UPGRADE OF THE CONTROL SYSTEM FOR THE ALPI CRYOGENIC DISTRIBUTION PLANT

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Abstract

In the LNL Heavy Ion Accelerator Complex, ALPI is a superconducting linear accelerator (Linac), whose first runs date back to 1993. In more than 15 years the LNL ALPI Linac evolved from an initial small configuration of 5 cryostats and 16 resonators to the actual size of 20 cryostats and 74 resonators. The superconducting character of ALPI implies the availability of a large cryogenic plant and distribution system to supply the liquid helium necessary to keep the resonators at 4.2 K.

While the Linac structure has grown in the years and, in the mean time, the related cryogenic plant and distribution systems were enlarged and upgraded twice, the related control system remained largely unchanged in its main parts and it is now the first sub-system that urgently needs a deep renewing.

The challenge to renovate a working control system with limited shut-downs is the subject of this presentation.

INTRODUCTION

At LNL ALPI is a Linac (Fig. 1) now made up of 20 cryostats, each housing 2 or 4 RF superconducting resonators (80 and 160 MHz, either niobium bulk or niobium sputtered on copper) for a total number of 74 accelerating or bunching cavities. For all the ALPI resonators the temperature must be kept below the niobium superconductivity transition point (9.2 K), and they are therefore cooled down at about 4.2 K by liquid helium. Inside the cryostats high vacuum insulation is maintained and a cryogenic shield at 60-80 K is cooled by low-temperature gas Helium, to reduce thermal losses toward the external room temperature environment. A steel tank inside the cryostat (its capacity is about 100 l) is continuously refilled with liquid helium to keep the resonators below 9.2 K.

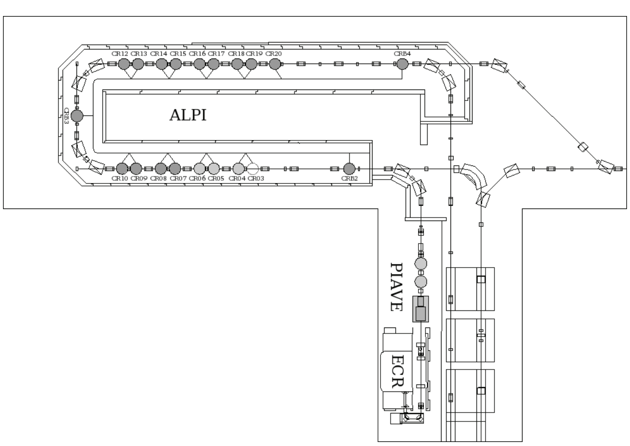

Figure 1: The ALPI linac layout.

The cryogenic plant necessary for ALPI [1] is a liquefier/refrigerator (Fig. 2) supplying both the liquid Helium at 4.2 and the 60-80 K gas Helium for the shields. The plant is composed by 2 screw cycle compressors (Mycom) housed in an external building and by a cold-box (Air Liquide - France) installed in the middle of the ALPI room, where the liquid helium is produced. A 2000 l dewar is directly connected to the cold-box for storage. The liquid helium line, the cold gas Helium line and the return lines (from the tanks and the shields) have a closed ring shape and are thermally insulated by means of Mylar and high vacuum. The cryostat tanks and shields are connected to the lines through valve boxes, In most cases one valve box feeds two cryostats, only for 3 cryostats in special positions (housing bunching or de bunching resonators) the valve box is sized for only one cryostat.

Figure 2: ALPI Cold-Box.

A good management of both the cryogenic plant (cycle compressors and cold-box) and of the distribution lines and cryostats tanks refilling system is essential to have stable and reliable working periods of the ALPI Linac.

THE ACTUAL CONTROL SYSTEM

The different parts of the ALPI cryogenic plant and distribution system are controlled by different PLC based systems. The communication among them, when present, makes use of common electrical signals or data exchange through serial lines.

The two cycle compressors are controlled by two local Schneider Twido PLCs, one for each compressor. These controllers have been already renewed some years ago. They have a limited hardware connection with the cold box control system (states, interlocks and a few common analogue signals of pressure) and no supervisory system.

Also the cold box control system was renewed some years ago and is now based on an Eurotherm PLC (PC3000), interconnected with the cycle compressors by interlocks and states and with the distribution control system through a serial line. This control system is supervised by a proprietary SCADA (Fig. 3), has a main control console, a second read-only monitor in the linac general console (for checks during the linac operation) and a separated logging system built on an OPC server with a Labview graphical user interface.

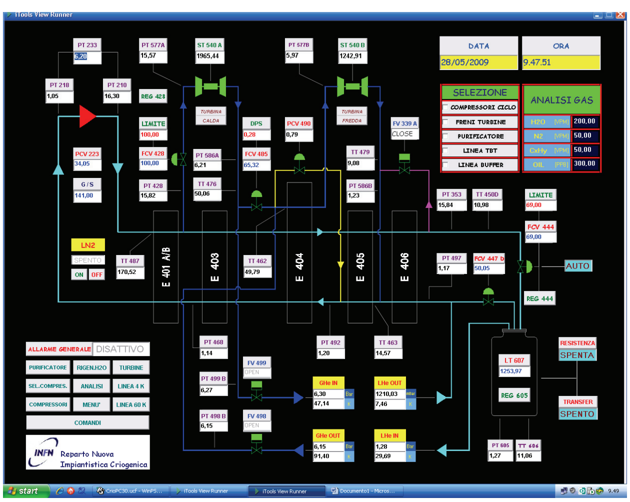

Figure 3: ALPI Cold-Box Supervisory Page.

The distribution system (cryogenic lines and cryostats) has its own control system dating back to 1992-1994. It is the biggest of the cryogenic control subsystems, with 20 PLCs a distributed topology and a large number of different instruments and actuators and the last one that needs to be renewed.

Hardware of the Distribution Control System

In the actual configuration the local thermal control of each cryostat and its tank refilling is demanded to a single Tecnint PLC model TPLC130C and its set of digital and analogue I/O cards and RS232 ports card (for cryogenic multi-sensors temperature monitors) (in Fig. 4 a rack for two cryostats is shown). All the local PLC controllers are connected by RS485 ports to a central terminal server through 485/232 converters. In the same central terminal server a group of RS232 serial lines are reserved for some monitors of the temperatures and of the insulating vacuum instruments on the distribution ring lines. The central terminal server is located in the linac ALPI room and is connected to a local control PC and to the master PC by a proprietary network (ARCNET). A connection with the cold-box control system is present on one of the serial lines, to acquire some summary states. Another connection with the ALPI vacuum control system is present both at level of local Tecnint PLCs (states and interlocks) and on one of the RS232 ports of the master PC (cryostats temperatures are supplied to the vacuum system).

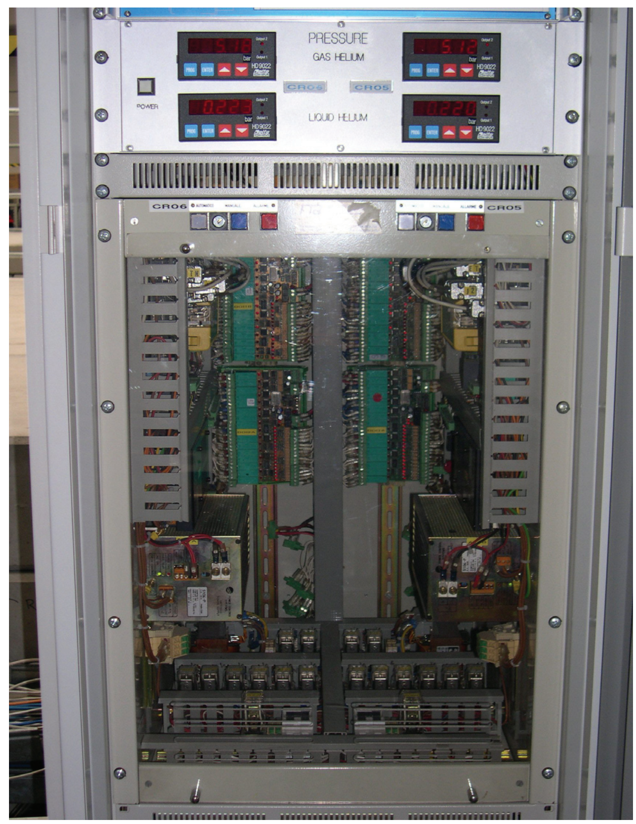

Figure 4: A rack for 2 PLCs of the Cryogenics Distribution System.

Software of the Distribution Control System

The total amount of signals that in each cryostat PLC have to be managed may be so grouped:

- 34 analogue inputs (but 24 of them come from 3 RS232 connected instruments);
- 3 analogue outputs;
- 24 digital inputs;
- 24 digital outputs.

Actually in the local control of each cryostat only some basic automation procedures, using these signals, are implemented:

- automatic management (switching on/off) of the probe for the liquid Helium level in the tanks;
- PID control of the liquid Helium level in the cryostat tanks, to maintain a given level set-point;
- baking on-off control of the resonators with one or two electrical warmer for each resonator.

All the local signals, controls and automation procedures are reported to the master PC where the supervisory system, in QNX environment, allows to monitor all measurements and states, to manually control all the valves, to start and stop the automation procedures. Several control windows are available.

An alarm management system is also included, together with a local logger. The actual master PC is shown in Fig. 5.

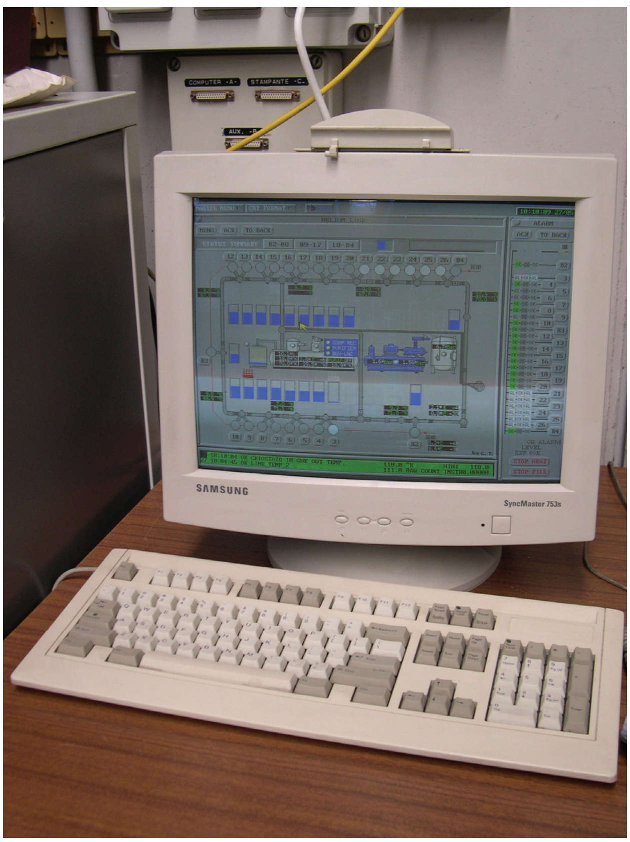

Figure 5: The master PC for the Cryogenics Distribution System.

THE REVAMPING PROJECT

The low-energy cryostat CR03 with 4 low-beta resonators is foreseen to be re-installed soon in the ALPI linac. This last module is a prototype with special features requiring a deep update of the cryostat cryogenic control: more temperature sensors, a liquid nitrogen line to cool down the RF couplers and, related to it, one more local regulation loop to keep in a stable range the coupler temperatures, when fed with RF power. This facts and the hardware-software obsolescence of the whole distribution control system were the main reasons to plan the design of a new control prototype on a more modern PLC model and with up-to-date software development tools.

Hardware

Two families of middle size PLC were considered for the new control prototype, from Siemens and Schneider.

The present control topology will be maintained, with a single control PLC for each cryostat. In the new complete system a standard LAN network (doubled, if required, for a higher availability) will be used to connect local control PLCs to a main supervisory PC with a second PC as backup on the same network. A smooth and slow transition is foreseen between the old and the new control system after a complete test of the first cryostat prototype.

Software

Both for the control PLC programming and for the supervisory PC graphical user interface the advantages of the modern integrated development environments (IDEs) will help in a rapid software development. Only industrial commercials tools and IDEs will be used.

FUTURE PLANS

The different ALPI cryogenic control subsystems, for the compressors, the cold-box and the distribution lines (in future, the helium dryers might be also added) are now almost completely disjoint and have different, if they have, supervisory systems. In the future a general purpose SCADA is planned to be used as a common framework for the differently controlled subsystems, to have a unified and general control of the whole cryogenic plant.

CONCLUSIONS

The challenge to renovate a working control system with limited shut-downs is the subject of this presentation. A prototype with modern hardware and some necessary and some useful control improvements for a single cryostat is the way that will be followed to keep the system old alive while rejuvenating it.

REFERENCES

[1] R. Pengo et al., "Cryogenics and related topics of the ALPI linac", Nuclear Instruments and methods in Physics research A328 (1993) p. 242-250 NH.