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UPGRADE OF THE ISIS MUON FRONT END MAGNETS: OLD AND NEW INSTRUMENT CONTROL SYSTEMS WORKING IN HARMONY

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Abstract

When the European Muon beamlines at the ISIS pulsed neutron and muon source [1] upgraded their front end magnets, it was desired that these new magnets should be controllable remotely. This work was undertaken by the team responsible for instrument control, who are in the process of a phased upgrade of instrument control software from a locally developed system (SECI) to an EPICS [2] based one (IBEX [3,4]). To increase the complexity of the task, parts of the front end needed to be controlled only by an individual instrument beamline, whilst some values needed to be tuned to the best compromise available for all three beamlines. Furthermore, the muon instruments were not ready for an upgrade to a full IBEX system at that time. By combining SECI, IBEX and the Mantid [5] data reduction package the required control and tuning has been achieved. This paper will give details of the challenges, the topology of the solution, how the current mixed system is performing, and what will be changed when the muon instruments are converted to IBEX.

BACKGROUND

The Muon beamlines at ISIS have been taking data for the last 30 years. During that time a number of upgrades have been made to the instrument [6]. In 2014 it was proposed to further develop the primary beamline, also known as the front end, in order to improve the performance of the beamlines and to replace aging components [7].

As well as these hardware changes it was decided to provide remote control capabilities for the beamline, which could allow tuning to be undertaken from a computer in a fraction of the time it takes to set the values by hand. There would also be a significant increase in the efficiency made by comparing the received rate of muons across all three instruments for different tunings. This comparison would need to be undertaken using the detector data from each of the three instruments, MuSR [8], EMu [9] and HiFi [10], which meant that this control was treated as beamline rather than accelerator control, and so the work was undertaken by the instrument computing controls team.

This team was in the process of developing IBEX, a new control system based on EPICS. The inherently distributed nature of EPICS meant that IBEX was the obvious choice for supplying this functionality. These muon instruments were not scheduled for conversion to IBEX at this time, and as such work needed to be undertaken to combine the new IBEX system and the existing SECI system which is heavily reliant on LabVIEW [11].

CHALLENGES

As well as the obvious challenge of combining of two control systems, there were a few other factors to consider.

The beamline consists of magnets controlled by 25 power supply units (PSUs), from 2 different manufacturers, using 4 different models and using various communication protocols and command sets.

Within those PSUs some were to be controlled for tuning across all three beamlines, whereas others belong to a single beamline. Some are to be settable only at the start of an ISIS cycle, others can be altered during the cycle.

At ISIS, the standard approach to any device, or item of sample environment equipment is to take the values currently set in the device as the preferred value when a software connection is made. However, there was a requirement with these PSUs to ensure that they start up with a set of known values, which meant taking the value stored in the computer as the preferred value.

There was also motion control to integrate into this front end, via a controller which is already shared between the three instruments.

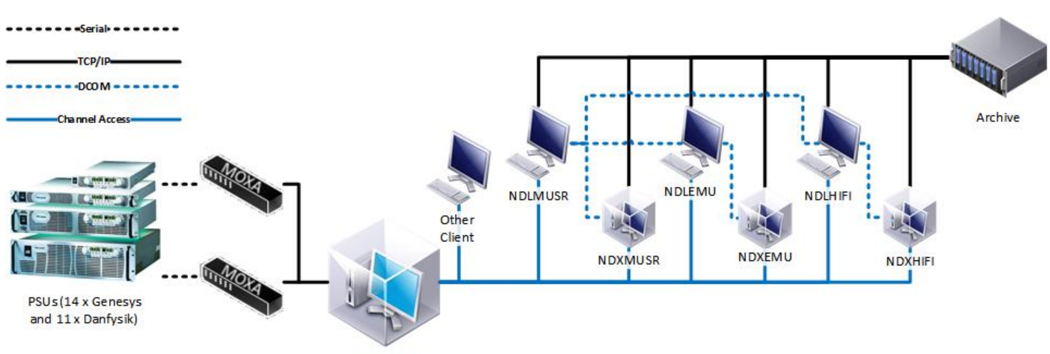

Figure 1: Hardware and computer overview of the muon front end system.

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TOPOLOGY OF THE SOLUTION

There are two layers of topology to consider, each of which places limitations on how the solution can be enacted. An overview of these topologies follows.

The first of these is the hardware and computer layer (see Fig. 1). In order to simplify system recovery, each instrument is controlled by a Virtual Machine (VM), the NDX named systems in the figure, which are accessed via a remote desktop connection from another system. The use of a VM was continued for the new front end system, and one was created that is hosted on a Windows Hyper-V cluster, NDEMUONFE. The NDL named systems are used for analysis of the data collected, and in one case at the moment for undertaking the tuning.

Due to the use of VMs, a large amount of the control for devices such as PSUs, or other sample environment equipment, requires an indirect communications method. Typically this is via ‘something over Ethernet’. In the case of the PSUs for the front end this is serial over Ethernet, and is provided by Moxa [12] 5650 models in order to facilitate both the RS232 and RS422 serial protocols which are used by the PSUs.

The second area of topology to consider is the software layers (see Fig 2.).

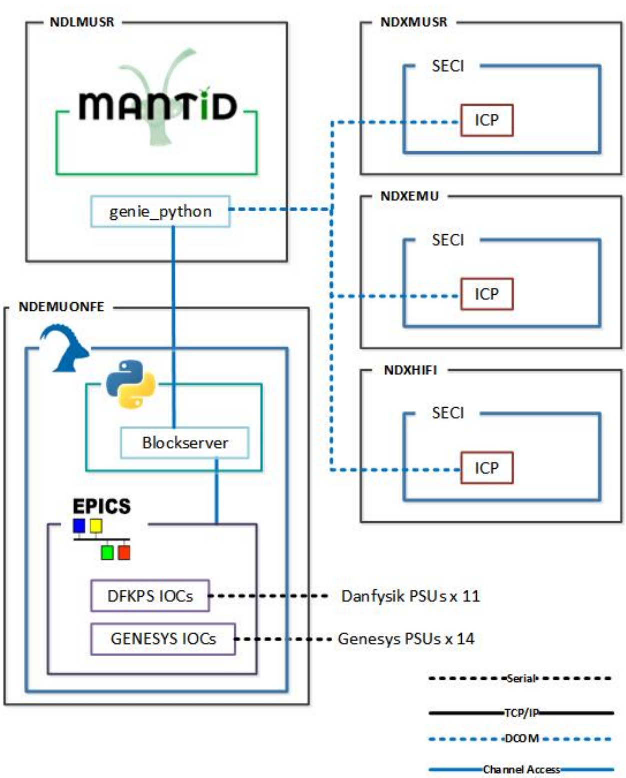

Figure 2: Software overview of the muon front end system.

The software overview also highlights which programs are being run on which of the computer systems.

The ICP referred to in Fig. 2 is the original ISIS Instrument Control Program, which controls and interacts with the Data Acquisition Electronics (DAE) developed for use at the facility.

genie_python is a Python [13] library developed in-house which contains commands to aid in the automation of experiments. In order to streamline the process, the python-aware Mantid instance on one of the NDL systems loads the genie_python library to provide instrument control alongside the analysis.

The Blockserver is a Python program which is a core component of the IBEX server. It provides, amongst other things, a naming service, allowing users to define their own names (conventionally known as blocks at ISIS). This and the EPICS Input/Output Controllers (IOCs) are run on the IBEX server computer.

A block is typically focussed on experiment information with a descriptive name here related to location and purpose. This means that the setting of a current is achieved by interacting with, for example “UQ6_CURR”, so that the concept becomes the more meaningful setting of the value by functional concept, rather than the Process Variable (PV) name which as a standard at ISIS is identified by device type. A PV like a block is the name given to a relevant piece of information, but is associated with the control and interaction of a device beyond what is called for by the experiment.

Not listed in the figure is use of the EPICS gateway [14]. Whilst the main purpose of the gateway is to ease distribution of PVs, it also provides a layer of extra security. This security layer is leveraged in this solution to provide access to the beamline specific magnets to only that beamline in order to minimise the risk of a miscommunication.

During the normal running of a muon instrument there is a desire to monitor the front end magnets, and to control instrument specific ones. The muon instruments are not yet ready to run IBEX, therefore, this has to be undertaken in LabVIEW for the information to be made available to SECI; the PVs from the front end are made available to SECI via CA Lab [15].

THE TUNING PROCESS

Initial State

On starting the IBEX server the Blockserver loads a configuration, which specifies the IOCs to start and the names of the blocks associated with the functionality.

The IOCs interact with the hardware, reading in the status of the PSUs, such as the current and voltage that they are outputting, and sending new setpoints, or turning the PSU on or off. At startup the IOCs will read back the previous values, and if specified previously will then re-apply the original setpoints.

Each of the instrument SECI systems needs to be started ready to take data, and set beamline parameters such as temperature in order to gain a useful measurement.

Mantid needs to be started and genie_python loaded. This is then the computer that has control over the system.

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Taking Measurements - Simplified

Within a python script in Mantid, each PSU is set to a specific current value via the blocks, which are mapper to real process variable names via EPICS gateway aliases.

The IOC hosting the real PV then writes the value to the PSU via a serial connection. The device then actions the value to set, and starts ramping to that value.

Once the magnets have reached the requested value, the python script in Mantid will send a command via DCOM [16] to the Instrument computers in order to begin a run on each of them and gather information on the rate of the muons received with the given configuration. Typically this command is set to wait until a specified number of frames are returned to give an adequate amount of data to compare.

Once the runs have finished, the script will load the files generated, and analyse them. The simplest measurement used is the mean count rate, but there is also the capability to fit the data to a model function and tabulate the parameters, allowing for such comparisons as asymmetry versus the magnet settings. The table, which is a standard Mantid table, also contains the run numbers, allowing for the data to be re-analysed. By using this type of table all of the plotting commands in Mantid are available to be used with this data.

An example of an analysis plot is shown in Fig. 3.

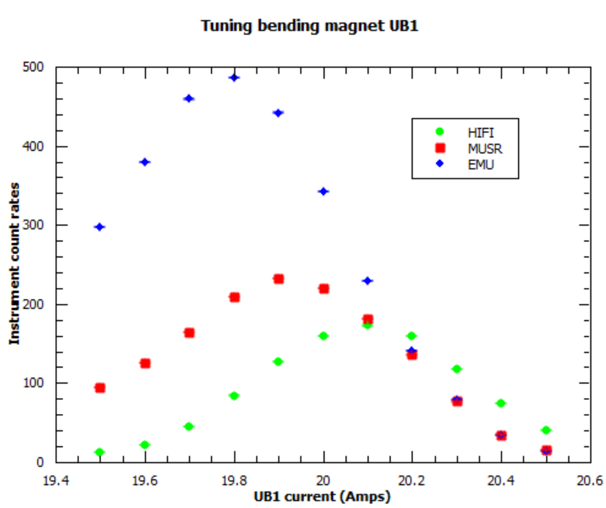

Figure 3: The rate of muons collected vs. the settings of a magnet.

This set of tests is run against each magnet so that the values that give the best rate across all three beamlines can be ascertained.

There is also a camera on HIFI, which is used in a basic form at the moment. This camera is separate to the main system, but images taken from the camera during the run time can also be stored alongside the other data in the table. These images can be analysed, giving beam spot size, position and intensity, and this information is recorded alongside everything else in the table.

The script is packaged as a Mantid Algorithm, and a scan such as the one in Fig. 3 would take 10-20 minutes, after which the scientist will choose the best tuned value, set it, and move on to the next parameter. It is possible for a higher level script to be written which can run several of these scans overnight.

FUTURE CHANGES

On Conversion of the Muon Instruments to IBEX

As the instruments are converted to IBEX significant changes to the python script, and to the interactions between the systems will be required. Running IBEX it will be possible to use channel access between the Mantid system and the DAE control systems, eliminating the need for DCOM communications.

Another consequence will be the need to carefully manage the security access to the various settable items, but with the benefit of greater flexibility as to which computer is running the tests.

The setting of the beamline specific magnets would also be undertaken more natively, and the inclusion of LabVIEW and CA Lab will no longer be necessary.

Planned Changes

There are still some PSUs to be replaced, which will increase the number of different models from 4 to 5, and will add some extra Ethernet lines to the topology.

There are 4 slit sets involved in these beamlines, one as part of the shared system, and one on each of the instrument beamlines. These are all controlled via one motion controller, with a firewall providing routing for TCP/IP connections for each item. The aim is to use only the front end system to interact with that controller, and as with the beamline specific magnets, provide access to control the slits via distributed PVs. At the moment, each system, including the front end for the shared slit set, all communicate with the controller individually.

There are other controllable items in the front end, that at the moment are neither monitored nor controllable from a remote location or automatically changeable. Consideration is being made to integrate these in as well, as whilst control is usually manageable, error and fault status reporting and monitoring from remote systems is desirable.

In order to limit the reliance on the network it is hoped that we will be able to move the front end computer system into a similar setup, with a dedicated host in the vicinity of the hardware, as is standard for our instrument machines.

RIKEN Beamlines

As well as MuSR, EMu and HiFi there are muon beamlines maintained by RIKEN [17] at ISIS, and work has started to provide similar functionality for their shared PSUs

CONCLUSION

The time taken to tune the beamline has now been significantly reduced. Rather than having one person stood by

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the PSUs pushing buttons and having to communicate the completion of ramps by phone to someone else with control of the instruments to undertake the data collection; one person can write a script which can run overnight.

Monitoring of these PSUs, and in time other aspects of the front end system, will also lead to less lost time when there are issues with them. Previously this had to be checked in person, usually based on experimental runs that were either empty, or had very atypical results.

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