UPGRADE OF THE CLS ACCELERATOR CONTROL AND INSTRUMENTATION SYSTEMS*

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Abstract

The Canadian Light Source is undertaking a major upgrade to its accelerator system in preparation for the eventual migration to top-up and to meet the increasing demanding needs of its synchrotron user community. These upgrades on the Linac include the development of software for new modulators, RF sections, power supplies and current monitors. On the booster ring the upgrades include the development of new improved BPM instrumentation and improved diagnostics on the extracted beam. For the storage ring these upgrades include fast orbit correct, instrumentation for use by the safety systems and a new transverse feedback system.

CLS ACCELERATOR

The CLS linear accelerator was originally constructed in 1964, with major upgrades and enhancements in the 1980s and again in 1999 when the machine was repurposed as an injector for the new synchrotron. The booster ring, storage ring and first round of synchrotron beamlines were constructed and commissioned between 1999 and 2003. The 1999 upgrade included replacing all of pre-existing CAMAC equipment with VME and the adoption of EPICS. The only legacy control equipment after 1999 was hard-wired electronics and Modicon Micro84 PLC.

In order to effectively offer top-up operation a series of upgrades focused on machine reliability, availability and reproducibility are currently under way.

Currently under construction at the CLS is a second linear accelerator designed to demonstrate the feasibility of producing Molybdenum^{99} using a particle accelerator. This accelerator is a standalone machine not integrated into the main accelerator control system.

COMMON ELEMENTS

Architecture

As shown in Figure 1, CLS utilises an EPICS based control system using EPICS Channel Access as the primary enterprise data-bus.

EPICS is utilised at the lower layer. High level accelerator control screens have been developed using EDM. The Matlab - Accelerator Tool Box is used for high-level on-line physics applications.

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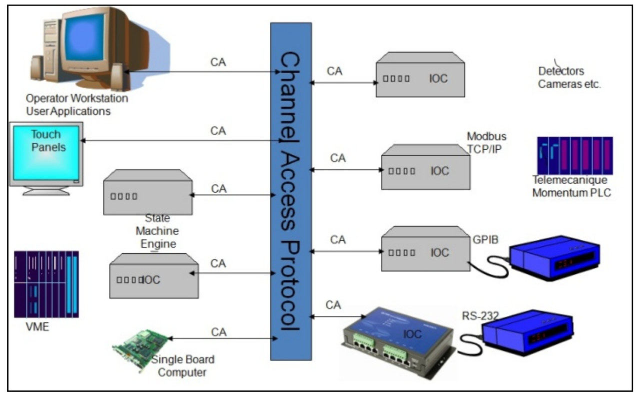

Figure 1: Architecture.

We find the use of the Moxa MIPS based controllers (Model UC-7408-LX and DA-662-16-LX) compelling [3]. Over the past four years CLS has deployed 120 Moxa computers in the facility and has yet to experience any significant hardware failure. The Moxas are used as full fledged EPICS IOCs primarily interfacing Ethernet, USB and Serial devices into the control system.

Increasing we are seeing a series of network aware Ethernet based devices being integrated into the control system.

Modicon Momentum PLCs continue to be used primarily for machine protection. These are interfaced into the CLS control system through Modbus over TCP/IP. Siemens S7/300 and S7/400 are used in the cryogenics plant, Booster Ring RF and Storage Ring RF Systems.

VME64x is primarily used for motion control and data acquisition applications. The Prodex MaxV is used with a combination of drivers [1]. Data acquisition is primarily accomplished with the use of SIS3820 scalar boards.

Some preliminary development work is occurring on the use of microTCA equipment, primarily focused on beamline data acquisition.

Alarm Handler

CLS has completed the transition from a locally developed legacy alarm handler to using the SNS BEAST[2] alarm handler. BEAST is built on top of the Control System Studio Toolkit [3]. The CLS deployment uses mySQL as the relational database for alarm storage.

Working closely with accelerator operations staff a strategy was adopted to limit alarms to those process variables that require action to be taken by operational staff.

CNSC regulatory requirements dictated that a proper human factors engineering review be performed using relevant sections of NREG-0700. Based on careful review we were able to demonstrate compliance [4].

Currently under development is a second deployment of BEST targeting mechanical maintenance staff. These alarms would be restricted to process variable alarms that would indicate the need for preventative maintenance to occur.

The alarm handler is supplemented with a series of auto-diallers that are triggered based on certain critical process variables.

Electronic Logbook

After many years of relying on paper based log-books, CLS in the past year has started to introduce an electronic logbook based on the TRIUMF electronic log book system.

The electronic logbook system is currently operated in parallel and redundantly with the paper based logbook.

Save and Restore

CLS utilises a locally developed Save-Restore application. Originally driven by the need to support diskless IOCs, the CLS Save and Restore is a server based application that also permits accelerator operations staff to take and restore machine snap-shots of the accelerator configuration.

Radiation Monitoring

CLS has used the Canberra ADM606M radiation monitors for nearly eight years. The local indicators (horns and lights) were found to be inadequate given background noise in close proximity to the monitors. As a result of a human factors assessment of the monitors it was determined that the following two upgrades were required: (1) local annunciation needed to be augmented with the use of additional strobes and horns and (2) the control room interface needed to be upgraded based on human factors engineering standards [5].

An improved local annunciation system was developed and deployed. Data from the ADM monitors is obtained by EPICS running on Moxa UC7408 computers.

LINAC

The Linac is the oldest accelerator at CLS, originally constructed for nuclear physics experiment the Linac was repurposed in 1999 as an injector for the synchrotron facility. The machine has performed well over the past ten years, however given its age and the transition to top-up it is now necessary to upgrade the accelerator.

Linac ACIS System

CLS has used the Siemens S7/400 F PLC platform in the design of lockup systems for many years. However the Linac hall was the last remaining hall/tunnel to still make use of an older Modicon Micro84 based system. In October of 2009 CLS replaced the last remaining Modicon Micro84 system with a Siemens S7/400 system [6]. The system design is based on the requirements of IEC 61508.

The As-Low-As-Reasonably-Practical (ALARP) hazard and risk analysis technique was applied to the design of this system.

Linac Modulators

Work is ongoing in the replacement of end of life components on the linac, including linac sections, the gun, and modulators. New modulators were installed in April of 2011 with the installation of new sections expected in 2012.In the modulator upgrade, 6 old PFN type modulators were replaced with 6 solid state modulators from ScandiNova. Each modulator has 30 solid state IGBT's which discharge at 1170V and fire directly to a "split core" pulse transformer. The klystron pulse voltage is 250 KV, pulse current 250A, pulse width is 4 µs, and the pulse power is 62.5 MW.

Two MOXA DA662 computers are used for modulator monitor and control. Each computer communicates with 3 modulators using ScandiNova TCP/IP protocol, which is a variant of TCP/IP. StreamDevice is used for EPICS device support. The driver is based on an EPICS driver developed by PSI/Swiss Light Source.

A Modicon Momentum PLC is used to monitor vacuum and water status to provide external machine protection interlocks.

BOOSTER RING (BR1) ENHANCEMENT

Tbe booster is a relatively new machine that was installed in 2002.

Upgraded BPM Electronics

The CLS booster ring was commissioned using Bergoz BPM electronics. Once commissioned the need for BPMs diminished and they were not regularly used. As part of a plan to better characterise the injection system we decided to upgrade the booster to Libera Brilliance BPMs.

Eight Libera Brilliance BPMs have been installed in the booster ring to better understand the operation of the booster. The first measurement carried out with these Libera BPMs was to monitor the booster tunes. Figure 2 shows the booster tune measurement results at the beginning of the ramp, which were obtained by simple fast Fourier transform of the turn-by-turn beam position in each plane. To evaluate the performance of the booster during the whole ramp (600 ms), further attempts were made to monitor the tunes later in the ramp. Unfortunately, oscillations were not big enough to get a tune measurement at later times of the ramp. Therefore, the booster extraction kicker was used to excite the beam to introduce an oscillation at different stages of the ramp. In the past, the tunes at the extraction time were assumed to be the same as the tunes at injection, i.e., ν_x=0.806 and ν_y=0.77. The measurement results show a tune shift at the extraction time, ν_x=0.81 and ν_y=0.704. Recently, the booster response matrix was measured with stored beam in the booster at 150 MeV. Further efforts will be made to invert the response matrix with singular value decomposition and apply correction to improve the injection efficiency.

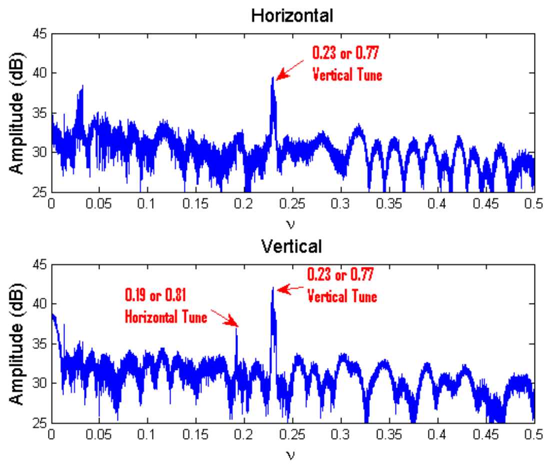

Figure 2: Booster Tune at the beginning of a ramp.

TRANSFER LINES

Power Supply Upgrade

Many of the original power supplies used in the CLS transfer lines were nearly 20 years old and dated back to the original EROS ring. CLS has recently completed a major replacement program to upgrade thelegacy power supplies with new power supplies from IE Power. The motivation for this upgrade was to reduce unplanned down-time and gain increased machine reproducibility, something critical as we move towards top-up operation.

Booster to Transfer Line BPM Monitor

CLS is currently testing a Libera Brilliance Single Pass BPM connected to strip-lines in the transfer line.

Current Transformers

CLS is currently installing additional Bergoz Fast Current Transformers (FCT) along the LTB transfer line connected to oscilloscopes. This augments a series of pre-existing Bergoz Integrated Current Transformers (ICT) that are connected to charge integrating ADC boards.

STORAGE RING (SR1) ENHANCEMENT

Transverse Feedback Systems

Due to the inherit stability of the storage ring, CLS was able to operate without the use of a transverse feedback system for many years. As the need for higher current operation became evident and user needs advanced, it became necessary to develop a transverse feedback system.

A transverse feedback system has been deployed to the CLS storage ring. It has three main functions:

1) Since high purity single bunch injection cannot be achieved at the CLS, any unwanted bunches have to be kicked out after injection. The transverse feedback system can work as a bunch cleaning system to establish an arbitrary fill pattern after injection. An enhanced feature, periodic bunch cleaning mode, has also been introduced to maintain high bunch purity, i.e., 10^{-5} at any time during a single bunch run.
2) The CLS transverse feedback system can be used to damp the transverse betatron oscillation associated with coupled-bunch instabilities. With the transverse feedback system, it is now possible to completely fill the storage ring, resulting in fewer electrons per bunch and consequently an increase in the beam lifetime. Figure 3 shows the comparison of the beam profile without/with the transverse feedback system.
3) Previously, the beam had to be excited by the injection kicker to determine the storage ring transverse tunes. With the transverse feedback system, it is now possible to excite only one bunch with limited amplitude for tune measurement. This feature has been extensively used for beam optics studies by CLS accelerator physicists.

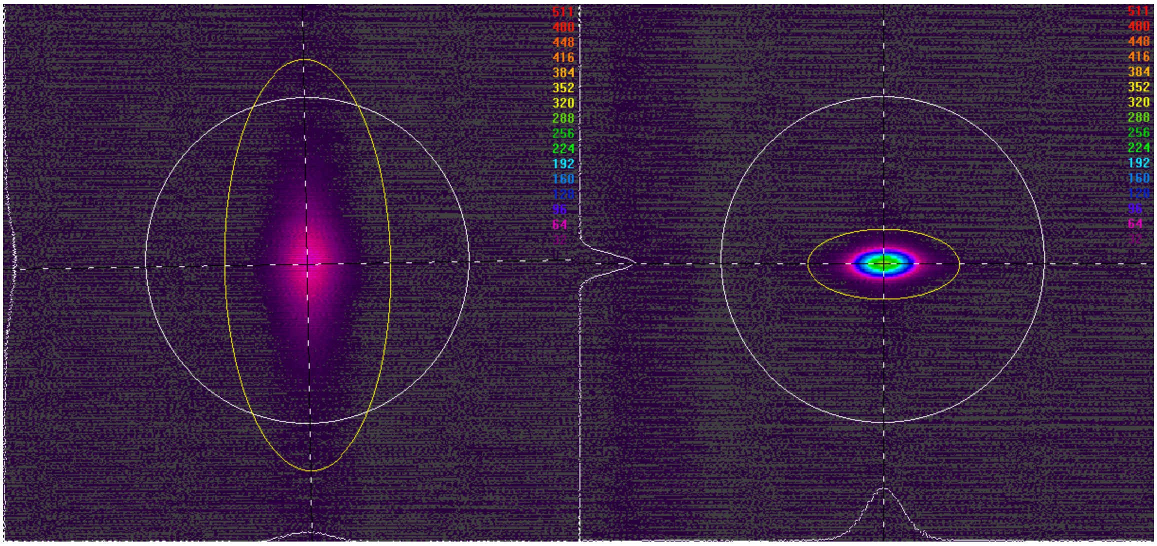

Figure 3: Transverse beam profile without/with TFB.

Orbit Correction

Due to the inherit stability of the machine CLS a fairly slow Matlab orbit correction scheme meet our initial needs. CLS is now in the process of commissioning a faster orbit correction system based on RTEMS.

CONCLUSION

Driven by the need to meet evolving requirements for increased machine reliability, availability and reproducibility we are undertaking a series of upgrades to the CLS accelerator control system.

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