The EPICS-based remote control system for muon beam line devices at J-PARC MUSE

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Abstract. The remote control system for muon beam line devices of J-PARC MUSE has been developed with the Experimental Physics and Industrial Control System (EPICS). The EPICS input/output controller was installed in standard Linux PCs for slow control of the devices. Power supplies for 21 magnetic elements and four slit controllers for the decay-surface muon beam line in the Materials and Life Science Experimental Facility are now accessible via Ethernet from a graphical user interface which has been composed using the Motif Editor and Display Manger.

1. Introduction

The MUon Science Establishment (MUSE) is located at the Materials and Life Science Experimental Facility (MLF) at J-PARC in Tokai, Japan [1]. A high intensity proton beam is incident on a graphite muon production target [2] in order to produce muons that are captured by four independent secondary beam lines. These include the decay-surface muon beam line, the surface muon beam line, the Super-Omega muon beam line [3], and the high momentum muon beam line. The first beam line to be completed was the decay-surface muon beam line, where the first muon beam has successfully been delivered on September, 2008.

The decay-surface muon beam line captures both surface and decay muons and transports them into experimental area No.2, where the beam line splits into the D1 and D2 channels. The beam line consists of three bending magnets, 18 quadrupole magnets, four slits, a DC separator, a superconducting solenoid, and a beam slicer for the D1 channel [4]. A septum magnet and beam kicker will be installed at the branch point of the D1 and D2 channels in the future for simultaneous operation. Of the 21 magnetic elements currently available, quadrupoles DQ1 through DQ9 are common to both channels, while quadrupoles DQ10 through DQ12 and DQ16 through DQ18 provide beam to the D1 channel, and quadrupoles DQ13 through DQ15 transport the beam into the D2 channel.

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Among the beam line elements, the bending magnets, the quadrupole magnets, and the slits are integrated into a common control system. This system can broadly be separated into three categories. They include functions that are performed at the hardware level, processes that are hard-wired into the Programmable Logic Controller (PLC) equipped in each controlled device, and those that are controlled directly by the human machine interface (HMI). In this paper, we focus on the HMI for remote control of the decay-surface muon beam line devices using the Experimental Physics and Industrial Control System (EPICS).

2. EPICS-based remote control system for decay-surface muon beam line devices

2.1. Programmable Logic Controller
The power supplies (PS) for the beam line magnets are located in the power supply yard inside the experimental area No. 2. They can be operated locally using a local control panel available on each power supply, or remotely via Ethernet. Each power supply is equipped with its own PLC with an Ethernet port (FA-M3R, Yokogawa Denki Corp.) and is integrated into a closed control system network available at MLF. The power supply hardware is parameterized through the PLC hardware registry. The variables defined in the registry can then be used to program, via ladder logic, to provide functions such as switches, set points, and interlocks.

The four slits are powered and governed by two controllers with own PLCs. The slit controller for three slits, DSL2, DSL3-1, and DSL3-2, is equipped with a PLC with a serial communication port (KV-3000, Keyence Corp.) while the other one for DSL4 is controlled by a PLC with an Ethernet port (KV-5000, Keyence Corp.). The four slits can be operated locally using local touch-screens, or remotely via RS-232C or Ethernet.

2.2. Experimental Physics and Industrial Control System
The EPICS is a set of Open Source software tools, libraries, and applications to create distributed soft control systems for large scientific experiments [5]. Developed at Argonne National Laboratory, the EPICS is used extensively for real-time and slow control of accelerator devices. At MUSE, the EPICS is used for the slow control of the beam line devices via the PLC. The EPICS software framework was installed in standard Linux PCs, including a Channel Access (CA) client and the Input/Output Controller (IOC) to serve as a server that communicates with the PLC and publish the information to the CA client using the CA network protocol. A graphical user interface (GUI) was composed using the Motif Editor and Display Manager (MEDM) [6], allowing users easily to access the PLCs via EPICS.

2.3. EPICS-based remote control system on MLF control system network
The EPICS-based remote control system for the decay-surface muon beam line devices is modeled after that of the accelerator EPICS control system. A schematic drawing of this system is shown in Fig. 1. Two Linux PCs are currently used as platforms for the EPICS-IOCs which communicate with the PLCs via Ethernet on the closed control system network or RS-232C. The EPICS-IOC for the magnet PSs was installed on Red Hat Enterprise Linux running on the PC1, communicating with the FA-M3R via Ethernet. A device support for the FA-M3R was developed at Japan Atomic Energy Research Institute (JAERI) and Japan Atomic Energy Agency (JAEA). Relations between the PS functions mapped into the PLC registry and EPICS records were defined in EPICS database.

The EPICS-IOCs for controlling the slits were installed on Debian GNU/Linux running on the PC2. A device support for the KV-3000 connected with the PC2 via RS-232C was developed on the top of a serial communication support of asynDriver [7]. On the other hand, netDev [8] including a device support for Keyence PLCs was used for construction of the EPICS-IOC communicating with the KV-5000 via Ethernet.
Fig. 1: A schematic drawing of the EPICS-based remote control system for the decay-surface muon beam line devices.

Fig. 2: A screenshot of the status monitor. The status of PS for a longitudinal coil installed to a $\mu$SR spectrometer at the D1 port is displayed in addition to that for the decay-surface muon beam line magnets.
The GUI for monitoring and changing device status via EPICS was also installed on the PC1. A screenshot of a status monitor is shown in Fig. 2. The magnet PS status (main power, control power, current output, polarity, current set point, current monitored, voltage monitored), the positions of the slits, and the proton beam intensity are displayed on the status monitor and updated typically every one second. Since our system and the accelerator EPICS control system are connected to the MLF control system network, the proton beam intensity can be monitored at MUSE.

This panel also works as a launcher of control panels for each beam line component and built-in functions written in perl, such as save/load of particular beam line tunes. Features are added such that it is possible to change the PS currents of group of magnets from a pre-set reference value in order to facilitate beam line tuning. This feature allows the user to scale the currents of all beam line magnets from their present value to match the tune to a different momentum.

Typical examples of the control panel for the magnet PS and the slit are shown in Fig.3. The users can control the on/off switch, current set point and ramp switch, polarity switch, and interlock reset switch of the magnet PS, and the move/stop switch and set point of the slit position from these panels. The control panel for the magnet PS allows for continuous monitoring of interlock and warning status as well.

In addition to local alarms that are available on the magnet PSs, the Alarm Handler is equipped in the remote control system. When the interlock is triggered, the Alarm Handler is designed to issue audible warnings from the PC1. Furthermore, the Alarm Handler will issue warnings when the network connection between the PC1 and any of the PLC is severed for more than a predetermined period of time.

Values of the EPICS records are logged by the Channel Archiver [9] installed in the PC1. The logged variables, such as the output current, the slit positions, and the proton beam intensity, can be displayed as functions of time using a data visualization software written in Java included in a package of the Channel Archiver.

3. Summary
We developed the EPICS-based remote control system for the decay-surface muon beam line devices at J-PARC MUSE. The EPICS-IOCs and the MEDM-based GUI were installed in standard Linux PCs on the MLF control system network for slow control of the magnet PSs with FA-M3R and the slit controllers with KV-3000/5000. The device support for FA-M3R developed at JAERI/JAEA, asynDriver, and netDev were used for construction of the EPICS-IOCs. Major functions of the magnet PSs and the slits are accessible from the GUI via Ethernet.
References

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