THE CONTROL SYSTEM OF THE L.N.L. LINAC

G. Bassato, A. Battistella, M. Bellato, S. Canella
I. N. F. N. Laboratori Nazionali di Legnaro - (Italy)

Abstract

This paper describes the control system of the superconducting Linac under construction at L.N.L. The general architecture is presented and the reasons for both the hardware and software choices are discussed.

INTRODUCTION

The first approach to the control system design has been to identify the functional tasks to be carried out. Following a top-down classification, we can distinguish the following functions:

- Operator Interface: a set of graphical facilities must be provided to give the operator the capability of setting and monitoring all the accelerator components. Physically, the operator interface is implemented by means of workstations placed in the control room.
- Data Base management: this function provides the storage and retrieval of many types of data files (for example: device calibration files, allocation tables of physical I/O channels, machine setup for a given beam characteristics or files containing the 'history' of monitored parameters, etc.)
- Control Interconnect: a certain number of computers must be dedicated to route data between the different layers of the control system or share system resources between different networks.
- Physical Device Control: this function is accomplished by a large number of specific controllers or processors that directly interact with the accelerator hardware. The physical implementation is strongly dependent on device characteristics, in terms of input / output requirements and response time constraints.

This classification is purely functional and can be translated into different architecture schemes; we considered a basic design rule to keep isolated as much as possible the high level functions from the device control tasks: this has been realized by using intelligent controllers associated to each device or group of devices.

Another primary goal has been to design a system with a high modularity degree, easy to maintain and open to the accelerator developments planned for the near future at L.N.L. To meet such requirements we choosed for the ALPI control system a network distributed architecture, where the design keys can be summarized as follows:

- Unix based workstations for the Operator Interface function
- Ethernet + TCP/IP for the Control Interconnect
- VME hardware + dedicated processors for the Physical Device Control.

This solution takes advantage, on one side, of acceptance of well proven standards and, by the other side, of the most recent developments in hardware technology, resulting in an expectancy for long term support and easy upgrading capability in the future.

SYSTEM OVERVIEW

As shown in fig. 1, the ALPI control system has been designed on a three level architecture. At the top level there are the workstations supplying the Operator Interface function; these machines are DECstations 5000, with high resolution accelerated graphics, 16 Mbytes RAM and 426 Mbytes internal disc. The choice of having an internal disc, sufficient to hold the operanting system and a local copy of the application programs, seemed preferable with respect the diskless cluster solution, to avoid a unwanted traffic on the network and in consideration of the very low cost of such mass storage devices. The workstation number, when the system will be completed, is planned to be six; each machine will be dedicated to the control of a particular accelerator subsystem, even if, in principle, each machine will be perfectly interchangeable, in its function, with the other.

At the workstation level one machine, with no graphics options, is dedicated to perform the function of file server: it manages all the data files concerning with the accelerator operation. The reason of having a centralized data base resides essentially in in a better capability of checking the data integrity and in maintenance simplicity .

At the second level there are the computers forming the Control Interconnect ; their primary function is to route commands, read-out data and messages to / from the workstation and the low-level device controllers. In the ALPI control system there are two independent networks, linked through a bridge: the main network and the beam diagnostics network. The choice of using a separate network for the beam diagnostics is mainly due to a significant difference in data traffic, since some functions, like the live display of beam profile , require a fast signal sampling and a prompt data transfer along the network. The computers dedicated to the Control Interconnect are VME machines, based on the 68030 microprocessor and running under Unix. The CPU card is the Motorola MVME 147, including 8 Mb of RAM, an Ethernet and a SCSI controller; each machine has a 150 Mb disc.

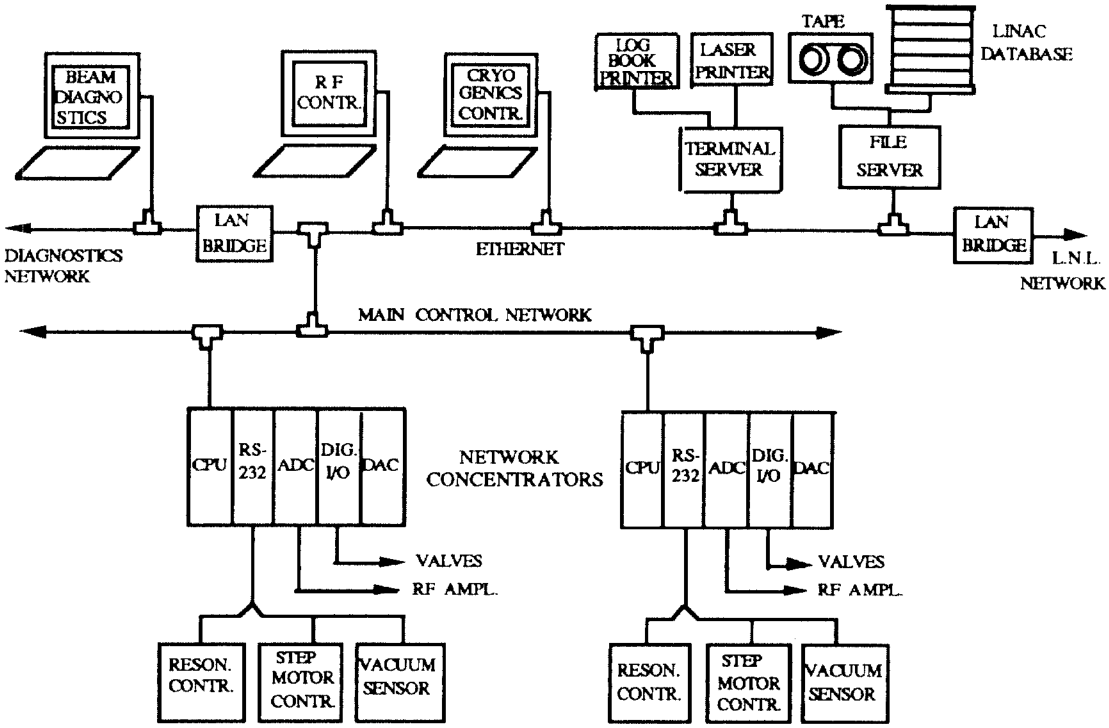

Fig.1 Hardware architecture

These network concentrators actually have a hybrid role, in the sense that they not only provide the commands and data routing as mentioned above, but also directly supervise, through analog and digital I/O cards, those devices for which there was no availability of intelligent controllers. It should be noted that the network concentrators used for the beam diagnostics have the same CPU card but run under a real time operating system in a network-hosted configuration (they are disk-less computers and boot from a dedicated node); the choice of using a real time operating system was dictated by some timing constraints in signal acquisition sequence that required a deterministic response from the local processor.

At the lowest level there are many types of specialized controllers directly interacting with the accelerator hardware. The Linac components have been classified in six subsystems, that are:

1) the beam pulsing system, including the choppers, bunchers and phase stabilization circuits

2) the RF distribution system, that provides the resonant cavities with RF power, keeping them locked, with different phase angles, to a reference oscillator

3) the cryogenic system, that controls the helium distribution from the refrigerator to the cryostats and to the resonators

4) the vacuum control system

5) the magnets

6) the beam diagnostics hardware, that includes grids, Faraday cups and silicon detectors to provide informations about the beam profile, current and energy.

Some components, like the helium refrigerator or the magnets, came from the suppliers with their own controller, generally with a serial line interface. In other cases, i.e. for the vacuum control or for the resonator phase and amplitude lock, microprocessor based boards have been developed at L.N.L. As general rule, all the feedback loops are closed locally at the controller level, making the time constraints for the communication with the higher layers of the control system much less tight.

SOFTWARE OVERVIEW

The goals in the software design of ALPI control system were:

- hardware independence, standardization and easy maintenance
- network distributed control capability
- friendly man-machine interface with fast response to operator commands

Unix has been choosen as development platform, since it provides powerful graphics and networking support; C-language, X-Windows and TCP/IP protocol have been the natural consequence of operating in Unix environment. In particular, for graphics development the X-11 toolkit and the Athena Widget library, which is a collection of built-in high level graphic objects, have been used; stream sockets with client-server paradigm have been the basis for networking and interprocess communication.

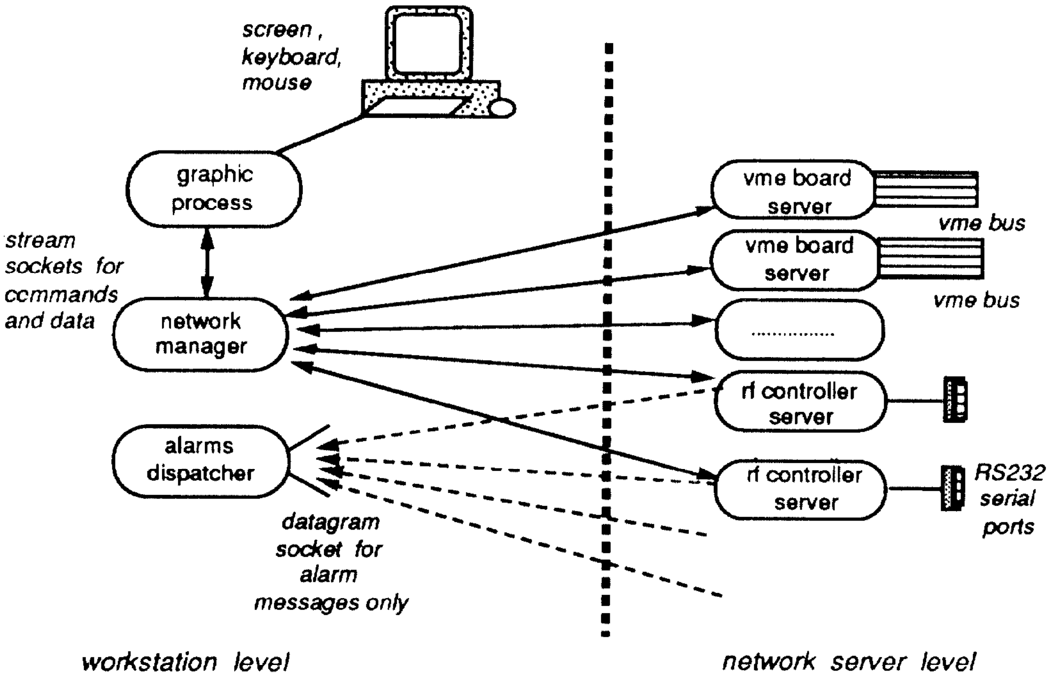

Fig. 2 Interprocess communication architecture

Unix is used both on graphic workstations (Ultrix 4.2) and on nodes of the main control network (System V); as already mentioned, the nodes of diagnostic network are loaded with a real time kernel (VxWorks): the choice of such operating system is mainly due to its fast response and full compatibility with Unix features.

The software architecture is based on a set of distributed processes running both on workstations and on network concentrators. The fig. 2 shows a scheme of interprocess communication, where four kind of processes are involved:

- a graphic process (man-machine interface)
- a network manager, which acts as a network configurator at start time and as a router at run time
- network servers, which manage the communication with the low-level device controllers
- an alarm dispatcher, which collects the alarm messages coming from the network severs and dispatches them to the operator console

The man-machine interface is hierarchic: from a main menu the different control subsystems may be selected and each of them appears with a general page summarizing the subsystem status; then more detailed informations may be requested about a group of devices or about a single component. Generally, it is possible to move both vertically (from one page to a more detailed one, and back) and horizontally (from a group of devices to another of the same class).

Virtual channels for interprocess and network communications are stream sockets for commands and data; datagram sockets are used for warning and alarm messages.

CONCLUSIONS

Preliminary tests of the control system performance have been carried out in 1991 with satisfactory results. An important aspect on which we focused our attention was the evaluation of the total response time to an operator command (that is the transit time for a command issued at workstation level to reach a device controller). Due to the Unix non deterministic response, this could have been a weak point in the control sistem design: we found that, in the worst case, such time is no longer than few tenths of second, that fits well with our needs. Nevertheless, we plan in the near future to install VxWorks on all the network concentrators, removing the disks from them; the simplified hardware configuration will result in a lower cost for the new machines and a increased long-term reliability.

We plan to complete the development and installation of the control system within the current year.

REFERENCES

[1] G. Fortuna et al., The ALPI Project at the Laboratori Nazionali di Legnaro, 5th International Conference on Electrostatic Accelerators and Associated Boosters, Heidelberg, May 1989)

[2] I. Ben-Zvi , M. Birk, J. Brennan, C. Broude, G. Glitz, M. Sidi, J. Sokolowski: The control and electronics of a superconducting booster module N.I.M. A245, 1986, 1-12