THE LLS MAGNET TEST FACILITY AS AN EVALUATION OF THE ACCELERATOR CONTROL SYSTEM REQUIREMENTS

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Abstract

In this paper we describe the control system of the bending magnet prototype test bench at the Barcelona Synchrotron Laboratory (LLS, formerly LSB). We have implemented the control system of this bench in two architectures: (a) PC based with fully commercial hardware and software, (b) distributed system using EPICS. We present here the advantages of the first implementation for this type of simple applications, and we also present the performance of the second as an evaluation for the global control system of the future LLS accelerator.

We also describe the general features of the DAQ/control system for the automation of calibration and measurement procedures. We describe the results in terms of cost and development effort of using both approaches, as well as design power and future expansion.

1 INTRODUCTION

The detailed design for a synchrotron accelerator in Barcelona composed of a 0.1 GeV pre-injector, a booster synchrotron ramping the energy from 0.1 GeV to 2.5 GeV, and a storage ring working at least at 2.5 GeV, includes the construction and evaluation of several prototypes of certain elements of the final project. In the process of making this design, we are setting up a magnet test facility to verify at the same time the dipole prototype performance and the control system architecture and design.

This is achieved by implementing a control system with the philosophy chosen for the future accelerator [1]: (i) use of commercial software packages, (ii) use of stand-alone instruments controlled remotely via bus, (iii) simplification of used bus types, and (iv) manpower minimization.

In order to not interfere with the evaluation of the magnet prototype, we have implemented the architecture of the test facility control system using two solutions: (a) PC based with fully commercial hardware and software, (b) distributed VME based system using EPICS. Obviously, both systems are not equivalent, and they are not comparable *stricto sensu*. However, we can evaluate the performance of the PC based implementation and its suitability for this type of “closed” and relatively small application and, also, we can use the magnet test bench, and the EPICS option as an evaluation of its feasibility for the accelerator control system.

2 EXPERIMENTAL SET-UP AND CONTROL REQUIREMENTS

The measurement system is composed of a 3D Hall magnetometer attached to a high precision (± 10 μm) mechanical arm, a power converter (1500 A, 100 ppm) which feeds the bending magnet prototype, and a NMR system with a small magnet fed by another power supply which is used to calibrate the Hall probes. The objective of this set-up is to measure the three components of the magnetic field with a precision of $\Delta B/B_o = \pm 10^{-4}$ with $B_0 \approx 1$ T created by the magnet prototype in the 3D region with a base 2.5×0.33 m^2 spanning between its poles.

The low level equipment to be controlled can be classified according to the used field bus:

- GPIB controlled: 1 voltage power supply feeding the Hall probes, 3 voltmeters to measure the Hall signal, 1 magnet high power converter, 1 calibration magnet power supply, 1 NMR teslameter for the calibration.
- RS485 controlled (BiSync protocol [2]): 1 controller to stabilize the Hall probe temperature and 2 indicators to measure the magnet prototype temperature.
- RS232/VME controlled: 3-axis PMAC DC-motor controller to move the mechanical arm.

With respect to the control system requirements, we have imposed the following:

- It has to support three modes of operation: (a) calibration, (b) step-by-step measurement and, (c) on-the-fly measurement.
- The interface with the user has to be friendly (graphical), allowing the user to configure the main parameters of the calibration or the measurement, and indicating its evolution.
- The equipment peculiarities and its presence in the system have to be easily selectable by the user, i.e., a configuration database must be used.
- The user has to be able to abort the execution of the measurement at any time, and the data taken up to that moment has to be saved to disk.

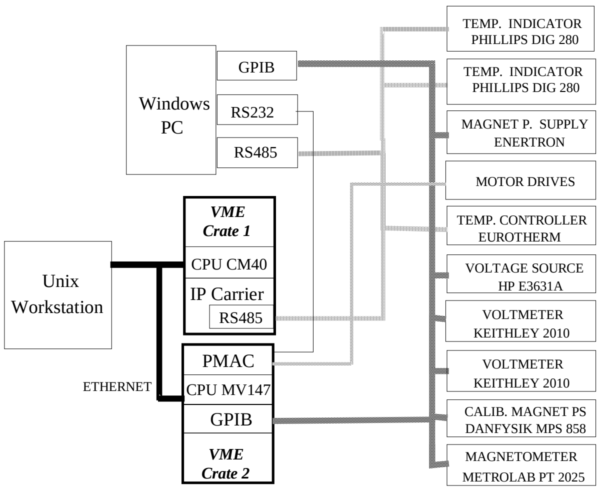

Figure 1. Block diagram of both hardware architectures used in the test bench.

3 DESCRIPTION OF THE CONTROL SYSTEMS

As already mentioned, we have implemented two architectures (see Fig. 1). The first one takes advantage of the existence of fully commercially available instrumentation packages for PC. We have implemented a robust control/DAQ system for the magnet test facility using the LabView 4.0 graphical programming package [3], National Instruments GPIB and serial communication boards, and a standard PC.

With this first architecture, we will satisfy all the requirements with the exception of the on-the-fly mode of operation, because it requires real-time capabilities that are far away from the features provided by LabView.

The second architecture is based on the powerful tools available for real-time VME-based control systems. We have implemented an accelerator-like control system using the EPICS toolkit, a National Instruments VME GPIB module controlled by a Motorola 68k CPU board, an IP Carrier with an Octal-485 module from GreenSpring for serial communications controlled by a Computadores Modulares (Spanish) 68k CPU board, and a Sun workstation as a host computer. The network used between the host and the VME Input/Output controllers is Ethernet and the connections are managed by a 3Com Switch. EPICS (Experimental Physics and Industry Control System) is a software toolkit originally created for accelerator control systems [4]. EPICS software runs on the host and the target and this latter uses the VxWorks 5.3.1 hard real-time operating system, and offers the possibility to implement distributed processing tasks among all the CPUs of the system.

This second architecture is also the basic hardware unit of the control system foreseen for the LLS, because it includes both the high and low levels of distributed processing characterizing such a system, it uses the software tools foreseen for the LLS, and it interacts with equipment in an application in which accuracy, speed and easy user interaction are the objectives. Thus, this applications is a good (in a smaller scale) test for the whole accelerator control system.

3.1 The LabView implementation

The LabView implementation has been done taking advantage of the GPIB/Serial packages for the communication with the instruments as well as all the graphical user interface facilities. Because of that, the time of writing and debugging the code is really low, around 1 month for one person full time, mainly limited by the instrumentation set-up.

With respect to the evaluation, we have computed several figures of merit for the calibration mode of operation (which involves more instruments than the others). These are shown in the following table.

Table 1. Evaluation panel for the LabView system.

System installation difficulty:	Very low
Learning curve:	Smooth
Easy programming:	Yes
Cost:	Low
Performance:	
Real-time facilities:	Poor
Asynchronous facilities:	Very few
Modularity:	Yes
Scalability:	No
Time for a GPIB transaction:	33 ms
Time for a RS485 transaction:	26 ms
Time for one point acquisition:	42 s

The LabView implementation has a basic limitation: it does not produce a hard real-time code. In addition, the execution of the code is basically limited by a sequential data flow. Therefore, many steps which could be done in parallel have to be done in sequence, with its inherent limitation in time. Furthermore, all the communications with the instruments have to be implemented on the basis of synchronous transactions, thus increasing write access times and therefore the total execution time.

3.2 The EPICS implementation

The implementation of EPICS (see Fig. 2) has been done taking advantage of its excellent collaboration, which provides in many cases with off-the-shelf drivers and devices for the communication with the instruments as well as a toolkit to develop the applications (graphical editor, database editor, network communication library, etc). In our case, however, we had to modify both the GPIB and the RS-485 drivers to adapt them better to our system.

Despite of this, the time needed to install, write and debug the code is considerably reduced, around 2 months for one person full time, mainly limited by installation problems like compatibility of software versions, the lack of devices adapted to some specific instruments and the difficulty of fully understand the EPICS internals.

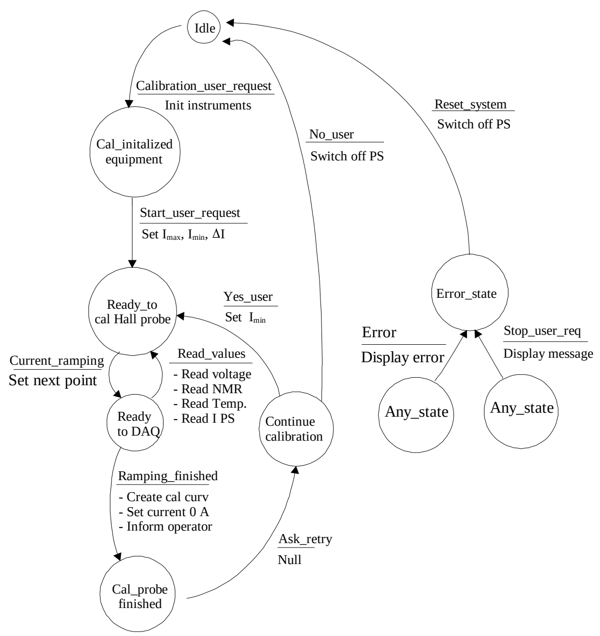

Figure 2. State Machine used to implement the calibration code with the EPICS *Sequencer* tool.

With respect to the evaluation, we have computed the same figures of merit for the calibration mode of operation as in the LabView case, as shown in Table 2.

Table 2. Evaluation panel for the EPICS system.

System installation difficulty:	High
Learning curve:	Steep
Easy programming:	Yes
Cost:	High
Performance:	
Real-time facilities:	Excellent
Asynchronous facilities:	Many
Modularity:	Yes
Scalability:	Yes
Time for a GPIB transaction:	23 ms
Time for a RS485 transaction:	25 ms
Time for one point acquisition:	30 s

The EPICS implementation has many advantages: it uses the VxWorks real-time operating system, Channel Access for transparent network communication and supports high speed buses as VME or VXI.

4 DISCUSSION

Whilst the LabView implementation is adequate for a robust control system for users only interested in the magnetic measurements, the EPICS solution offers an excellent real-time environment and supports the architecture and the tools that we require for the future accelerator control system.

From this point of view, we have tested that the main limitation (in our case at least) is the learning and setting-up times. Once this is accomplished, it is relatively easy to implement powerful applications, taking advantage of the excellent collaboration in which EPICS is based. This collaboration is a very useful forum for discussion and is very convenient to solve daily problems and share software components.

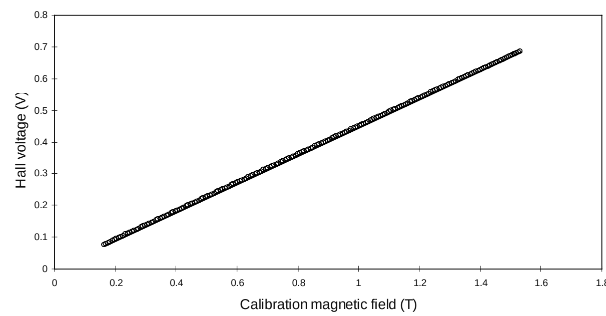

Figure 3. Calibration curve for the *y* Hall probe. The result is independent on the control system used.

As a result of two working systems we get the same calibration curve (shown in Fig. 3) for one of the probes. The reproducibility of this calibration is better than 2 Gauss in the whole magnetic field range.

5 CONCLUSIONS

We have described and evaluated the control system of the magnet prototype test bench at the LLS. We have implemented it using two architectures: (a) fully commercial PC-based, (b) distributed system with EPICS.

The performance of these two implementations, expressed in terms of design power, cost, development effort, real-time capabilities, and graphical features confirm us our choice of EPICS as a good solution for the implementation of the whole LLS accelerator control system.

However, for small test benches, commercial alternatives exist (e.g. LabView) that are useful for quick tests and very suitable when a rapid control/DAQ system is needed.

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