COMPUTER AUTOMATION OF THE MILAN SUPERCONDUCTING CYCLOTRON VACUUM SYSTEM

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Abstract

A modular microcontroller-based system has been designed for the control of the vacuum plants of the Milan K800 cyclotron. The control system has been designed as a network of modules each one dedicated to a predefined part of the plant (near which it is assembled), in order to increase the flexibility and the capability of future expansions of the system. The modules normally are connected together onto an high speed SDLC like serial bus (Bitbus) but they may work in a stand alone configuration for test or maintenance purposes.

In the paper a detailed description of the system is discussed.

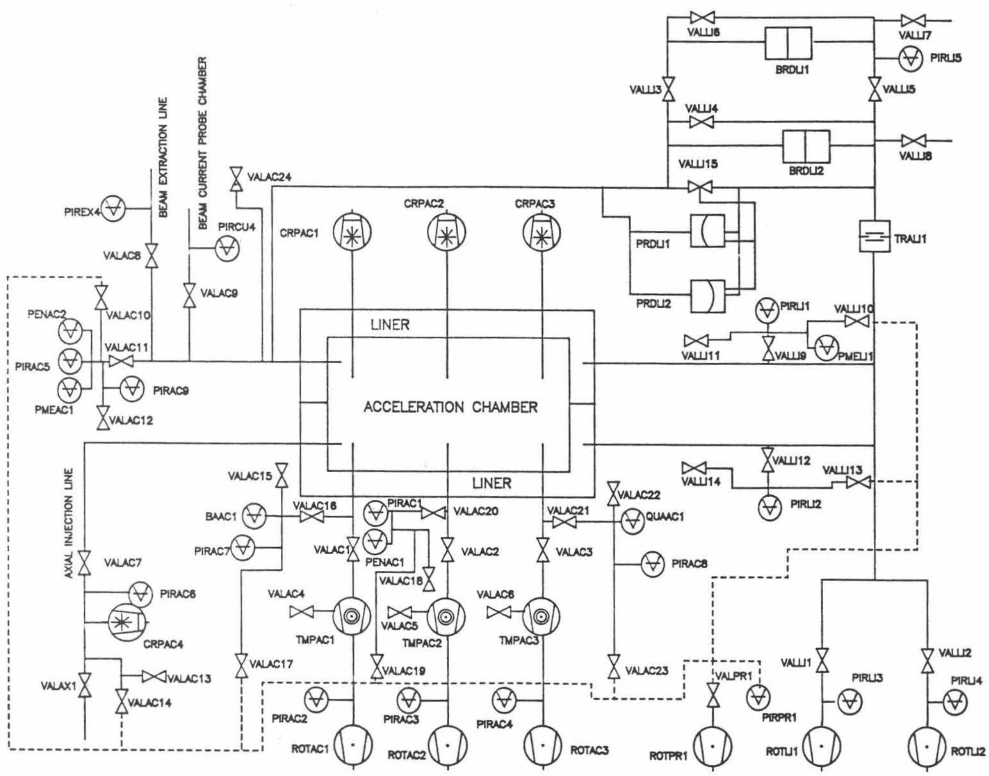

Fig. 1 - General layout of the vacuum system

Introduction

The pumping system layout for the Milan Superconducting Cyclotron is mainly dictated by the geometrical constrains of the accelerator.

The compactness of the cyclotron and the presence of a relatively large number of different subsystems which require vacuum to operate, force to design a structure with both internal and external pumping elements. Taking into account conductance considerations and pressure requests a dedicated vacuum plant has been designed for each different subsystem of the cyclotron. This philosophy leads to have 7 different vacuum plants. Such a structure makes the overall system more complicated (and expensive) but allows to operate each section independently from the others. This feature is particularly important because each plant will be installed together with the related equipments and this will happen in different moments.

Fig. 1 shows a schematic layout of the system.

Vacuum system description

The vacuum system of the cyclotron consists of 26 pumps,71 valves and 56 gauges and is subdivided in 7 plants[1]:

- acceleration chamber;
- liner;
- cryostat insulation chamber;
- guard vacuum;
- axial injection;
- beam extraction line;
- current probe chamber.

Three special designed split cryopumps, assembled in the upper RF cavities, have been chosen as the main pumping system of the acceleration chamber. These pumps will ensure a pumping speed of 25000 ls-1 which is well suited to reduce the pressure down to the operative one ($2\text{-}3\cdot10^{-7}$ mbar). Three turbomolecular pumping units have been assembled at the bottom of the lower RF cavities for rough vacuum and cryopump regeneration.

The volume under the liner has been divided from the acceleration chamber due to the large amount of gases evolving from epoxy-resin impregnated correction coils. Two rotary vane pumps, connected in parallel (total pumping speed 60 m3h-1) reduce the pressure difference across the liner structure to a value of few tens of mbar.

The cryostat vacuum system ensures thermal insulation between room temperature and liquid helium parts. It consists of 2 diffusion pump groups. A more detailed description is reported in another paper at the Conference[2].

A guard vacuum system has been provided in order to let operative the machine also if leaks are present in critical sealings. A rotary vane pump has been dedicated to this application.

The structure of the axial injection vacuum plant is the typical one used in beam line vacuum plants. Cryogenic and turbomolecular pumps have been used. The same criteria has been applied to the beam extraction line and to the current probe vacuum chamber.

Control system design criteria

The commissioning of the vacuum control system has been started in 1988.

The modular structure of the pumping system layout is well suited for a modern approach to automation system design[3]. The advent of microcomputer technology and the development of interconnecting strategies among "intelligent" devices have produced a dramatic change in the way of designing a control system. At the plant level control stations perform high speed data acquisition from sensors, convert measurements to engineering units and provide complex real-time controls. Plant equipments may be accessed directly from the stations, using hardware links or through 'field buses'. The concept of 'field bus' arises from the integration of microprocessors (µp) and microcontrollers (µc) directly inside each relevant part of a piece of equipment. The enormous amount of products available on the control market gives a fantastic flexibility in the choice of the architecture rules for control stations and their input/output (I/O) sections.

Major requirements of the vacuum control system may be so summarized:

-definition of stand-alone pumping systems, fully programmable both for the sequence of operation and for data acquisition, which may be the elementary units of the whole plant;

-capability to drive each element both in a remote way from the main console and "locally" with the same functionality;

-standardization of the interface toward the control system and toward vacuum elements;

-validation of each command by the dedicated computing element, also during local mode of operation.

Hardware

The control station level of the computer control system for the Milan cyclotron has been stardardized on Multibus I cardcages connected by means of an optical Ethernet network[4]. The I/O section allows more freedom in the choice, giving the opportunity to take advantage of existing products in the area of interest. Three solutions have been investigated for the I/O level of the vacuum system: turnkey vacuum controllers, programmable logic controllers (PLC) and microcontroller based boards.

Turnkey vacuum controllers, manufactured by vacuum specialized firms, allow automatic control of preselected steps or cycles, to suit a process incorporating pumps, valves and gauges. The philosophy adopted is to use a central processor (mostly the popular Z80) and I/O modules connected together on a proprietary internal bus. I/O points number seldom exceed 32 and insulation from devices is not provided. The main drawback of these units is that there is no way to connect in a parallel fashion more elements as the only supplied interface is an RS-232 port for the connection to a central host. This feature makes unpractical to design a distributed control system based on these devices.

PLCs are devices where the control relay logic is replaced by a solid state processor and memory configuration. The PLC processing circuitry contains a µp and line-solver logic which provide the vehicle for program processing. Handling of I/O points, ranging from ten to ten thousands, with scan time of the order of few milliseconds, management of remote I/O over proprietary feeder bus, fault tolerant architectures available at both the processor and I/O link levels, make the PLC a good choice.

Modules containing a dedicated µc can be tailored to fit a particular application and only necessary features are included in the design. Intelligent elements can be programmed to perform decision-making functions locally,with far less supervisory intervention. This reduces burden on the computer of the local station, enabling the use of simpler, lower cost equipments. Hardware characteristics are quite similar to those of PLC.

Modules based on INTEL 8044 µc and designed by an Italian firm have been the final choice for the plant level of the vacuum control system (fig. 2). They have been preferred with respect to a network of small PLC for their better flexibility (both h/w and s/w), high level programming language and intermodule communication software. Main characteristics of the remote I/O unit may be so summarized:

- -CPU: Intel 8044 8 bit µc,12 MHz;
- -MEMORY: 64 Kbytes of EPROM, 32 KBytes RAM (battery backup);
- -I/O: 32 bidirectional I/O points (relais outputs, optoisolated inputs), 8 optoisolated inputs; PNP or NPN logic selectable by the user; 1 watch dog output;
- -COMMUNICATION : 1 serial optoisolated RS 485 port for Bitbus; 1 serial port RS 232;
- -VISUALIZATION : power on, logic watch dog, communication watch dog, run-down battery, local failure, system failure;
- -POWER : 24 Vdc or 24 Vac.

The final architecture of the vacuum control system consists of a minicomputer (based on 80286 CPU) which acts as a master of a network of 13 µc boards and is connected to the control Ethernet LAN. Bitbus (an INTEL proposal) has been chosen as the protocol for the distributed network. It is an order/reply protocol based on IBM SDLC standard for the data link level and on RS 485 for the physical level. We have modified the physical level using a fiber optic media: the optical transceiver is shown in fig. 3. Throughput of nearly 30 kbyte/sec has been measured on a network of 150 meters, which simulates the extension of the vacuum distributed control.

Microcontroller boards are fitted inside the racks where vacuum instrumentation is assembled. Each rack contains 2 of such boards, while one has been dedicated as a gateway toward the PLCs of the cryostat vacum system[2].

Nine different interface devices have been designed to accomplish signals conditioning and to allow easy local/remote operation of the plant. These modules have to be inserted between µc boards and vacuum elements, each one being dedicated to a defined group of devices (turbomolecular pumps, cryogenic pumps, gauges, etc.). The aim of this design has been to use commercial vacuum instrumentation without making any modification in internal circuitry, but adding more functionality by means of separate electronics. This philosophy allows to easy integrate in the control system any plant already installed simply adding the related interface module and a µc board. Such a feature is particularly interesting taking into account the future expansions of the vacuum system to include beam lines at the final installation of the cyclotron in Catania.

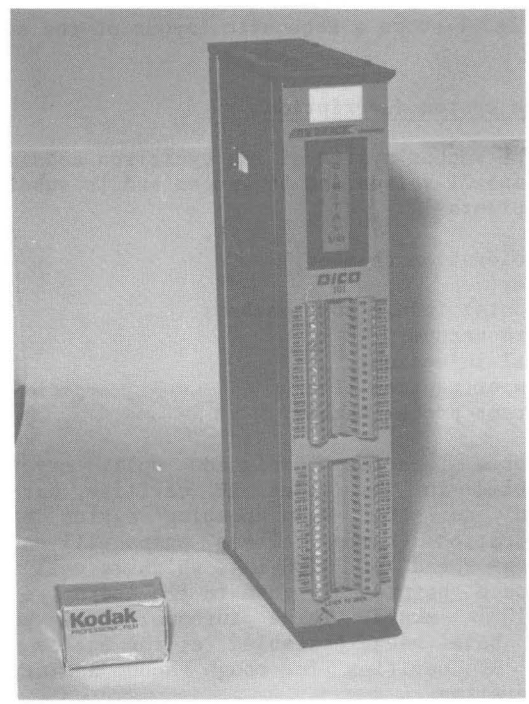

Fig. 2 - Field level I/O module.

Software

The software on the µc boards is programmed in PL/M 51, a structured language from INTEL for microcontrollers of the 8051 family. The structure of the application programs on each board is the same, regardless the specific functions to be performed. Moreover, an extensive use of structured programming techniques allows easy modifications of single procedures, without affecting other parts. Programs wait either for network order from the master CPU or for manual actions on front panel instruments. A key on the interface element selects local/remote mode of operation and according to its position the program act. When a module has been chosen to operate in local mode, manual operations are checked by the software to match interlock relations. If a request is prevented an appropriate signal is activated.

The structure of the interface modules allows the application programs to test the functioning of the vacuum elements, providing an high degree of fail-safe operation and a valuable help in maintenance planning. The RS 232 port on the μc boards is used for monitoring purposes.

To allow stand alone operation of each board menu driven programs have been developed on a Personal Computer using Quick Basic and an interface to Bitbus. This feature is useful in the debugging phase of each plant or during non trivial maintenance operations.

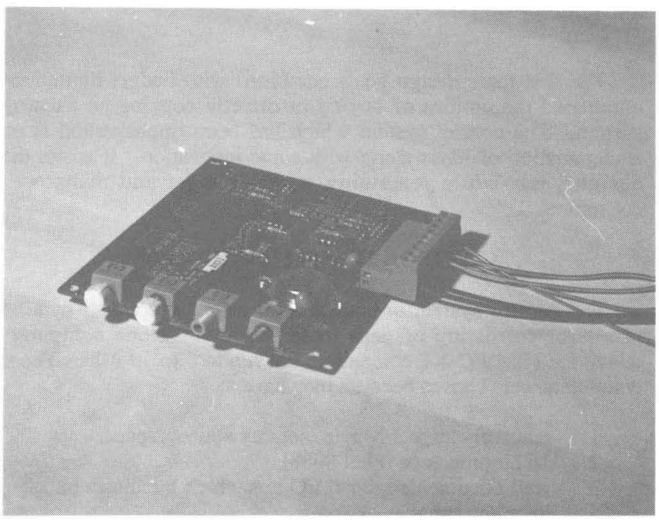

Fig. 3 - The Bitbus fiber optic transceiver.

Conclusions

The architecture of the vacuum control system for the Milan Cyclotron is completed and all the hardware elements have been already realized and tested. Applicative software is under development. Installation of the system will follow the schedule of the accelerator.

References

1) P. Michelato et al., The Milan K800 Vacuum system, Proc. XI Int. Conf. on Cyclotrons and their Appl., Tokyo, IONICS, 1987, p. 401
2) P. Michelato et al., Operational Experience on the Milan Superconducting Cyclotron Cryostat Vacuum System, paper at this Conference
3) G. Cuttone et al., Modern Control and Data Acquisition Systems for Large Vacuum Plants, VACUUM, vol. 38, 1989, p.727
4) F. Aghion et al., The Distributed Control System with Decentralized Access to an Optical Bus for the Milan Superconducting Cyclotron, Proc. XI Int. Conf. on Cyclotrons and their Appl., Tokyo, IONICS, 1987, p. 428