PROGRESS OF A CONTROL SYSTEM FOR SLOW-EXTRACTION BEAM LINES AT J-PARC

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ABSTRACT

We have developed the core part of the local control system for the slow-extraction beam lines in the Hadron Experimental hall (HD-hall) at Japan Proton Accelerator Research Complex (J-PARC). The existing system for the magnet power supplies can communicate with the accelerator control system via relational databases. The read-out electronics for beam loss monitors and profile monitors have been developed and tested in the existing beam lines at KEK 12GeV Proton Synchrotron (12GeV-PS). The VME modules to transport analog signals for real-time feedback via 3 km optical cables have been designed. The present manuscript describes the details of each subsystem.

OVERVIEW OF THE CONTROL SYSTEM

The local control system for the slow-extraction beam lines at J-PARC [1] is a part of J-PARC accelerator control [2]. The proton beams of 50 GeV-15 μA (750 kW) are extracted from 50 GeV Proton Synchrotron (50GeV-PS) for the duration of 0.7 second. Figure 1 illustrates the slow-extraction beam lines and HD-hall. The extracted beams are transported to the production target (T1) through the slow-extraction beam line in the beam-switching yard. On the T1 target, about 30 % of the beams are lost to produce the secondary beams of kaons and pions for physics experiments. The residual beams are transported to the beam dump.

The magnets on the beam lines are powered with regulated DC power supplies. The profiles and losses of the beams are continuously monitored to keep beam losses as low as possible. Temperature rise on the equipments around the T1 target and Beam dump, where large beam losses are anticipated, must be continuously monitored with thermocouples. Figure 2 shows the schematic drawing of a part of the present control system. The monitored data are managed with EPICS (Experimental Physics and Industrial Control Systems) [3] and shared with the J-PARC accelerator control group.

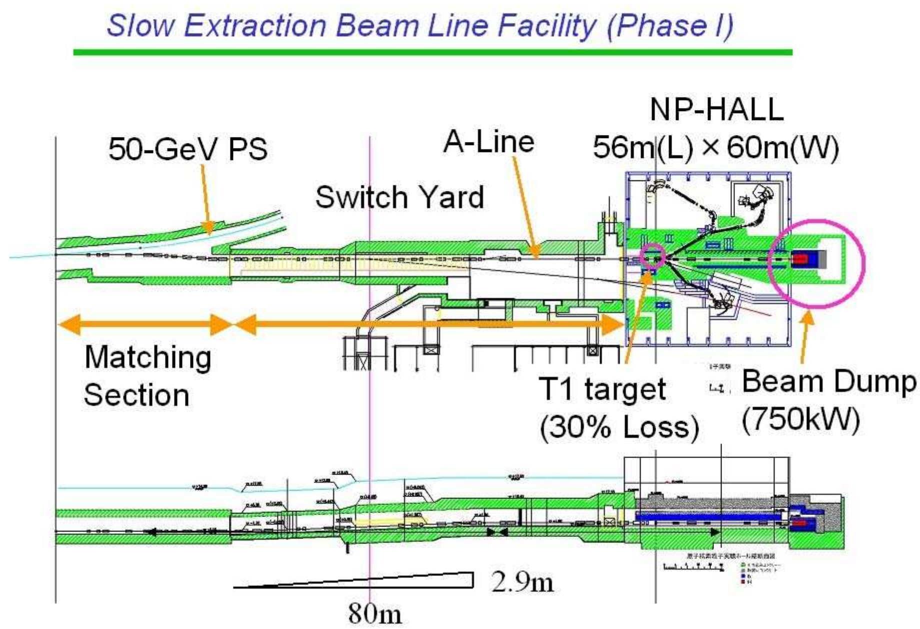

Figure 1: The slow-extraction beam lines and Hadron Experimental Hall (HD-hall)

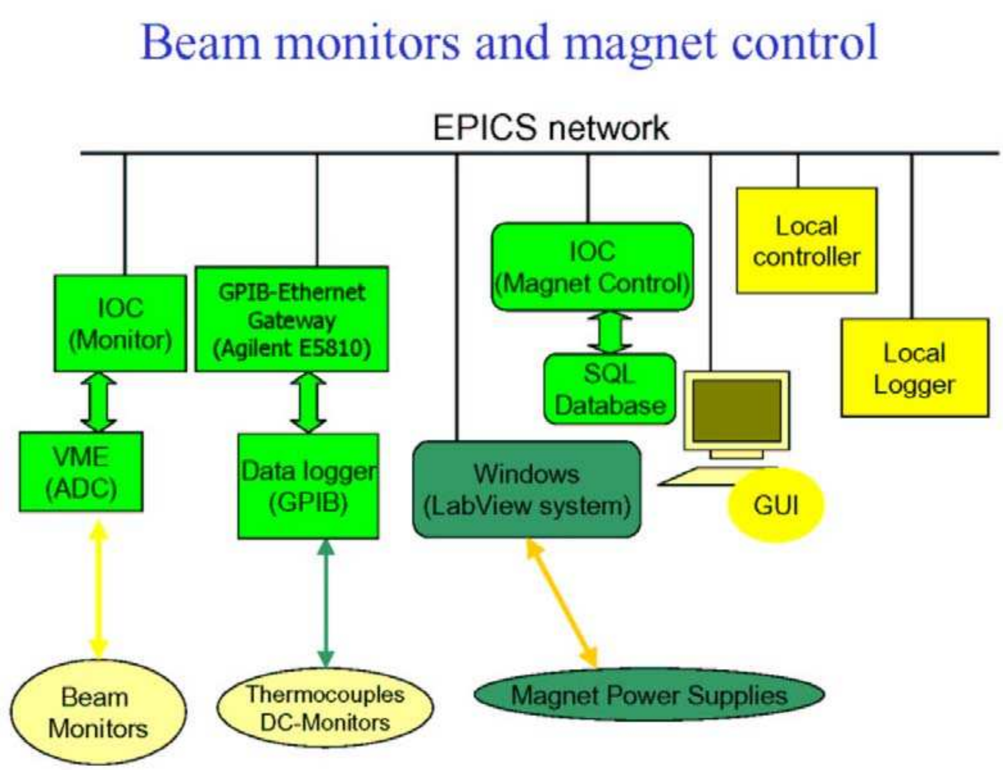

Figure 2: A schematic drawing of beam monitoring and magnet control system in HD-hall

MAGNET CONTROL SYSTEM WITH RELATIONAL DATABASES

Many of the magnets and their power supplies in the beam lines at KEK 12 GeV-PS are going to be reused at J-PARC after modifications and improvements. Thus, the existing magnet control system, which has been working stably for more than 10 years, is available without major modifications [4]. On the other hand, it is necessary for the magnet control system to communicate with J-PARC accelerator control via EPICS. Therefore, we have chosen relational databases as interface between the existing system and EPICS.

Figure 3 shows a schematic drawing of the magnet control system. The relational databases (MySQL-4.0) that represent the status of each magnet (current, voltage, polarity, and alarm information) are prepared on a Linux-PC server (Xeon 3.2 GHz with 2 GB memory, Kernel-2.4.22, and gcc-3.2.3). The existing magnet control system, which is based on Windows-LabView, can access to the magnet databases with Microsoft Open Database Connectivity (MS-ODBC). Figure 4 shows the benchmark of MySQL database with the table of 100 columns via C-language API (Application Program Interface). Considering the maximum number of the beam line magnets is 200, MySQL databases shows sufficient performance at 1 Hz access speed.

The special EPICS record (Magnet Record) has been developed to access to the magnet databases with EPICS Channel Access (CA) protocols. Magnet Record represents a set of data for a magnet power supply (set current, current read-out, voltage read-out, polarity, and status information). Each data of a magnet is assigned to a field value of Magnet Record, although the conventional waveform record cannot define different type values in a record. Users can access to the magnet data by writing record databases of EPICS channel in the conventional manner. Magnet Record has been implemented on the asynchronous driver [5] to prevent hang-up of Input-Output controller when network connection becomes unstable. Long-term stability has been tested with a sample database and the system had been working stably for more than half year without troubles.

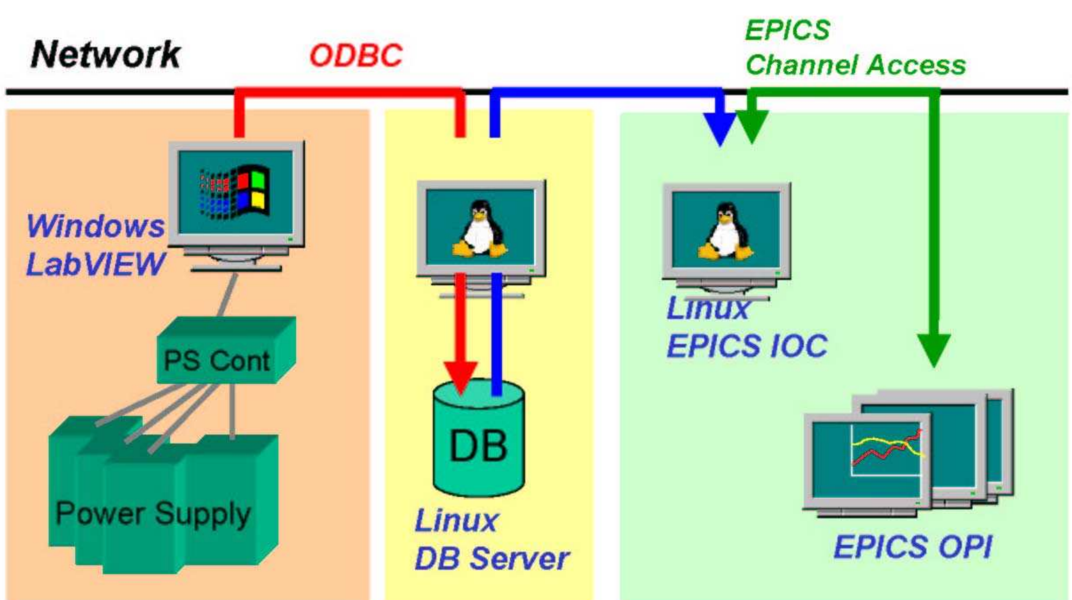

Figure 3: Magnet Power supply control system with relational databases

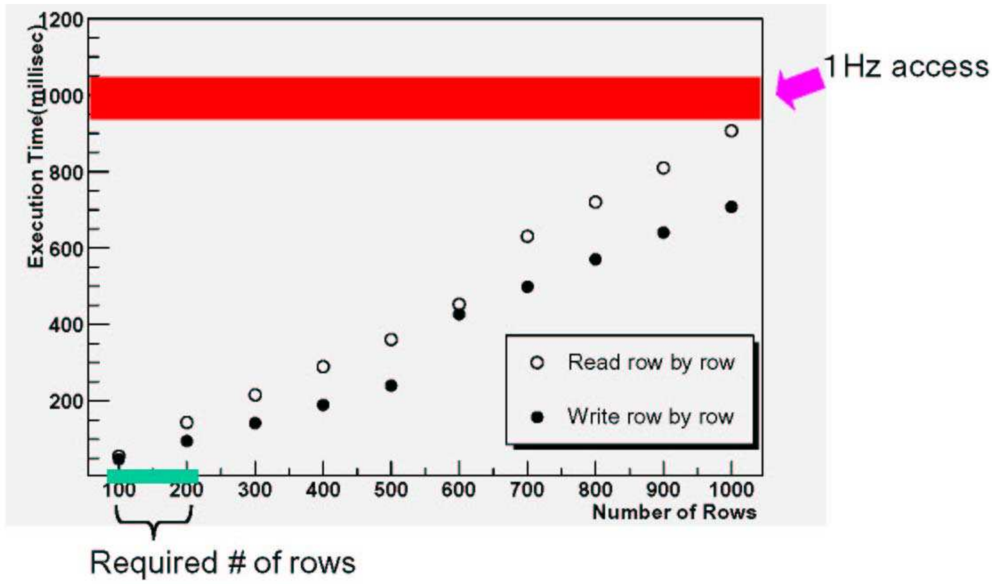

Figure 4: Benchmark of MySQL database (100 columns) with C-API

BEAM MONITORS AND READ-OUT ELECTRONICS

The beam permit system at J-PARC is comprised of Machine Protection System (MPS) for equipment protections and Personnel Protection System (PPS) for access control, radiation safety, and operation modes. MPS is not implemented in the HD-hall beam lines, but the signals generated by the beam loss monitors are transferred to the accelerator control and used for aborting beams to the local dump in 50 GeV-PS when large loss of beams occurs.

The radiations caused by losses of beams are detected with Air-filled Ionization Chambers (AIC) [6] mounted on the beam ducts. Typically two AICs will be installed at the same place to make the system redundant. The charge produced by ionizations are collected and integrated over during the beam extraction (typically ~ 1 sec.) with the current integrator (CI) modules on standard VME crates. The 16-ch CI modules, which have been developed with KEK electronics group, can be chosen from the dynamic range of 0.4, 4.0, 40, and 400 nC input signals, which correspond to DC 5 V output signals at maximum. Typical resolution of the CI modules is about 8-9 bit.

The output voltage signals of the CI modules are connected parallel to the A/D converter for digitising and the interlock modules for the beam permit system. We have chosen the 64-ch scanning A/D converter (Advanet advme2607), which has DC 5 V dynamic range with 12-bit resolution and scanning time of 64 μsec per channel [7].

The interlock modules to make the signals for aborting beams have been implemented on standard VME board. The threshold voltage for 32-ch input signals can be adjusted on the front panel and via standard VME bus commands. When the input signals exceed over the threshold level during the gated period (typically 1 second), the output TTL signals are generated for aborting beams.

The signals of beam profile monitors are also processed with the CI modules and scanning A/D converter.

SPILL MONITORING AND SIGNAL TRANSPORTER

The slow-extraction of proton beams from the 50 GeV-PS requires the real-time feedback signal that reflects the time-structure of the extracted beams. At KEK 12 GeV-PS, the signals of scintillation counters in the secondary beam lines are transported from the experimental facility to the accelerator control room with standard coaxial cables of about 300 m length. At J-PARC, however, standard coaxial cables are not realistic because the distance between HD-hall and the accelerator control room is about 3 km. The required specifications of the feedback signals are the sampling rate of 100 k sample / sec and over 10 kHz frequency. To fulfil the requirements, we have designed a signal transport modules that can digitise analog signals and transport through optical cables.

Figure 5 shows a schematic drawing of signal transport modules. The optical signal transmitter module with 65 MHz sample ADC is located in the local control room. The optical receiver module with digital-to-analog converter is located in the accelerator control room. The transmitter and receiver modules are implemented on standard VME-6U board which works on KEK-VME crate [8]. Design of transport modules is completed.

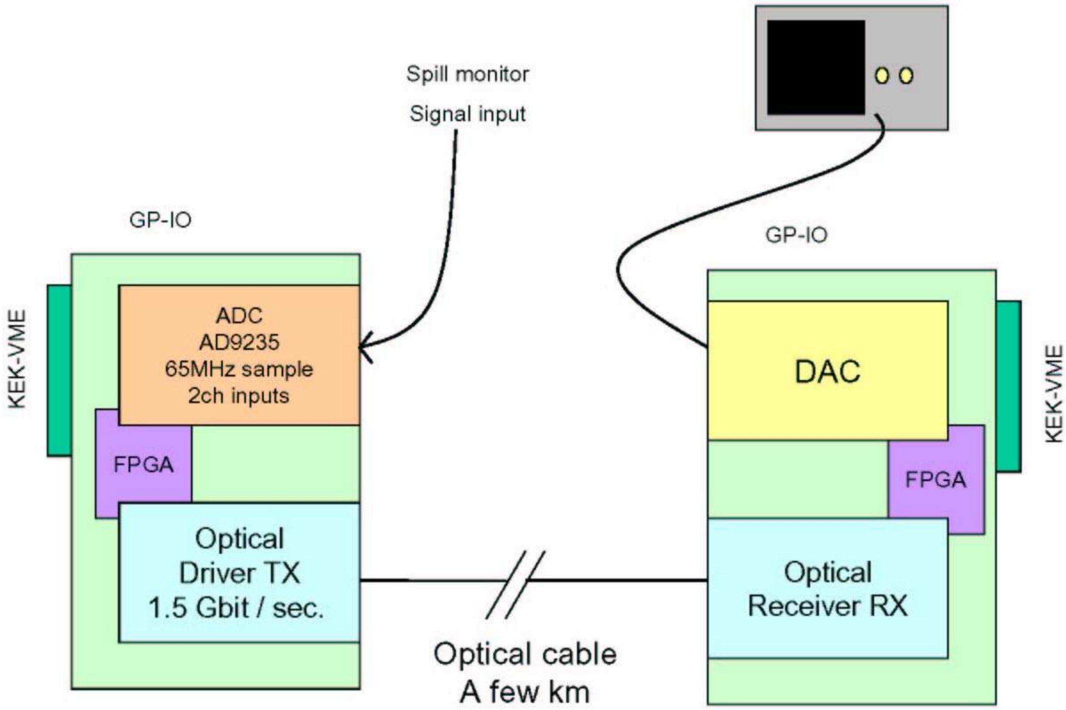

Figure 5: A schematic drawing of analog-to-optical signal transporter

TEMPERATURE MONITOR AND EPICS APPLICATIONS

At HD-hall, the large beam loss occurs on T1 target (30%) and beam dump (100%). Temperature rise must be monitored with thermocouples mounted on the equipments that the large heat deposit is anticipated. The signal cables from the thermocouples are connected to the 60-ch scanning module (Agilent 34970). The scanning module can be controlled with the standard GP-IB connection. We have chosen the Ethernet-GPIB Gateway module (Agilent E5810A) to control GP-IB modules with EPICS via Ethernet network. The EPICS device support for Agilent E5810A is commonly available and the asynchronous driver described above works without troubles. The detailed descriptions about the present monitor and EPICS applications can be found in ref. [9].

SUMMARY

The magnet control system using MySQL databases and the Magnet Record have been working without troubles. The electronics modules for beam loss monitors and profile monitors have been developed and tested at KEK 12 GeV-PS. The analog-to-optical signal tranport modules have been designed and will be tested in near future. Temperature monitors and their application with EPICS have been tested and show good performances.

The important items of the local control system at HD-hall are ready for the real construction at J-PARC site.

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