

CHAPTER VIII - CONTROL SYSTEMS

1. INTRODUCTION

This chapter describes the solutions envisaged for the SPIRAL2 project concerning:

- networking,
- control systems for the sources, the accelerator, the plug, the low energy beamline, the n+ source the identification station and the CIME beamline,
- interface between the SPIRAL2 and the legacy GANIL control systems.

The following is intended to provide the basic solutions and elements needed for the accomplishment of a coherent control system. This analysis is based mostly on commercially available products for hardware and on solutions developed in the accelerator community for software.

2. NETWORK LAYOUT

The SPIRAL2 controls network is a 100-Mbps switched Ethernet network, with a backbone at 1 Gbps. The number of nodes to be connected to the site network has been estimated for each part of the facility. The total number of nodes is around 100. The chosen network design will provide enough flexibility for the number of nodes to be increased without difficulty if required.

Each node will be connected to a switch by a point-to-point link. A switch creates private connections to nodes connected to it and separates the LAN into collision domains. Therefore the traffic on the shared part of the network is dramatically reduced and most collisions are avoided. The switches will also be connected to the site high-speed backbone through 1-Gbps uplinks.

3. HARDWARE FOR EQUIPMENT INTERFACING

Although it has been in existence for more than 15 years, the VME standard is still widely used. In the accelerator domain, most new projects (DIAMOND, NLC, SLS, SNS) still use VME as the main equipment interface. It is worth noting that GANIL uses VME for most of its needs for equipment interfacing. A set of standard VME modules will provide interfaces for analogue and digital input and output signals as well as motors, encoders, and serial line connections. In the domain of fieldbuses, there are several systems on the market and there is no consensus on the use of any particular one in the accelerator community. As the choice of a standard fieldbus must be made using a combination of criteria such as experience, preference, solutions available from other laboratories, etc., we have decided to use the CANbus for several applications (power supplies interfacing, low-level control and RF communication). A facility with such varied requirements will also need “non-standard” solutions to interface the control system with some particular equipment: e.g. GPIB to interface high-precision multimeters, numerical oscilloscopes, function generators, etc., RS232 to interface diverse controllers and fibre-optically linked distributed system for HV controls.

Programmable-logic controllers (PLCs) will be used to manage functions relating to safety: i.e. safety of the accelerator (vacuum, cryogenics, beam inhibit) or the safety of personnel. The situation here is different from that with VME systems, where a combination of solutions provided by different suppliers can be found. The PLC market is mostly based on proprietary solutions, i.e. for the PLCs themselves, their I/O boards, the supported fieldbuses and the actuator/sensor hardware to be connected to these fieldbuses. Therefore care must be taken when choosing a supplier and this choice must be enforced site-wide. It is likely that the solutions already used at GANIL will be extended for SPIRAL2.

An estimation of the different VME systems needed was carried out. This estimation is based on several criteria: separation by functions to be possible, avoidance of overloaded systems, reduction

of prohibitively long cabling, and avoidance of isolated systems with few modules. All these criteria must be met.

The estimation of the different PLCs was done with the following assumptions:

- All functions related to safety and availability will be handled by PLCs (e.g. beam inhibit system, vacuum, sources operation). For all other functions, a VME-based solution is preferred (better performance, flexibility, lower cost).
- Stand-alone PLCs dedicated to critical safety functions (personal safety, nuclear ventilation, etc.) are excluded from this study
- PLCs dedicated to the conventional facilities (the building AC, electrical stations, etc.) are also excluded as they will most likely be delivered by external sub-contractors. It is to be hoped that these PLCs will be connected to the main control system to report status and alarms.
- As some discussions are still in progress, the precise distribution of PLCs will probably evolve slightly before the construction phase.

The analysis to date results in the following proposed system layout:

	VME	PLC
Source D+ , LEBT1	1	2 *
Ion source 1, LEBT2	1	1
RFQ 1, MEBT1	1	2 *
Ion source 2, LEBT3	1	1
RFQ 2, MEBT2	1	1
Linac	2	2 *
HEBT1, HEBT2	1	1 *
HEBT3, HEBT4	1	
Converter 1, Target 1	1	
ECR Source 1	1	2 §
Separator 1, LIRAT 1	1	1 *
Identification line	1	1
1+/N+	1	1
Beam transfer	1	1 *
Converter 2, Target 2	1	
ECR Source 2	1	2 §
Separator 2, LIRAT 2	1	1 *

* : 1 PLC dedicated to vacuum

§ : 1 PLC located on the source HV platform

This evaluation gives a total of 18 VME front-end systems, 19 PLCs and one VXI acquisition system for the identification station. This VXI solution for the identification station is already in use for SPIRAL.

4. GLOBAL COMPUTER SYSTEMS

Computer system with global roles will be required at different stages. For such applications, PCs running Linux are undoubtedly the most effective, powerful and cheapest solution. These systems will be dedicated to the following applications:

- Supervision workstations: these PCs will interface the control systems with the operators. A total of 6 of these workstations is foreseen in the control room.
- Supervision mobile workstations: these laptops will be used in alcoves, close to the machine (RFQ, linac, converter) for local tests. A total of 6 laptops is foreseen.
- Database server: a powerful PC with suitable capabilities in term of storage and backup will be used to run the configuration database system.
- Archive server: this system will continuously acquire all the parameters on all VME systems. To avoid unnecessary network activity and to save disk space, this process will be active on value change only.
- VME boot server: this PC will store all the programs needed by the diskless VME systems when they are rebooted.
- Development server: it will be mainly used for vxWorks application development. The new ECLIPSE development environment for vxWorks is now available on Linux.
- Development workstations: these are general-purpose Linux PCs used to develop, test and maintain applications. As Linux makes use of X11, it will be possible to access the graphical applications running on all the other computer systems from the development workstations.

5. CONTROL SOFTWARE

5.1. EPICS software

The basis of the control software for SPIRAL2 will be EPICS. There are several reasons for this: the manpower in laboratories is decreasing, users have ever-increasing requirements and the solutions tend to be more and more complex. This analysis was made by most of the laboratories which have recognized EPICS as a good toolkit to build efficiently a powerful and scalable control system. Most new projects have opted for EPICS: e.g. BEPC2, Diamond, IPHI, NLC, SLS, SNS and SSRF. Today around 100 facilities worldwide use EPICS. It is also worth to notice that the ISAC control system at TRIUMF uses EPICS with the same infrastructure aimed at for SPIRAL2 (VME with vxWorks, CANbus). This could lead to some hardware and software sharing between these two laboratories.

The core of the control software is a real-time memory-resident database. The software running this database permits sophisticated operations, such as computing an output value with respect to a rule calculated with several input signals, or deducing an alarm condition by carrying out Boolean operations on several binary inputs, etc. This database is accessed from outside the Input/Output Controller (IOC) by a dedicated protocol called Channel Access.

On the workstation side, clients access the database through Channel Access. EPICS designers always have performance in mind: monitors, asynchronous access, alarm and archive “deadbands” are fundamental mechanisms for achieving maximum performance and scalability. Access security protects IOC databases from unauthorised access. This is believed to be a crucial issue for a facility like SPIRAL2. Access security is based on the following criteria: who wants access, where is the request made from, what action is to be carried out, and when can this access be made (based on rules which can result from the accelerator status).

Basic tools required to run the control systems are available off-the-shelf:

- A display manager for synoptics creation and animation.
- A real-time strip-chart plotting tool.
- An alarm handler.

- An archiving facility and archived data visualization.
- a save/restore facility (save and restore later a set of parameters).
- Error and log-message management.

Several commercial general-purpose software products interface with EPICS, such as Excel spreadsheets, the Mathematica computing tool and IDL visualization software. At least 4 electronic logbooks exist in the EPICS community, developed by the following laboratories:

- Dortmund, for the DELTA synchrotron radiation facility (based on a mySQL database).
- CEBAF and SNS (based on an Oracle database).
- DESY, for TTF (based on simple files).

All these logbooks are “EPICS-aware”, which means that data can be automatically transferred from the control system to logbook pages.

Figure 1 shows the logical organization of the software with some of the most common clients. As shown, all the tools required for controlling and monitoring a large facility are present. An Application Programme Interface (API) for most of the languages (C, C++, F77, Java, Tcl/tk, Python) is available. It is therefore possible to develop customised tools with the most appropriate language.

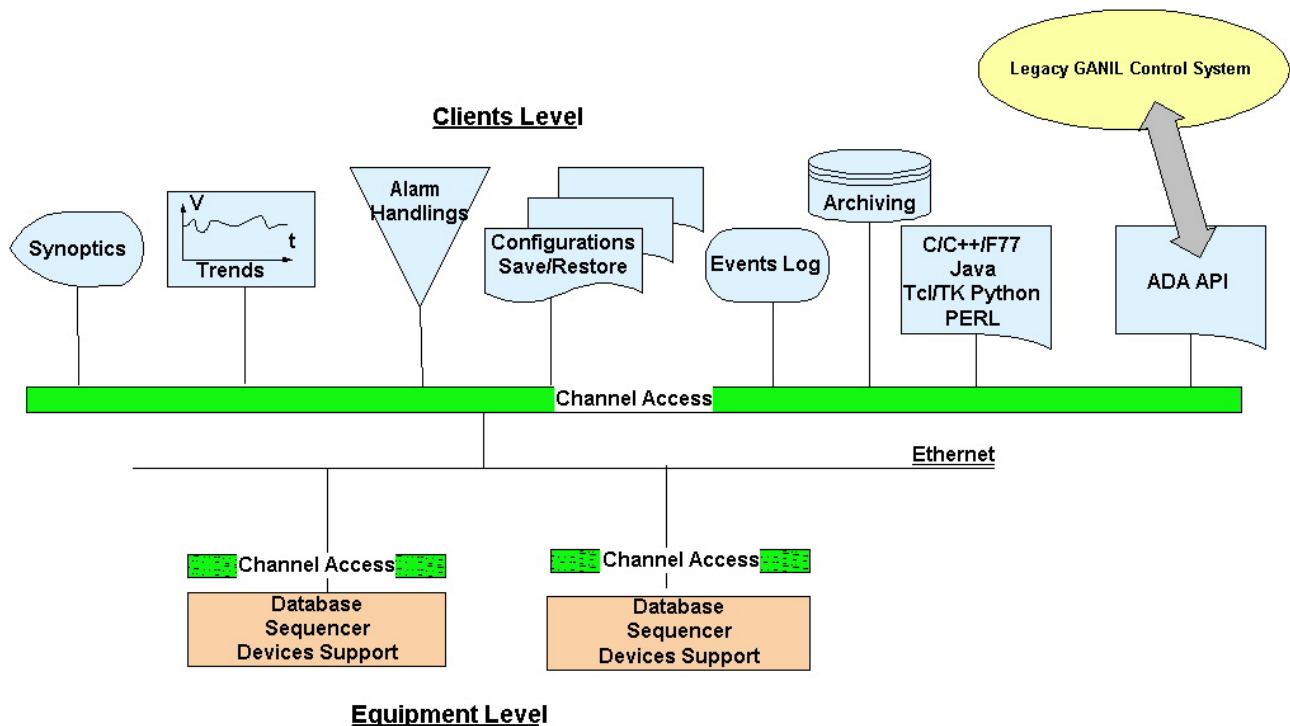


Figure 1: EPICS software architecture.

5.2. Interface to legacy GANIL control system

The GANIL control system is a two-level system:

1. VME crates with I/O boards to connect the equipment, housing a database downloaded from the database server
2. Work-stations, with graphical user interfaces to run beam tuning programs, sending orders to the VME crates with a specific protocol via TCP/IP.

The main server offers the usual services such as archiving, alarm handling, event logs and data collection. All the software in the VME crates and in the workstations is programmed in ADA.

Although very similar for the operator services, the GANIL control system does not use EPICS. However, a migration plan is underway, aiming to replace the work-stations by Linux PCs. A study

will also be pursued to replace the specific communication protocol by the CORBA middleware, as done in other laboratories such as ESRF, SLS, and LNL-INFN.

A complete ADA binding will be required in order to exchange data and commands between the EPICS VME crates and the control of the exotic beam lines and CIME cyclotron, still programmed in ADA. Preliminary tests have been achieved. To make this test as simple as possible, the EZCA package – which provides a simplified interface to the Channel Access protocol – was used. Later on, if more performance and functionalities are desirable, a direct interface between ADA and Channel Access will be developed.

For the PLC, the use of a gateway will later limit the extension of the whole architecture, so a direct communication protocol via TCP/IP must be used between the PLCs and the Linux/PCs. This could be evaluated during the end of the analysis and then developed or integrated soon after that.

As far as possible, in order to reduce maintenance cost, the hardware will be standardized with the present hardware used for the controls of GANIL.

5.3. Configuration Database

The facility will have a few thousand parameters, so the database which stores all the configuration parameters is a very important issue. In many projects, a general-purpose commercial database is used to store all information concerning the accelerator. From this comprehensive, project-wide relational database, EPICS distributed databases, to be downloaded in the VME, will be produced by adequate extraction tools. The database will be based on a consistent, hierarchical, site-wide naming convention. Such a naming convention has already been undertaken by the Conventional Facilities Group.

Following the experience gained with the GANIL control system, based on several uses of relational databases (e.g. equipment configuration, beam-parameter management, machine dynamic configuration, deployment of computerized maintenance management software or CMMS), an appropriate database management will be provided, also benefiting from approaches and solutions already developed by different laboratories among the EPICS community.

6. SYSTEM ARCHITECTURE

The control system for the entire accelerator, beam lines, targets and the slow control of the experiment areas, will have the same architecture. The hardware architecture supporting EPICS is very simple. It is split into two levels. The first one consists of VME crates (so-called IOCs) connected to the equipment. The second one consists of workstations (so called OPIs), which either play dedicated roles (e.g. as file-server or archiver) or offer a man-machine interface function. These two levels communicate via TCP/IP on Ethernet.

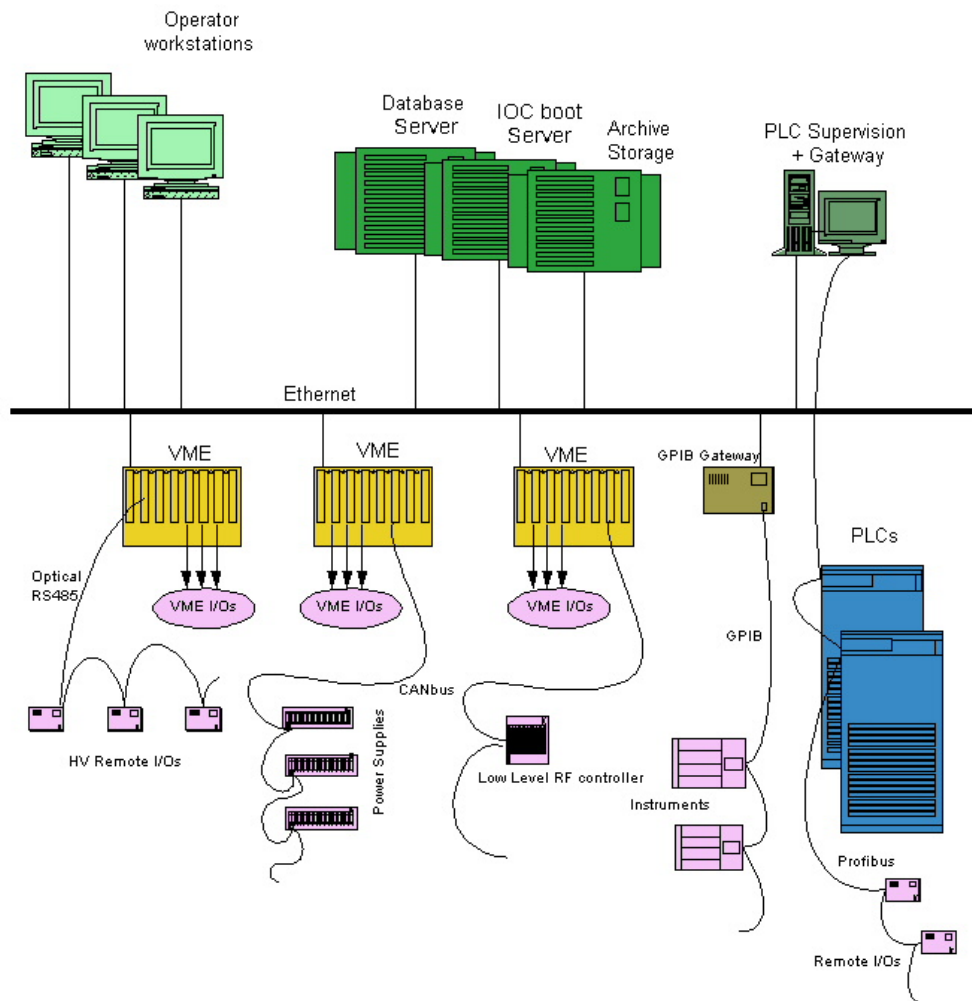


Figure 2: System architecture for controls.

As shown in Figure 2, the following hardware configurations for interfacing the equipment and supported by EPICS will be used:

- VME crates with various standardized IO boards (ADC, DAC, binary I/Os, motor controller) and custom boards when needed (diagnostics, power supplies interfacing).
- VME crates with optical links with specific modules will be used for the control of all equipment at HV (namely the ion sources).
- VME crates with CANbus connections to connect to power supplies controller and to embedded systems for low-level RF controls. It is likely that some equipment will also be connected through serial lines.
- A GPIB interface: a black box connected to the Ethernet network will provide connection to dedicated appliances.
- Programmable logic controllers will be used to manage functions relating to safety: safety of the accelerator (vacuum, cryogenics, beam inhibit) or safety of personnel. As already adopted on several major sites (e.g. DESY, and the SNS for the cryogenic plant and the conventional facilities), the supervision task for PLCs can be handled at the level of the general EPICS control system. This has the advantage of avoiding expensive proprietary solutions and providing a homogeneous integration of the supervision. Despite these advantages, for historical reasons, several proprietary PLC supervision systems will be unavoidable in domains like vacuum and the access safety system.

7. CONCLUSION

The technical choices made for networking, controls, acquisition and computers are intended to offer the guarantees required for such a facility:

- Reliability and availability
- Scalability
- Performance
- User-friendliness and ease of maintenance.

These choices were made keeping in mind the time-span between this feasibility study phase and the construction phase. Some solutions must still be consolidated (CPU type for the VME systems, VME interface boards, database system) and some minor adaptations made, but the overall architecture is expected to remain as described here.

