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A CONTROL SYSTEM FOR A FREE ELECTRON LASER EXPERIMENT

D. GIOVE

INFN MILAN -LASA, Via Flli Cervi 201 Segrate (Milan), Italy

Abstract

The general layout of a control and data acquisition system for a Free Electron Laser experiment will be discussed. Some general considerations about the requirements and the architecture of the whole system will be developed.

I. INTRODUCTION

The aim of the ELFA (Electron Laser Facility) experiment is to study the physics of a single pass FEL amplifier operating in the high gain Compton regime using a short electron pulse beam. The experimental purpose is the production of high peak power (0.3-1 GW) of microwave radiation, with a basic wavelength of λr=3 mm, and the possibility of tuning from λ = 1 cm to λr=0.1 mm. In order to achieve this goal an electron beam of very high current (400 A) in short pulses (6 cm) and with a maximum energy around 10 MeV will be injected into the wiggler midplane.

The accelerator consists of two sections: a photocathode injector providing a 3.5 MeV beam and a superconducting LEP II module to increase the energy up to 10 MeV. The wiggler will be a composite one, consisting of two coupled sections: the first part made with an hybrid structure (iron poles and permanent magnets) and a second part with an e.m. structure. A complete review of the project is given in [1] and a general layout of the experiment is showed in fig. 1.

The ELFA project has been funded by INFN and a lot of work has been done in order to define the conceptual design of the major components and to deeply investigate the FEL physics.

II. BASIC CONTROL PHILOSOPHY

A preliminary analysis of the characteristics required to the control system for ELFA pointed out the following items:

- ELFA needs both a control and a data acquisition system. Since ELFA is an experiment itself it is mandatory to have a complete data acquisition system for the measurements which have been planned to verify the basic ideas of the project. It is not possible to separate machine operations from physicist work. The two systems must be designed at the same time, sharing , as much as possible, the same philosophy and allowing an easy exchange of data.

- ELFA would take at least one year to "freeze" the characteristics of the major components. Nevertheless before of these period the control philosophy has to be fully developed and tested, in order to be an intrinsic feature of every component. A control system must play a central role in the whole design of a machine, to be really effective and to justify its budget requirements,. It is an old-fashion, money-wasting philosophy that one which consider the control system as just an "add-on" of the machine. In this way the control equipments just duplicate features already present and does not provide any improvement in performances. At the same careful attention has to be paid in order to evaluate the trend of development of computer technology. One has to balance today requirements and needs, with tomorrow availability and costs. This is more difficult to do since the different growth rates of the two basic components of a computer system : hardware and software.

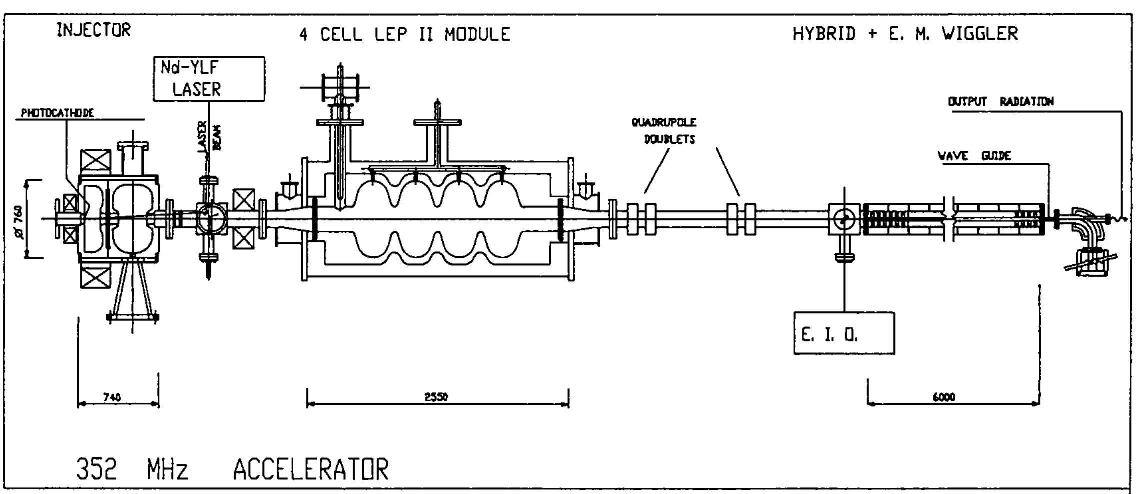

Fig.1 -General layout of the ELFA experiment

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- ELFA would experience during its lifetime a lot of developments and the overall structure would follow this evolution. This statements outlines one of the most stringent requirements on every accelerator and experimental physics control system. Unlike the other basic subsystems of the machine, which will experience a limited amount of developments, the control system is required to be flexible and to satisfy a lot of requirements, that during the design phase have never been examined or discussed. This implies that a system that just meets today needs will not be able to work tomorrow. A lot of attractive self-contained systems are today available on the market, usually based on Personal Computers. These systems have an exciting first look but the experience gained working with them teaches that there is a not negligible risk to be tied from their internal structure.

- ELFA requires some general tools which will help to manage the whole project. Since the different subsystems would start their design and testing phase in a parallel fashion, it is very hard to take into account all the news coming from the different teams and to coordinate all the jobs. The control system in an experiment of this sort would be a valuable help in the analysis phase. Models definitions and simulation of the different views of the experiment would be possible using automatic tools. General rules and specific requirements would be cross referenced, pointing out inconsistencies or helping in optimizing performances.

Keeping into account all the points above discussed a conceptual design of the control and data acquisition systems has been made. The most relevant characteristics may be so summarized :

- the systems will be based on a fully distributed environment. Distributed systems represent an ideal answer to demands about flexibility and modularity and may be easily implemented using commercial standard products. The availability of components which follow international or DE-facto standards represents a great improvement in the way to think a control system. The attention may be moved from the home made development of basic components, which is a really expensive and time consuming activity, to the definition of general rules for the integration of commercial products in a multivendor, suitable environment.

- The systems must follow general rules both for hardware and software components. An extensive analysis of the general requirements coming from the different subsystems must be carried out in order to define the smallest number of different boards and software modules to deal with. This task is particularly difficult in small projects where there are a lot of single components.

- The user of the systems must be unaware of the details of them. The duty of the control group is to provide an high level environment for the programmer, being a physicist or a member of the technical staff, to let him to develop application programs, which require his scientific or technical skill, without have to deal with device or control architecture characteristics. All the operations on the equipments or on the experimental areas should be carried out using logical names related to the specific functions. No matter if they are on different control subsystems, or if they are moved from a controller to another one during system modifications. All the data must be available to the physicists when they need them in a simple and standard way.

- The development of the control system should be based on an extensive use of automatic tools. This would start in the design phase, with a special emphasis on software, and continue up to the installation tests. A lot of informations must be recorded and analyzed during the project evolution to guarantee an homogeneous environment. This will enforce the use of advanced programming techniques giving the possibility to the user to take full advantage of such an approach.

III. CONTROL SYSTEM ARCHITECTURE

Regardless of the real complexity of the experiment, modern distributed control architectures develops on three levels: the plant level,where we have the single equipment control; the process level, which is responsible for the operation of a set of functional related devices; the supervisor level with the operator interface. This general scheme has been adopted also for the general layout of the ELFA control and data acquisition systems (fig. 2). The main difference between the two systems is the absence of the plant level for the data acquisition system .

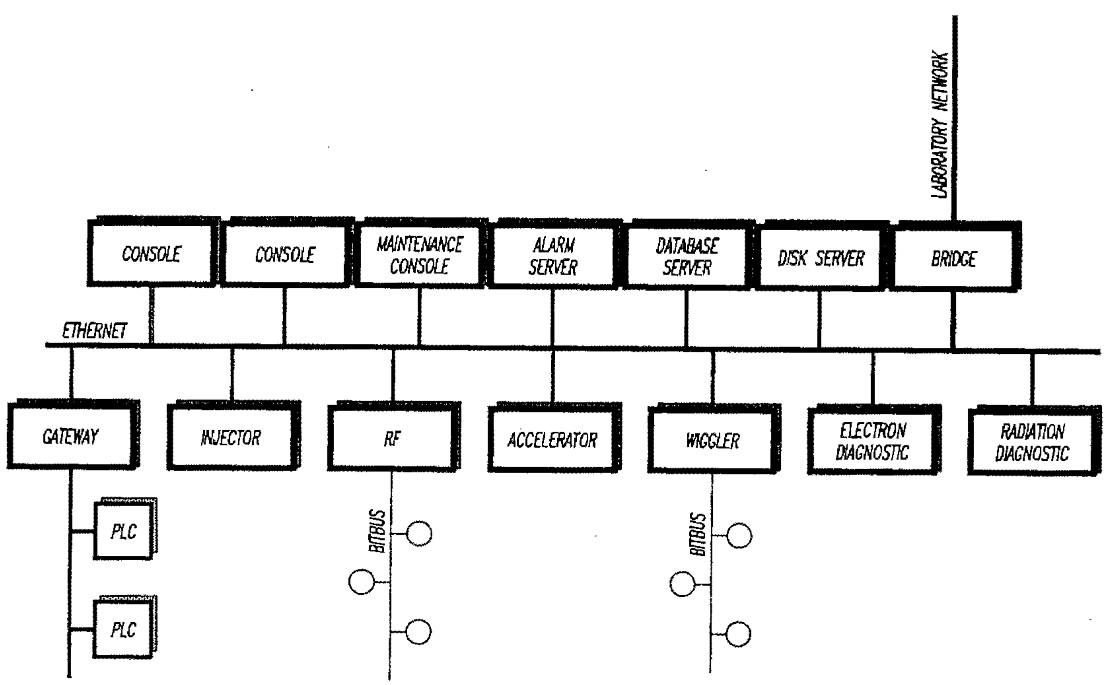

Fig. 2 - The hardware architecture of the control system

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The process level has been designed as a set of Process Units (PU) connected on the main Ethernet network of the control and data acquisition systems. The PU are based on the VMEbus and the Motorola 680x0 microprocessor family. At this level the main tasks are to acquire and process data from the plant level, for the control system, or from detectors, for the data acquisition system and to process them according to operator commands or control codes specific of the particular PU. According to the specific tasks which should be performed a PU may follow a single processor or a multiprocessor scheme. The choice of VME as the internal bus for process level stations, among other buses similar from the technical point of view, has been due to the world-wide diffusion of this bus, specially in the research environment, which gives the possibility to work with a lot of boards and drivers already developed. A special consideration would be dedicated to the control of alarms conditions arising from equipments which will compromise their safety. To handle these situations we have planned to use industrial PLC connected to the main network by means of a gateway.

The plant level has been designed as a set of microcontroller based boards. Each board is housed in the equipment to which is devoted giving an enormous flexibility to the whole structure and providing a first processing of field data close as much as possible to the field itself. Boards related to the same functional part of the machine will be connected by means of a bus, implemented using an HDLC based protocol (Bitbus), to the related PU. This scheme reduces in a valuable way the pick up of noise in signal transport and helps in device hiding.

The operator level will be implemented using dedicated workstations. This choice is quite a standard one nowadays and the experience gained using these machines is really satisfactory [2].

IV. SOFTWARE CHARACTERISTICS

The overall structure of the control and data acquisition systems has been carefully analyzed from the point of view of software requirements. Two items seems to be the most important :

- the capability to configure in every moment of the experiment the whole software structure in order to reflect modifications in the hardware or in the requirements from the experiment
- the possibility to develop programs without having to deal with the distributed nature of the control architecture.

Control programs and data acquisition tasks (which are stored in a dedicated computer) will be configured to reference to logical names and tables which every CPU will load at the bootstrap or following a specified command. This structure allows an enormous flexibility during operation of the machine. Tables will be extracted from a central database which stores all the informations related to the project. The choice to have a database where the whole data of the machine are stored plays a central role in the design of the whole machine. We are dealing with a tool based on a CAD program which directly interface to the database : designing a piece of equipment each relevant information may be directly stored or retrieved for cross reference checks. A particular situation is that one when the software itself in under development : we may analyze it using SA-SD models and store the structure and objects we require for those particular tasks in the database. At the end of a module one may start programs which try to find semantic or conceptual errors. Moreover it is possible to extract a detailed and complete set of informations which constitute the specs for writing the software. In this way we have both a graphical look at the structure of the code and a documented version of the code itself.

To handle data and commands exchange on the network it has been decided to use as much as possible the RPC protocol as developed for the LEP control system. This choice let us to meet immediately the goal to hide the network structure to the user and to obtain a reliable task to task communication in such a way that a program running on a PU may call a procedure to be executed by another PU. RPC protocol provides the possibility to communicate between PU and the operator worksites. It is not possible, as by now, to access directly an I/O point at the plant level using our scheme. This would be possible writing special drivers on the PU where the microcontroller boards are connected.

The operating system we have chosen for the process level is OS-9, while at the plant level an Intel kernel, iRMX 51, provides support both for multitasking operations and for message exchanges.

The operator workstations will use a Motif interface and will run a dedicated program where the operator will be able to build its own interface or use a predefined view of subsections of the experiment. The choice to use workstations as operator access point to the control system takes into account performance and budget considerations. The only possible alternative to the use of a workstation would be to use Personal Computers for low level jobs and maintenance purposes. As by now, we have experienced that a PC would use the facilities of the RPC protocol if it uses Xenix as the operating system. As a tool during equipment design and test, PCs would be used in a stand alone fashion with DOS as operating system. National Instruments boards and LabWindow software will be the products of choice for these purposes.

Acknowledgements

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[2] D. Giove et Al. "The Operator View of the Superconducting Cyclotron at LNS Catania" paper at this Conference