10. The control system of the EXCYT project

10.1. - Computer Control Group activity program in the 1997.

According to the last official Computer Control schedule time in the framework of the EXCYT project (A status report of the EXCYT Project, 20 May 1996), the following items were foreseen for the 1997:

Field and control level:

10.1.1. - Study (completed before the 1st half of the 1997)

10.1.2. - Test (completed before the end of the 1997)

10.1.3. - Construction (started in the 2nd half of the 1997).

The first item is the study and the analysis of the problems related to the control system architecture, the network, the apparatus interface and the man-machine interface. The goal is to consider all the choices nowadays available and, also looking the experience gained during more than 4 years of normal operations with the Superconducting Cyclotron, to design a new architecture (hardware and/or software) able to guarantee performances, reliability and high level of standardization.

The second item is the development of criteria and analysis methods of the solutions to be adopted and, after that, the quality test of the adopted solution.

The third item is the realization of the control system base structure and, in the following, the installation of each control station devoted to the apparatus management according to the time schedule of the whole project (SERSE, axial injection, primary beam line, secondary beam line and so on).

10.1.1. - Study

The evaluation and study of the problems related with the computer control system development is completed and here are reported, shortly but complete, the result of this work.

The hardware platform selected both at field level (control station) and as man-machine interface (console level) is a PC with an Pentium family processor. The control station will be provided of a suited number of interfaces mainly devoted to the instrumentation control through standard protocols (RS 232, RS 485, GPIB, etc.) or direct analog/digital I/O and data transfer toward the LAN. The console workstation will be provided of a suited number of adapters (graphics, network, tape, etc.) able to grant the access to the all local and remote resources.

The development platform selected is the operative system Windows NT. Its main characteristics are: operative system *multi-process*, *multi-thread*, process-priority assignment, the capability to manage and administer more computers and users through a LAN, compatibility with the most popular and efficient programming languages allowing a wide choice in terms of instrumentation's interface and control.

Concerning the programming languages, Object Oriented Programming (OOP), (Visual C++ and Visual Basic) and Virtual Instrumentation (VI) programming (LabView) can satisfy any requirements developing instrumentation as well as man-machine interface applications.

In particular, for the instrumentation interface the main request is the availability of low-level as well as high-level drivers that are realized by the producers themselves for the most popular programming languages and hardware platforms. LabView for Windows NT guarantees the maximum compatibility with a wide choice of products. National Instruments itself is a big hardware and software producer and this offers also an easiest way to select and individuate the best solution concerning the instrumentation control. Last, but not least, this programming language is oriented (hardware and software) toward *multi-process* and *real-time* (*embedded*) features; this is very important prospect for the future.

The applications devoted to the man-machine interface (MMI) have different requirements; in the following are reported some typical requirements at the console level.

Easy configuration and management of the display on the workstation.

Advanced graphic capabilities to display information and to set the parameter's field.

Help on line in order to help the operator in his choices.

Full control of the resources (network, printers, back-up units, storage devices, etc.) accessible from the workstations.

Integration with advanced software tools (applications) for presentation, analysis, organization and on-line/off-line data management.

Open-system with respect the network, to grant the bi-directional access to the global informational system (*internet*).

To satisfy all these requirements it is necessary to use a programming language able to access, manage and get the full control of all the workstation resources through the operative system. Nowadays and for the next future, Visual C++ is the only language that can guarantee all these requirements under Windows NT through the MFC and OLE programming; furthermore, if the graphics is developed with a programming tool oriented to the virtual instrumentation (Component Works), than any requirement can be satisfied.

10.1.2. - Test

The foreseen test program consists in the realization of some applications devoted to prove the results pointed out of the study phase, to evaluate their capability to satisfy the requirements and to furnish the necessary tools for the quantitative analysis and optimization of the system in terms of performances, reliability and versatility. In this sense, three general test categories were fixed: communication software along the *network*, *integration* between the programming languages and the communication software, instrumentation *interface*.

The most important feature of a computer control system is the engine that allows the data exchange along the network between the control stations and the console. It is not so easy to define this item mainly because it doesn't exist a commercial tool that allows a configurable, efficient and reliable data transfer, through ETHERNET, based on the communication protocol TCP/IP. For this reason it was necessary to develop such kind of application. We established a cooperation agreement with a local software-house (**SeaSoft**) with a big experience in the programming under Windows NT using Visual C^{++}; the result of this collaboration was the realization of a network tool (**SeaNet**) able to create *client* and *server* processes devoted to the data exchange between PCs through a LAN. Its main features are the versatility to realize different architectures, the on-line management of the communication channels, the update time configuration for each single station and many others. To test the performances of this tool we realized an application written in Visual C^{++} allowing us to choose the best architecture in terms of data throughout and reliability. To do that we performed several tests changing the communication channels number, the packet size, the update rate of each control station and the refresh time of the whole system. The goal was to obtain a whole update frequency of 5 Hz; the first test showed that it is possible, optimizing the update rate of each control station according to its characteristics and criticality, to obtain a refresh frequency of 10 Hz. Moreover, it is also possible to improve this rate for particular cases, for example the beam diagnostics, but this must be evaluate carefully especially looking the stability of the whole system. Another very important result of this test was the definition of the communication architecture. Such an architecture foresees no central machine, as in the past, to manage and group all the informations coming from the control stations and routing them toward the console. Now all the informations are available at the console level through dedicate communication channels directly from the control stations. The result of this new architecture, compatible with the Windows NT operating system and TCP/IP protocol features, is the improvement of the whole update rate and of the general reliability not yet so critically related with the reliability of a single machine. The network test, nevertheless their advanced status, can't be considered finished. A deeper analysis and monitor of the system behavior must be performed during the whole control system development.

Another very important test category was the integration of the communication engine with the selected programming languages. This evaluation was performed with great care because we decided to adopt an advanced technique to exchange the informations between different applications running on the same machine with the aim to improve not only the performances but also the reliability and the integration with the development environment. The communication software (**SeaNet**) was written as an **OLE** server that allows through its *methods* and *properties* a fully interaction with the environment where is installed. This means that all the applications running on the same machine have the full access, through *instance*, to the data managed by the server. OLE and MFC programming methods are the native one under Windows NT, so there are no integration problems with the MMI applications written in Visual C^{++}. It is different the situation for the LabView based applications used for the instrumentation control. OLE programming was recently implemented also in LabView, only with the latest versions, and some difficulties still persist for a full integration. We also established a cooperation agreement with National Instruments (**National Instruments Alliance Program**) to better investigate these problems trying to solve them in the best way. To obtain the full integration in the shorter time we decided to implement some special *methods* in our OLE server. The test bench for the control software was the applications developed for the new ECR source and for the axial injection line into the Superconducting Cyclotron. At the moment the integration is proved to be satisfactory.

The last test category was devoted to prove the versatility of the LabView programming language concerning the realization of high-level as well as low-level instrumentation interface applications. High-level instrumentation (power supplies, meters, multiplexers, etc.) typically uses standard serial or parallel communication. The only limitation for the serial line RS 232 is the limited number of ports available on the PC and the limited speed (baud); we solved this problems adopting, where possible, standard *multi-drop* bus as RS 422, RS 485 and CAN that don't have any serious limitation in terms of connections and speed. All these standard were successfully tested with the LabView drivers to interface different apparatus of the new source and injection line (microwave generator, coils power supplies, line magnets power supplies). The control of low-level instrumentation through analog/digital I/O lines presents the main difficulty in the standard choice; that is mainly due to the difficulty to mach the typical field level requirements with the available standards also considering the budget limitations. To realize this control level we need to develop the hardware and software necessary to interface all the instrumentation not furnished of standard interface, as beam diagnostics, motors, actuations, service plants (vacuum meters, gas, pumps, etc.) and, generally speaking, all the systems that require I/O control. Considering that the control applications are written in LabView, it was natural to investigate the solutions proposed by National Instruments; we decided to use the SCXI standard because it matches the right balance between performance and cost. Furthermore, programming with LabView it is also possible the integration of special applications (for example, imaging for beam diagnostics) until now managed through separated stand-alone machines. We are also investigating the possibility to extend the use of CAN bus at this level to solve high-performances and high-numbers problems in the data acquisition.

10.1.3. - Construction

The construction consists in the realization of the control system itself. This means that has to be assembled, configured and tested all the hardware and software necessary to realize the control stations at field level, at console level and the communication network. Also included in this work is considered the upgrading of the structure of the existing console.

The most important part of this job is the realization of the base configuration of the control system, that can be identified into the assembling of one or two control stations able to communicate through ETHERNET with one console machine from which is possible the apparatus management. This structure will permit to test all the hardware and software choices at any level. The obtained information will be as much complete as much complete will be the instrumentation set under control.

Following the time schedule of the EXCYT project, we identified in the ECR source and in the axial injection line the base structure of the control system. The high-level instrumentation interface is already done and tested. The I/O lines management application is under construction together with the related hardware. This hardware is already acquired and the assembling is in progress; it also needs the development of some electronics board devoted to particular signal treatment (for example, beam diagnostics). From the software point of view, many of the single modules are already done and tested. Now the integration of these modules will be completed in a single server process that will realize the first control station. Also at the console level the application to realize the man-machine interface is in progress; in the beginning it will receive only the data coming from the ECR source control station.

In the following, it will be reported a detailed list of all the activities, the status of the work and the foreseen end. The final goal is to manage both the source and the injection line from the console before the end of the 1998, allowing an efficient commissioning of the axial injection into the superconducting cyclotron.

10.2. - Computer Control Group activity program in the 1998.

In the program for the 1998 three main goals will be completed: the control station for the axial source, the control station for the axial injection line and the construction of the new console of the EXCYT facility. The scheduled time to set-up these control stations is strictly related with the scheduled time for the installation of the apparatus. Before the end of this year also the structure for the new console will be acquired and installed in the main console room. The workstations that will complete the console together with the network will be, at that time, already available and working. Here it is reported a detailed list of all the activities.

10.2.1. - ECR Source

10.2.1.1. - Hardware

- ECR source local console (designed together with the producer, the purchase has to be started, two months for the construction).
- High-level interface apparatus control (interfaces purchased and tested).
- Low-level interface apparatus control.

  Electronics for the HV power supplies (purchased and tested).

  Electronics for the oven (purchased, to be tested when it will be ready).

  Electronics to read the signals coming from the cryostat probes (purchased, to be tested after the first beam production test).

  Electronics to do the source spectrum (purchased and tested the B-H15 control, the analog signal conditioning has to be completed before the august 1998).

  Electronics for the motor (completed and tested).

  Electronics for the beam diagnostics signals conditioning (to be completed before the august 1998)

  Electronics for the gas injection and vacuum system (purchased, to be tested after the first beam production test).

  Electronics for beam transport line vacuum system (to be defined).

10.2.1.2 Software

High-level interface apparatus control.

- Microwaves generators (application interface purchased and tested).
- Analysis magnet/solenoid system (application interface completed and to be tested after the first beam production test).
- Superconducting coils power supply (application interface completed and to be tested after the first beam production test).

Low-level interface apparatus control.

- Gas injection and vacuum systems (to be completed and tested after the first beam production test).
- Pumping and vacuum systems (to be defined).
- HV power supplies (completed and tested).
- Oven (to be defined).
- Cryostat (to be completed and tested after the first beam production test).
- Source spectrum measuring system (to be completed and tested after the first beam production test).
- Beam diagnostics (completed and tested).

10.2.2. - Axial beam injection line

10.2.2.1. - Hardware

High-level interface apparatus control (interfaces purchased and tested).

Low-level interface apparatus control.

- Electronics to manage the beam diagnostics motors (completed the motors interface, purchased the remote control and tested).
- Electronics for the analog signals conditioning (to be completed and tested before the beam line assembling).
- Electronics for the digital signals (purchased and tested).
- Electronics for the vacuum system (to be defined).

10.2.2.2. - Software

High-level interface apparatus control.

- Power supplies (to be completed and tested before the supplies assembling).

Low-level interface apparatus control.

- Digital signals management (completed and to be tested before the beam line assembling).
- Beam diagnostics (to be completed and tested before the beam line assembling).
- Pumping and vacuum systems (to be defined).

10.2.3. - Console and LAN

10.2.3.1. - Hardware

- Communication network (defined and to be installed as soon as purchased).
- Upgrading of the remote accelerators console (designed together with the producer, the purchase has to be started, three months for the construction).
- Supplies and signals cables connections (to be done with the console).
- WorkStations and network interface (defined, the purchase is in progress).

10.2.3.2. - Software

- MMI (in progress).
- Network processes management (to be completed before October 1998).
- Communication processes via TCP/IP (completed and tested).
- Data-base and command-log (in progress).
- On-line/off-line data analysis (in progress).