

THE IMPLEMENTATION OF THE SPIRAL2 INJECTOR CONTROL SYSTEM

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Abstract

The EPICS framework was chosen for the Spiral2 project control system [1] in 2007. Four institutes are involved in the command control: Ganil (Caen), IPHC (Strasbourg) and IRFU (Saclay) and LPSC (Grenoble), the IRFU institute being in charge of the Injector controls. This injector includes two ECR sources (one for deuterons and one for $A/q=3$ ions) with their associated low-energy beam transport lines (LEBTs). The deuteron source is developed at Saclay and the $A/q=3$ ion source at Grenoble. Both lines will merge before injecting beam in a RFQ cavity for pre acceleration. This paper presents the control system for both injector beam lines with their diagnostics (Faraday cups, ACCT/DCCT, profilers, emittance-meters) and slits. This control relies on COTS VME boards and an EPICS software platform. Modbus/TCP protocol is also used with industrial devices like power supplies and Siemens PLCs. The Injector graphical user interface is based on EDM while the port to CSS BOY is under evaluation; also high level applications are developed in Java. This paper also emphasizes the EPICS development for new industrial VME boards ADAS ICV108/178 with a sampling rate ranging from 100 K Samples/s to 1.2 M Samples/s. This new software is used for the beam intensity measurement by diagnostics and the acquisition of sources.

THE SPIRAL2 INJECTOR

The Spiral2 Injector Control System is globally managed by CEA-IRFU.

The Spiral2 Injector is composed of 2 beam lines, one (LEBT1) developed at LPSC Laboratory, Grenoble and the other (LEBT2) at the IRFU Institute, CEA Saclay. Both lines will merge at the end of 2012, before injecting the beam into an RFQ cavity.

The beam line in Grenoble was commissioned in 2009. It is controlled by Epics but the Ion source has been controlled by a Labview PC for a long time. The goal is to control all the equipment from Epics. So, a replacement by Epics is in progress. All Labview interfaced parameters are implemented in a soft Epics database that uses the Labview-CA gateway.

On the LEBT2 at Saclay, the control system is being finalized. On 15th September, 2011, a 7mA proton beam was conducted to the end of the line, with 85% transmission, i.e. 5.5 mA at the end of the line.

The Saclay proton/deuteron source control system has been done in Epics. It controls several pieces of

equipment: a magnetron, a pulse generator, an impedance adaptor, an extracting beam High Voltage power supply, a gas injector controller and a repelling electrode power supply.

SPIRAL2 EPICS PLATFORM

Software Platform

The goal of this platform is to install all the PCs and VMEs of the Spiral2 accelerator in the same manner. This platform provides a software development model that each Epics developer has to use to build the different Spiral2 applications. In this way, we have got a homogeneous control system on the whole Injector. At present this platform uses Epics 3.14.12, VxWorks 6.8 and Linux RHEL5 on PCs. Modbus/TCP protocol is used to interface PLCs, power supplies and some beam diagnostics such as beam profilers.

A Subversion (SVN) repository is available at Ganil to manage the software development [2].

Hardware Platform

The Spiral2 Injector standard VME is composed of an Emerson Motorola MVME5500 and NEXEYA ADAS VME boards [3]:

- ICV150 with 32 ADCs, 16 bit resolution and 30K Samples/s
- ICV714 with 16 DACs, 12bit resolution
- ICV196 including 96 binary input/output channels
- ICV108, a controller board with a 4 M bytes RAM
- ICV178 with 8 $\Sigma\Delta$ ADCs, 16 bit resolution, 1.2 M Samples/s.

IRFU has developed the Epics drivers for these boards. Three VMEs control the LEBTs Epics control system and one specific VME is dedicated to controlling emittance-meters.

POWER SUPPLIES

This software was designed by Ganil [4]. All the power supplies are of Hazemayer type and are current power supplies. They are connected to the Ethernet field bus and are accessed via the Modbus/TCP protocol. The Epics driver, provided by Mark Rivers from the University of Chicago, is used to control these power supplies. At present on the line LEBT1, in Grenoble, there are 15 power supplies (1 Sextupole, 1 dipole, 1 solenoid, 2 triplets of quadrupoles, 6 steerers). On the LEBT2 line, at

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Saclay, there are 20 power supplies (2 dipoles, 2 solenoids, 7 quadrupoles, 9 steerers).

“FAST ACQUISITION” AND FARADAY CUPS, ACCTS AND DCCTS

The beam intensity of the Spiral2 Injector is measured in 2 ways. One way is beam destructive measurements with five Faraday cups [5] in the Low Energy Beamline Transfer, and beam non-destructive measurements by one ACCT and two DCCTs in the Low and Middle Energy Beamline Transfers. The beam runs in pulsed or CW mode.

At the beginning of the project, we developed a beam current measurement based on the VME ICV150 board (30 K Samples/s) but this acquisition wasn't precise enough with pulsed beam and couldn't display the shape of the pulse.

The principle for this acquisition is to synchronize the acquisition at the pulse start [6], to buffer the digitalised data, to display the pulse shape and to calculate an average value for each pulse.

The solution relies on the VME ADAS ICV108 and ICV178. These boards are described more precisely in [7]. Both boards communicate via the VME I/O P2 lines. The ICV108 includes an external trigger and a RAM buffer of 4 M bytes. This acquisition uses the RAM in “Flip/Flop” mode.

At present the Epics driver permits the use of two boards ICV178, i.e. 16 channels. To optimize running with regard to the 4 M bytes RAM and the sampling frequency, only the channels, corresponding to the equipment used for the intensity measurement, are sampled. The operator chooses the configuration on the display and the driver changes the configuration “on-fly”.

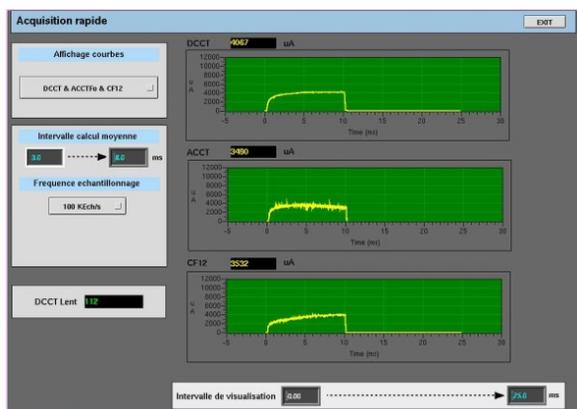


Figure 1: EDM display with one ACCT, one DCCT and one Faraday Cup.

This driver provides compressed (averaged) data, if necessary, to the applications, to speed up the visualization of graphs. The configuration “compressed” or “not compressed” is specified in the Epics database.

On the display (fig. 1), the operator has to give the interval of visualization and the interval dedicated to the average.

This fast acquisition is also used by Hall probes and emittance-meters.

BEAM PROFILERS

Profilers permit to measure and visualize the beam dynamics. In the LEBTs, these profilers are secondary emission profilers. This equipment and its control are completely managed by Ganimel. The communication with the electronics is based on Modbus/TCP. An Epics IOC application is used to configure measurements and to calculate average and offset subtraction. A JAVA server task [8] provides supplementary calculations to those carried out by the IOC application to the client applications. These new calculations are supplied as Epics Process Variables that are surface, signals sum, gravity center, standard deviations and widths. They are done for an area of a horizontal or vertical profile according to the requested configuration.

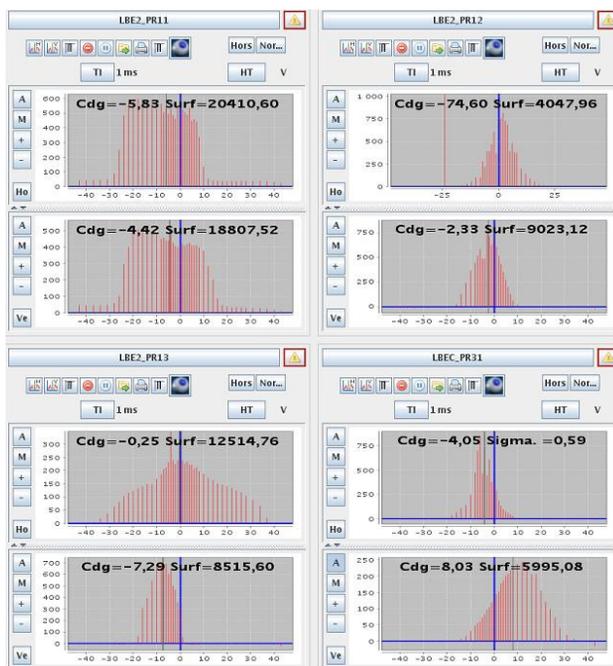


Figure 2: Beam profiles display, JAVA application using XAL framework.

EMITTANCE-METERS

The transversal emittance is the cartography of the transverse angles of the particles of the beam. It provides information on the divergent or convergent aspect of the beam and is used to measure the focal of the beam to study the propagation of the particles and to tune the beam.

At present a pair of emittance-meters is installed on each of the 2 beam lines. These emittance-meters and their control are carried out by IPHC Institute in Strasbourg.

A specific VME controls the 3 pairs of emittance-meters of the Injector. It is composed of the standard

VME boards: one ICV150 to acquire temperatures, a pair of ICV108/178 dedicated to faster acquisition, one ICV196 binary input/output board used for selection and configurations for hardware, one ICV714 to generate voltage ramps and besides an ISEG board to generate high voltage and a brushless motor board OMS MaxV to move the actuator of the measurement head.

When the emittance measurement is requested, the program gets the user parameters and waits for validation of the PLC process. Then, the program applies the maximum voltages requested to the plates of the measurement head and comes in a loop made up of 3 sequences: positioning, voltage ramp setting and current reading. For each position during the move, the voltages on the plates are decreased until an electrical field equal to zero is reached. Then, the field is inverted and the sequence position, voltage ramp, current reading is repeated. For every step of the voltage ramp, the current created in the Faraday cup is recorded.

For the human operator interface, there are 3 levels of EDM displays: data catching, configuration and debugging. A 3D visualisation is necessary. Therefore, a Java HMI was developed and recently a CSS BOY display has been created (fig. 3).

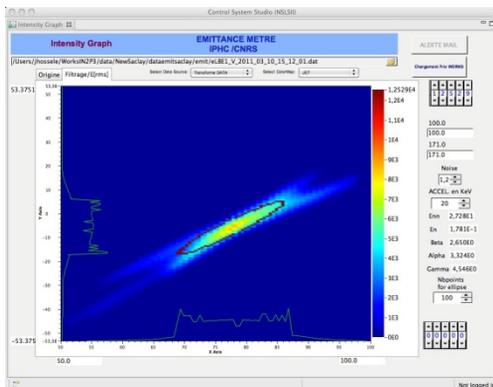


Figure 3: Emittance-meter HMI in BOY.

SLITS

The objective of the slits is to remove a part of the halo surrounding the heart of the beam. A pair of thermocouples is integrated into each slit to monitor the temperature that is controlled by an Epics IOC through the ICV150 ADC board. The control of the motor driver is based on Modbus/TCP in the same way as the power supplies.

PLCS FOR INTERLOCK AND VACUUM

Siemens S7 PLCs were chosen by the Spiral2 project. Interlock PLCs provide safety of the pieces of equipment on the beam line at Saclay and at Grenoble. When these 2 lines join at Ganil, only one PLC will ensure the two beam lines interlock. Vacuum is controlled by one PLC at Saclay and one PLC at Grenoble. The PLCs are connected to Ethernet and supervised by a Muscade

station and with Epics EDM HMIs. Muscade is a proprietary CEA SCADA whose objectives are supervision, diagnostics and distant maintenance. It runs on Windows PCs.

Protocol Modbus/TCP is used for the communication between Epics IOCs and PLCs.

The PLC can run in “local” or “distant” mode. This mode is read by Epics. When the PLC is in local mode, it memorizes the commands for Epics.

HOST-BASED PERL APPLICATIONS

A set of applications running on the Linux OPIs have been developed based on Linux. They are written in Perl and they use the cap5 Channel Access library provided by Andrew Johnson from ANL. A wrapper above cap5 has been designed to hide the details of the implementation. The interest of this approach has several aspects compared to a similar development made in SNL on the VME target for example: intrinsic power of the Perl language, ease of developments of applications based on an interpreted language, availability of a simple debugger. The performance is not a real issue for the type of applications aimed (fast acquisition buffers of several hundred of bytes can be read at 10Hz, processed and stored on disk without any problem).

The following applications have been developed: correlation of parameters for beam tuning, ECR sources beam spectrum acquisition, a thumbwheel generic tool for parameters fine setting and several utilities functions.

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