PRESENT STATUS OF THE J-PARC CONTROL SYSTEM

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Abstract

The present status of the design and construction of the control system for Japan Proton Accelerator Research Complex (J-PARC) is given. J-PARC is a 3-stage accelerator complex with a 200MeV Linac, a 3GeV Rapid Cycling Synchrotron (RCS) and a 50GeV Main Ring synchrotron (MR). The accelerators are under construction jointly by Japan Atomic Energy Research Institute (JAERI) and KEK, High Energy Accelerator Research Organization. Linac and RCS are being constructed mainly by JAERI and MR is mainly by KEK. [1,2] And the control systems for Linac and RCS [17] are constructed mainly by JAERI and that of MR is done mainly by KEK. [3]

Commissioning of Linac, RCS and MR are scheduled in September 2006, May 2007, and January 2008, respectively. There are three control systems under construction corresponding to three accelerators. These three control systems will be operated from one central control room when each control system is completed construction. We chose Experimental Physics and Industrial System (EPICS) [4] as the software environment so that three control systems can be unified easily to single control system.

J-PARC control system has the three-layer standard model architecture for accelerator controls that is very common in the EPICS world. We have chosen the standard network protocol TCP/IP and UDP/IP as the J-PARC standard field-bus used to connect interface units that links accelerator component to the control system.

Various developments on hardware and software have been done since the beginning of construction and some of them including the results of the Drift-Tube Linac (DTL) commissioning tests at KEK are also reported. [5]

INTRODUCTION

Accelerators

J-PARC accelerator complex consists of three stages of accelerators and is constructed in two phases, phase 1 and phase 2 as shown in Fig. 1. The first stage is Linac, which is composed of an ion source, Radio Frequency Quadrupole (RFQ) linac, 60MeV Drift-Tube Linac (DTL), and a 200MeV Separated-type DTL (SDTL). Energy of the Linac will be upgraded with a Super-Conducting Cavity (SCC) linac to 400MeV. Linacs can be operated at 50Hz. The second stage is a 3GeV Rapid Cycling Synchrotron (RCS) operated at 25Hz. The last stage is a 50GeV Main Ring synchrotron (MR) operated with about 3.63-second cycle time.

Extracted beam from MR will be transported to an experimental hall for nuclear and particle physics experiments. The beam from MR will also be guided to the neutrino oscillation experiments beam line aimed at Super-Kamiokande located about 300km west of J-PARC site. At the second phase of the J-PARC project, the beam from the linac will be guided to Accelerator Driven nuclear waste transmutation System (ADS) facility after accelerating up to 600MeV by using SCC linac.

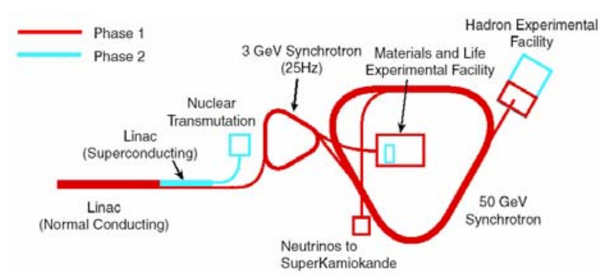

Figure 1: J-PARC accelerator complex.

J-PARC accelerators are designed to accelerate very high intensity proton beams and a slight loss may give a high radiation dose to the accelerator components such as vacuum chambers, magnets, beam monitors, cables, hoses, and etc. It makes the maintenance very hard. Therefore, we must design the control system carefully so that we can avoid such unnecessary irradiation. Our design rules are based on;

1. All the data should be taken and recorded.
2. All the operations should be monitored and recorded.
3. Design software system as it detects human errors before the operations.

The machine commissioning and operation will be done by both accelerator physicists and operators. There will be two kinds of software; one is for machine studies and the other for routine operation. The former requires flexibilities and easiness of coding, debugging and linking to various application tools. On the other hand, the latter requires strictness, simplicity of operation, and being free from software bugs.

For the first purpose, we plan to provide Structured Accelerator Design (SAD) environment [6] and python language environment. [7]

Control System Overview

The J-PARC control system is designed following so-called standard model architecture based on EPICS. The

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system consists of three layers, e.g. presentation layer, equipment control layer, and device interface layer as shown in Fig. 2.

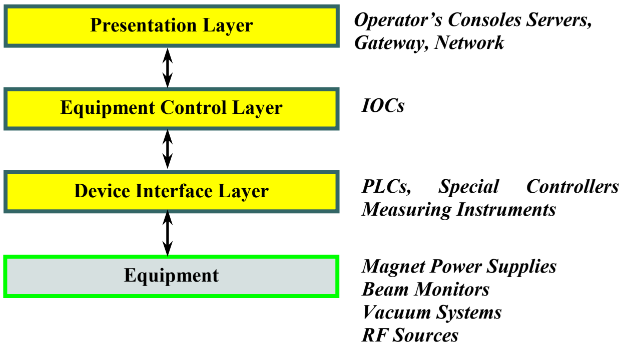

Figure 2: The standard model configuration.

At the presentation layer, server workstations and Personal Computers (PCs) will be used to make and run application programs for operations. This layer includes high-speed reliable network. The network is based on switched Gigabit Ethernet (GbE) operated in duplex mode.

At the equipment control layer, there are Input/Output Controllers (IOCs) equipped with VMEbus board-computers with VxWorks and a large number of embedded-type computers run linux or micro-iTRON (A Japanese real-time operating system for the embedded computer such as mobile phones.) as the operating systems.

At the device interface layer, we use TCP/IP protocol on the 10/100 Mbps Ethernet as the common field-bus instead of CAMAC or General Purpose Interface Bus (GPIB). We have been developing a common device driver for network devices and device support routines for various network devices [8,9]. There will be a very large number of Programmable Logic Controllers (PLCs) and intelligent equipment used in order to reduce cost and to get flexibilities in 10msec ranges. VMEbus modules will be used in order to obtain fast data acquisition and/or quick responses in 10 micro-second to milli-second range.

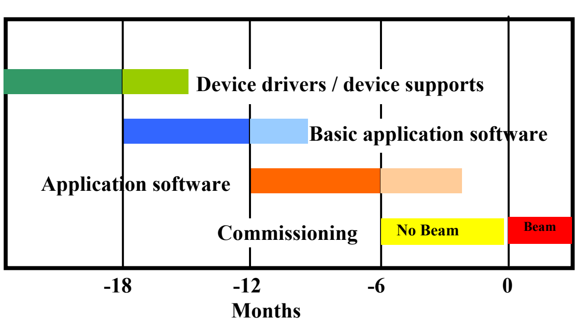

Figure 3: Software development before commissioning.

Schedule

The commissioning will start next year from linac, RCS to MR sequentially. We plan that construction of the control system for each accelerator will be completed at least 3 to 6 months before the commissioning of the accelerator and the accelerator will be first operated without beam. Taking the target date into account, we plan to finish developing fundamental hardware and software required at least 18 months before the commissioning. We plan to finish development of the basic application software 12 months before the commissioning and start developing application software for operation in the next 6 to 9 months as shown in Fig. 3.

DESIGN AND DEVELOPMENTS

Protection Systems

There are three systems that protect machines or personnel from radiation hazard or emergency situations, e.g. Machine Protection System (MPS), Beam Abort System (BAS) for MR, and Personnel Protection System (PPS) [11].

The MPS is designed to prevent linac components, especially low-energy part, from radiation damage. As stated above, J-PARC accelerators accelerates very high intensity proton beams and the beam will give high power deposit to the linac components because the energy is low enough to be stopped in them. Therefore, there is the special beam stopping mechanism. When a beam loss above certain threshold level is detected along the linac, fast signal transmission line tells the beam stopping system to stop the beam even within the pulse (see Fig. 4).

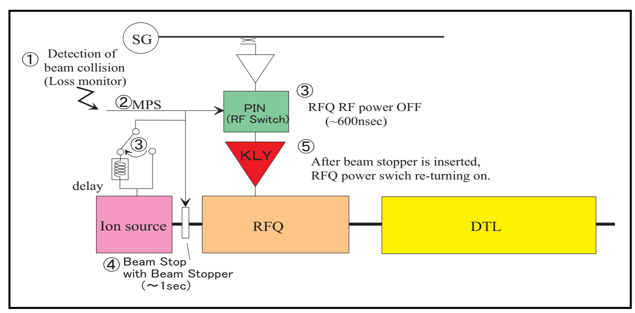

Figure 4: Schematic description of MPS.

MPS works as follows;
1: The beam loss is detected by the loss monitor.
2: Loss signal is transmitted to the RFQ part using MPS.
3: Switch off RFQ power and stop trigger signal to the ion source injection.
4: Insert beam stopper into the beam duct.
5: Then switch on RFQ power again as soon as possible for preventing RFQ from being cooled.

About the PPS, it was described in the paper before [12].

Timing System

The J-PARC timing system generates and distributes three kinds of signals [11,12]. The first one is 12MHz clock signal and second one is a 50Hz linac trigger signal. The last one is a serially encoded 32-bit "Type" signal that gives three 8-bit codes to the timing signal receivers. The receiver module selects a delay count value pointed by one the codes. A timing signal receiver works with the

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tick of 96MHz that is generated by multiplying 8 to 12MHz system clock.

J-PARC accelerators run synchronized with the 50Hz from the master clock synthesizer that gives very stable clock pulses. It makes the timing system so simple and controllable that there is no severe synchronization problem between two rings. Details are given elsewhere [11].

DTL COMMISSIONING

The injector part of the proton linac was constructed at KEK, Tsukuba. Commissioning studies of the Medium Energy Beam Transport line (MEBT) and the DTL have been carried out at KEK in 2002-2004 [14,15]. A prototype control system based on the EPICS toolkit was developed as a part of commissioning studies [5,15]. New software and hardware devices were developed and evaluated with proton beams during the commissioning periods.

EMB and DTL-Q

The EMB, a dedicated network-based controller, was developed for the DTL/SDTL-Q power-supplies. The EPICS driver, NetDev, was developed for various network devices including the EMBedded (EMB) controller [8]. In 2003, we installed the 77 DTL-Q magnets. Each DTL-Q magnet has a power-supply with an EMB controller. Control applications for the DTL-Q power-supplies were developed and used successfully in the commissioning studies of 2003-2004 [15].

WE7111 and Beam Diagnostics

We introduced a module-type measurement station, WE7000 provided by Yokogawa, as a low-cost network-based waveform monitor. The EPICS driver for a 100MS/s oscilloscope module (WE7111) was developed in 2003 [9]. There are three beam diagnostics systems: current monitor Slow Current Transformer (SCT), phase monitor Fast Current Transformer (FCT), and Beam-Position Monitor (BPM). We used the WE7111 modules as waveform monitors for all of these systems. Four WE7000 stations and 30 WE7111 modules (5 for SCT, 5 for FCT, 20 for BPM) were installed in 2004. The observed data-taking rate of synchronized 30 waveforms (each waveform size was 1,000 byte) was 5 Hz [8].

The whole system, including the Python-script applications, worked sufficiently stable in the commissioning studies.

In addition, PC-based console system was studied and demonstrated during the MEBT and the DTL commissioning studies. Detailed descriptions are given elsewhere [13].

SUMMARY

The control system for J-PARC accelerator complex is under construction. We have been developing device interface hardware and software early enough for the commissioning of accelerators. Hardware and software for the DTL were developed and tested successfully in the field demonstrating EPICS is a good toolkit. We still have much work to do before the real commissioning of J-PARC next year.

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