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Interfacing Industrial Process Control systems to LEP/LHC

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Abstract

Modern industrial process control systems have developed to meet the needs of industry to increase the production while decreasing the costs. Although particle accelerators designers have pioneered in control systems during the seventies, it has now become possible to them to profit of industrial solutions in substitution of, or in complement with the more traditional home made ones. Adapting and integrating such industrial systems to the accelerator control area will certainly benefit to the field in terms of finance, human resources and technical facilities offered off-the-shelf by the widely experienced industrial controls community; however this cannot be done without slightly affecting the overall accelerator control architecture. The paper briefly describes the industrial controls arena and takes example on an industrial process control system recently installed at CERN to discuss in detail the related choices and issues.

I. INTRODUCTION

Computers have gained a major importance in the overall design, construction, operation, maintenance and exploitation of today's accelerators and it is not exaggerated to say that, without them, physics research would not have become what it is, and conversely that the development of computers was highly due to the needs of basic research.

Pioneering in a statistic based research domain like particle physics leads the engineers and physicists to work at the limit of what is possible in fields like electronics, mechanics, computing, materials,etc. . They have to look permanently for and to try to make profit of new promising technologies, as soon as these emerge from laboratories. They then get used to live ahead of industry in a lot of scientific fields. They finally accept as a fact of life to develop everything they need, because they do it better, tailored to their needs, with higher performance than what they can readily find.

This is the case at CERN where people have felt in the early days the potential embedded in the computers to help them solving controls problems. Many of the basic components which make up a particle factory are now well known and currently manufactured by industry. The particle accelerators are quite comparable to other industrial machines. The running of a particle factory leans mostly on domains for which industry has developed several control systems solutions. One may profit today of this opportunity, in our new era of restricted human and financial resources.

II. THE COMPONENTS OF AN ACCELERATOR

A. *Inventory of components*

Components may be classified into two categories depending whether or not they actively participate in the production of particles: the first category will be referenced as *active* in this paper and the second as *passive* (see figure 1). Magnets, RF cavities, electrostatic separators, power converters, beam instrumentation are *active* components. All play an active role in keeping an accelerator state as well as in performing the transitions from one state to another. Electricity, vacuum, cooling & ventilation, cryogenics, personnel protection, site access are *passive* components.

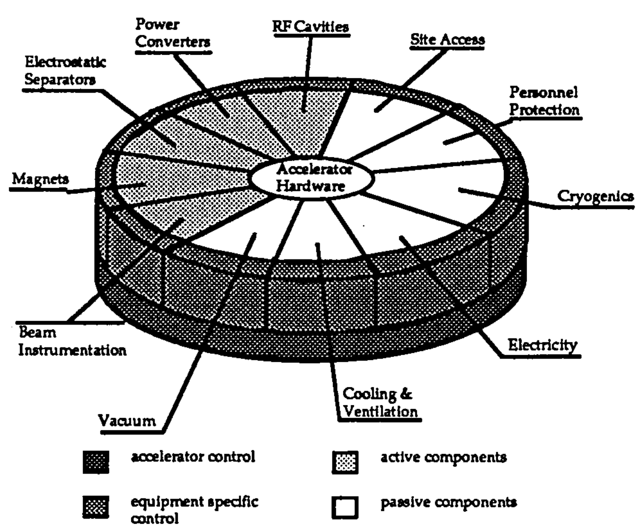

Figure 1. Accelerator components

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B. The two views

Although all these components possess their own process control layer which the operator accesses through the accelerator control system, a component represents a lot of similar devices geographically distributed along the accelerator. Therefore the architecture of the overall control system has to cope with both aspects of large variety of components and wide spread of equipment along the accelerator. This explains the two views which have always developed in the past. People responsible for their equipment like to have an overview on all their equipment through component oriented consoles whereas people responsible for the control of the overall accelerator want to operate from an accelerator oriented console. There is no reason why the accelerator control system can not be designed to offer the openness which is necessary to marry these two requirements.

III. THE INDUSTRIAL CONTROL OFFERINGS

A. Domains of application

Industrial control systems have considerably developed since the seventies. They are present in industrial fields like energy production, electrical energy transmission and distribution, pharmacy, chemistry and petrochemistry, food industry, metalworking industry, paper manufacturing, glassworks, cement works, transportation, etc. . From this large variety of fields of applications, industry has gained a lot of experience. Figure 2 shows the functional layers which have been identified by industry and on which common hardware and software is built, allowing the research and developments cost to be shared between the different buyers [1].

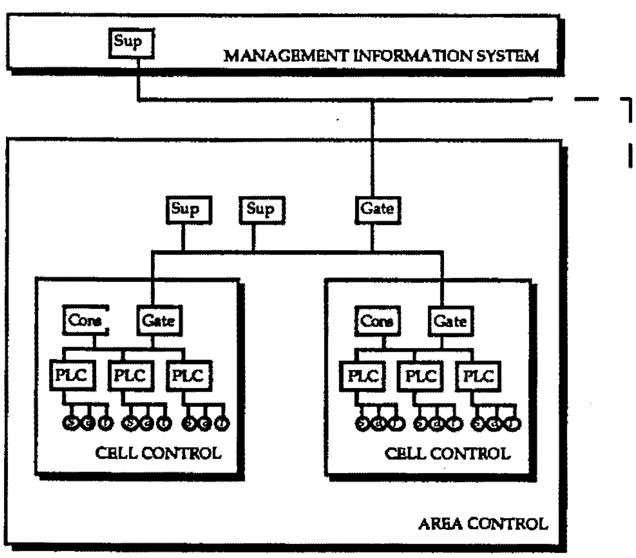

Figure 2. Industrial control functional layers

B. The different solutions

The industrial control market may be divided in two big categories.

The first one includes the Distributed Control System (DCS) supplies. They are provided by manufacturers issued from two different origins: big Programmable Logic Controller (PLC) makers or computer makers. All these suppliers offer complete control solutions with basically the same features:

- PLCs and full range of In/Out (I/O) interfaces to connect to sensors, actuators, etc.
- redundancy capability for I/O interfaces, controllers, power supplies, cabling, etc.
- environmental hardening
- local operating facilities
- multi-layered communication
- engineering tools for configuring, tuning and documenting
- color graphic operator interfaces for process control view or system overview with logging, trending, archiving and alarm management facilities
- application support including installation, commissioning, training and maintenance

The other category of supply is aiming at simplicity and low pricing. Their manufacturers have limited their offerings to the bottom layers and have in mind the supply of laboratories, restricted test facilities, and non distributed equipment. They offer:

- PLCs with restricted capacity in number of I/O points
- simple communication (RS232, etc.)
- limited graphic operator interface for process control view, with some logging, trending and alarm facilities
- primitive engineering tools for configuring

In order to fill in the gap between this small scale solution and the complete one, other companies have developed very sophisticated process oriented application enablers software packages on different standard hardware (PCs, Vaxstations, etc.) and software (UNIX™, DOS, OS/2™, etc.) platforms They provide interfaces to most of the PLCs. They have an unbeatable openness and attempt to integrate all the possible features one might expect to help configuring, tuning and supervising. A lot of attention has been paid to the application programming facilities and environment with graphics and animation editors, all kinds of operator inputs (keyboard, mouse, trackball, touch screen), math functions, logic operations, batch functions, graphic and language base programming facilities, time scheduled events and intervals, real-time and historical trending, alarm monitoring, supervision and logging, report generation, etc. .

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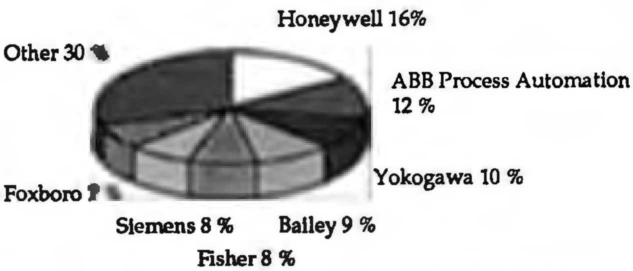
C. The contenders

In the first category there are less than thirty suppliers in the world and seven of them share more than two third of the market (see figure 3). The actual solutions they propose are very much proprietary. both at the hardware and software level. Due to their size and the commitment to preserve the investments of their customers, they have to keep compatibility during the evolution of their products. This is a very heavy constraint.



Source : ARC 1990 DCS Report

Figure 3. Worldwide DCS market shares

The second category is much more crowded and is occupied by hundreds of equipment manufacturers. They could care less about customers' investments as the cost of their supply is much more affordable. The market is covered by equipment manufacturers, laboratories and simple test systems. Examples of such supplier are Satt, Makmodul, SAIA, etc. . The big manufacturers of DCS are also offering products in that category. Industrial control application enablers package suppliers have names like FactoryLink™, Wizcon™, InTouch™, etc. .

D. Use of industrial controls in accelerators

Among the two categories of components in an accelerator, the *passive* components are the one which fit naturally with industrial control, as they run independently of the particle manufacturing process. Their processes do not fundamentally differ from those of similar equipment currently used in other factories, except for cryogenics for which there is not much experience in the world in the industrial production of very low temperature refrigerated helium.

The *active* components present to the control system very strong constraints. They are tightly coupled to the beam and, for an accelerator operator, are real-time process control elements. Those are normally attached to PLCs in an industrial control environment. Industry does not yet offer solutions matching large geographical spread together with tight real-time constraint.

IV. LEP ENERGY UPGRADE

A. LEP 200 new equipment inventory

LEP is the latest CERN leptons collider which came into operation in 1989. Its energy is currently limited to 50 Gev per beam but provision was made, at the design stage, for most of the equipment to allow for an increase in energy to almost 100 Gev per beam, in a second round. This energy increase project [2] is now on the way and is planned by the year 1994. The major differences with the actual machine come from the new 192 accelerating RF superconducting cavities, which will be installed in the four even interaction points of LEP . Each of this even point will be equipped with a cryoplant [3] having a cooling power of 12 kW at 4.5 K temperature. Other modifications concern:

- the replacement of the eight superconducting low-beta quadrupoles for another set of eight with a higher gradient (36 T/m→55 T/m)
- two additional electrostatic separators at each even interaction point
- new collimators at the end of the even arcs to shield the superconducting cavities from synchrotron radiation
- a few new beam position monitors
- forty new power converters, which added to the redistributed existing ones will extend the possible operation energy of the magnets from 65 to 100 Gev
- an increase in electrical power from 70 to 160 MW and its distribution
- eight new cooling towers in correspondence with the electrical power increase

B. Industrial controls for LEP 200

LEP has been completed in 1989. Although industrial controls have been sparsely used in cooling & ventilation and emerging cryogenics, their general introduction was not supported at that time by any coordinating body or task force. The problem of their integration in the overall control system was either treated as a single case or neglected. Since then, we have undertaken to study carefully the problems which will be posed by their wider introduction trying, in association with industry, to find harmonious solutions.

The first opportunity is given by the LEP energy upgrade. As may be seen from the above list of modifications, the major change concerns RF superconducting cavities and cryogenics. The other modifications are either a replacement or a minor extension of existing equipment. Cryogenics is far the best candidate for a first full industrial control implementation as it has a fair size, it belongs to the well fitted presumed category of *passive* components and HERA is making a similar trial with it [4]. In addition, time is just right to make this attempt as CERN is facing new economical conditions where the budget has to be kept constant while the human

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resources are regularly reducing towards a twenty per cent diminution level.

A specification was worked out under the responsibility of one cryogenics expert [5] who had the original idea of getting the control industry involved. It included the supply, installation and commissioning of:

- the hardware to interface to the different components of the cryoplant, i.e. compressors, cold boxes and cooled helium distribution
- the operating consoles and peripherals
- the basic system software with the various engineering tools
- the application software to run the processes and supervise the overall installation. Definition of the processes is a joined effort between the cryoplant components manufacturers and CERN cryogenics experts

The dimension of the overall cryogenics control system is in the order of 15000 I/O connections. The tender gave several positive responses, offering acceptable solutions and was adjudicated in April this year.

Although some guidelines were given in the specifications, integration in the CERN environment was left much more open as the best solution has to be found through various possibilities in a joined effort with the supplier.

The large area covered by the facilities existing at CERN has imposed the building of a large and well structured communication network on the CERN site. The basic communication system is a Time Division Multiplex (TDM) which runs over either coaxial cable or optic fibers, where the level of radiation permits it. This system follows the G703 recommendation of the CCITT [6]. The TDM offers a variety of services for the operation of the accelerator: computer networks, timing systems, data transmission, digital telephone exchange, etc..

The operation team of the particle accelerator sits in the Prévessin Control Room (PCR). The specialized cryogenics equipment will be controlled globally from a central location, the Cryogenics Control Room (CCR). The processes controlling cryogenics has to run inside computers situated in a Cryogenics Equipment Room (CER) near the equipment, all around the accelerator. Figure 4 shows the basic layout.

Supervision from the CCR needs reliable communication between the CERs and the CCR. For this purpose, the industrial control supplier was given the choice of either using point to point links via special supplier proprietary interfaces connected to private TDM channels or to make use of the computer network via the IEEE 802.5 (token passing ring) or IEEE 802.3 (Ethernet) standards. The usage of TCP/IP (Transmission Control Protocol/Internet Protocol) has been recommended. Tests of the different solutions have been planned for the end of this year in a joined effort with the supplier.

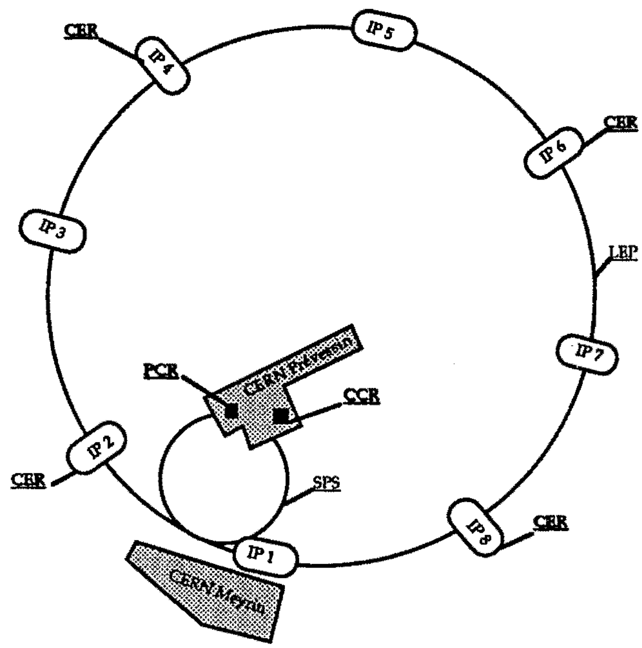

Figure 4. Cryogenics in LEP 200

Cryogenics as a *passive* component does not need very tight connection with the PCR. Cryogenics process operating states, a subset of the alarms and general diagram displays are sufficient to inform the accelerator operators of the cryogenics behavior. But provision has been made to allow for some restricted and well protected commands in order to get rid of eventual abnormal process behavior waiting to be understood and cured.

Industrial control suppliers currently offer solutions based on standard platforms to connect their system to the plant network. One µVAX 3100 running VMS and linked to Ethernet will give this possibility, by means of an access library available from the supplier, to access any equipment connected on its control system. Accelerator operation oriented data collection and restricted access will be easily implemented. All this is planned for installation before the end of this year.

V. LHC

A. LHC equipment inventory

LHC is the future CERN Large Hadron Collider to be installed above LEP in the same 27 kilometer tunnel. This machine will accelerate particles and hold them on a circular

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orbit by thousands of superconducting electromagnets, cooled down at a temperature of 1.8 K [7]. These will be the most challenging equipment as they require a huge cooling capacity. For this purpose, it is foreseen to increase to 18 kW the cooling capacity of the four refrigerators which are to be installed for the actual LEP energy upgrade. In addition, new refrigerators will have to be installed in the odd points. An extension will have to be added in order to lower the temperature to 1.8 K. The required 16 MV RF voltage will also be provided by superconducting cavities.

LHC is a complete new machine and requires the installation of a large number of new equipment of the *active* component category. The same requirement applies for the vacuum in the *passive* components category, but electricity, cooling & ventilation, cryogenics, personnel protection and site access will just require some extension to existing ones for LEP, if any.

The big difficulty will come from the sensitivity of the superconducting electromagnets to quenching under beam loss. Some of the *active* components will have to cooperate rapidly through computers to try to prevent this from happening [8]. It is premature to say that industrial control systems will be unable in more than 5 years from now to cope with such requirements. The question has not yet been debated with industry and has not the first priority in this preliminary industrial controls evaluation.

B. Industrial controls for LHC

The extension of cryogenics has already been foreseen in the contract with the industrial control supplier. A dimension of up to twice the size of the actual system could be envisaged without causing any problem.

Supposing hopefully that the cryogenics experience turns to be positive, the people responsible for other components in the *passive* category will have the difficult decision of opting for the extension of their process control system or for an industrial one. Important parameters of the decision will be the size of the extension, homogeneity, maintenance, training, consolidation, human and material cost, etc. . Replacement of existing LEP process control equipment to put the extension in a global industrial control solution might be even desired by the process experts but could prove to be difficult in the actual context of budgetary constraint.

Industrial control suppliers are fully aware of the importance of international standards. In the next few years, the traditional proprietary approach will be abandoned in favour of standard based solutions for all the products which will be supplied. This will range from basic hardware interfaces to operator consoles, from operating systems to software engineering applications. Openness and Management Information System will be the magic words of the next decade. The control industry and CERN have clearly a common approach which could well come out into some active collaboration in view of the LHC project.

VI. CONCLUSION

Passive components of an accelerator are the most promising equipment for which industrial controls solutions can be easily found. However if this would be rather easy to realize in a free environment, the implementation could prove much more difficult in the two major CERN projects of this decade, LEP 200 and LHC once approved, as most of the eligible new equipment will mostly appear as extensions. Nevertheless the opportunity could also come for LHC from aging equipment considerations, knowing the tremendous speed of evolution in the control domain. Meanwhile, aside accelerator prospects, there are other domains of applications in a laboratory like CERN where the industrial controls fit naturally. These are all the basic services like heat production, water distribution, general electricity (back-up electrical supply, distribution, etc.), etc. and the large bench test facilities needed to validate the numerous accelerator equipment before installation like magnets, RF cavities, etc. Basic services are already largely committed to industrial controls but their consolidation will need much more homogeneous and integrated solutions. Large test facilities have factory dimensions and are very much concerned with the traditional industrial production concepts. Industrial controls will play a very active role in all these domains in the very near future and there is no doubt that a huge experience will be gained for the benefit of our accelerators.

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