was developed independently by a device group. For example, the power-supplies of the MEBT (Medium-energy beam-transport) were controlled by a stand-alone PC (see 3.3). Such a situation caused problems: (a) remote operation from the central control room was unavailable, and (b) inter-communication between different devices (i.e. power-supplies and beam-monitors) was impossible. We decided to migrate such small control systems into a single EPICS-based control system.

We are now in the summer shutdown to extend the proton linac to have DTL (drift-tube linac) sections. The next commissioning will start in October, 2003. During the shutdown, we have been developing as many applications as possible to control the linac devices.

3.3 Status for each Linac Device

Pre-injector The pre-injector part (the ion-source and the pre-chopper) uses PLC's. They have been successfully controlled since 2002.

MEBT power-supply There are 13 power-supplies (hereafter PS's), each of which has a GPIB interface, controlled by a PC using LabView. In February, 2003, we changed the GPIB host from a PC to a LAN/GPIB box (Agilent E5810), the driver of which was developed in the EPICS community [12]. We then developed an application to control the MEBT PS's by using dm2k [2]. Later, we added 6 PS's with the EMB interface, but this modification was easy, since the EMB has an EPICS driver (NetDev). Fig. 2 shows the control application of the MEBT PS's.

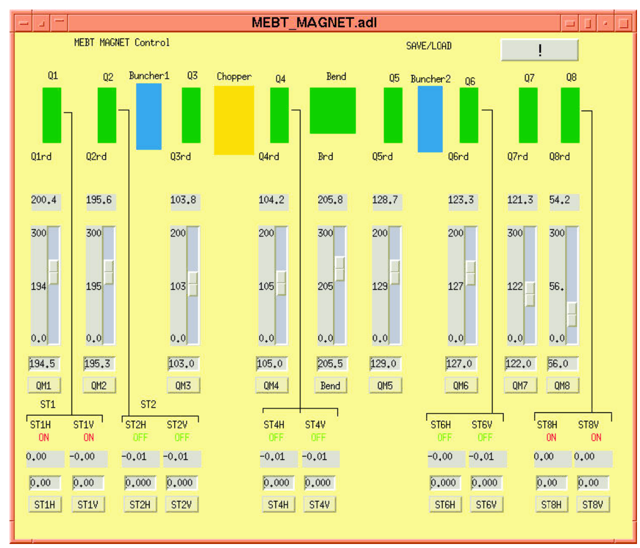

Figure 2: Control panel for the MEBT power-supplies

DTL-Q power-supply In the summer shutdown, we installed the 77 DTL-Q magnets. Each DTL-Q has a PS with an EMB interface. We developed an application, and have already used successfully it in test runs since August, 2003.

Other devices The timing system is controlled by a one PLC; 32bit-length delay values are supported. An application was developed and delay control functions have already been confirmed. The control for the RF system is under development. It uses 2 PLC's.[3] The status of the beam-monitor development is described in 3.4.

[2] A standard EPICS tool to develop graphic user interfaces.

[3] One PLC for the low-level RF, another for klystron power-supplies.

Summary In Table 2, we summarize the development status of the linac devices in September, 2003. Most of the interfaces in Table 2 will be used for the Tokai site accelerators, except for the timing system [11].

Table 2: Development status of the 60-MeV linac devices.

Device	Interface x Number	Development	EPICS database and GUI/dm2k
Ion-source	PLCx1	1999-2002	db configured ready in 2002
Pre-chopper	PLCx1	Aug. 2002	db configured ready in 2002
MEBT PS's	GPIBx13 EMBx6	Feb. 2003	db configured ready in Feb.03
DTL-Q PS's	EMBx77	Jun.-Aug. 2003	draft db test run in Aug.03
Timing	PLCx1	Apr-Aug 2003	db configured test run in Aug.03
RF	PLCx2	under develop.	under development

3.4 Status for Beam Monitors

There are four different beam-monitors: current monitor (CT), phase monitor (FCT), beam-position monitor (BPM), and wire scanner (WS) [2]. In the summer shutdown, applications for CT, FCT and BPM have been developed. We use the WE7111 modules (see 2.3) as front-end interfaces for all of these beam monitors.

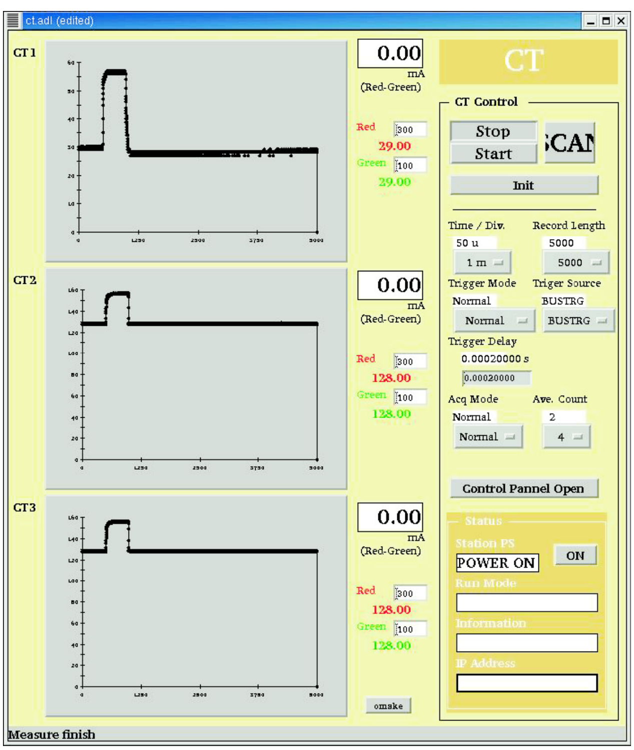

Figure 3: Observation of CT waveforms.

In February, 2003, we migrated the CT monitoring system from a PC-based system [4] to the EPICS-based control system. Fig. 3 is a screen copy of the dm2k application, which contains waveforms of three CT signals.[5] Migration makes it possible to observe beam-currents at any (and multiple) console terminal.

After various updates, the data-acquisition rates with dummy signals have been measured. The observed rates of 3 waveforms (each 5 kB) are from 6 Hz (average mode) to 10 Hz (normal mode) [10].

The development of applications for the FCT and the BPM was carried out during the summer shutdown. We will start evaluations of these applications with real beams soon during the next commissioning.

4 CONCLUSION

We have developed a prototype control system based on EPICS for the J-PARC 60-MeV proton linac. EPICS device supports for network devices (NetDev) and for the WE7000 waveform monitors have been developed.

Application development has been completed for the following devices: the ion-source, the pre-chopper, MEBT power-supplies, DTL-Q power-supplies, and the timing system. Control for the RF system is still in the development phase. The controls of these devices will soon be inspected during the next commissioning.

5 REFERENCES

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[13] http://www.yokogawa.com/html/tmc/tm/4sg_tm/tm-we7000_01.htm

[4] Visual Basic environment with commercial libraries of WE modules.

[5] The beam-currents in Fig. 3 were zero, since it is under development.