EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH
Laboratory for Particle Physics

Divisional Report

CERN LHC/2000-1 (IAS)

EXPERIENCE WITH THE MULTI-YEAR IMPLEMENTATION OF AN INDUSTRIAL CONTROL SYSTEM

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Presented at the Seventh European Particle Accelerator Conference (EPAC 2000)
26-30 June 2000, Vienna, Austria

Administrative Secretariat
LHC Division
CERN
CH - 1211 Geneva 23

Geneva, Switzerland
24 August 2000

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Abstract

In 1990, CERN passed a multi-year purchasing and installation contract for the LEP 200 Cryogenics control system with ABB, one of the world's leading suppliers of integrated Distributed Control Systems (DCS). A financial framework provided over a period of eight years the required supplies. These were called up with so called 'Release Orders', taking into account the latest technical developments. The issues and experiences with such a new approach and the resulting control system are described.

1 THE HELIUM LIQUEFIERS

In 1990 CERN started the project "LEP 200 Upgrade", successfully concluded in 1998. The beam energy of the LEP collider (at 104.2 GEV today) was to more than double with the installation of 288 superconducting RF cavities. Each of the four even numbered LEP sites was to be equipped with a helium liquefier with 12kW capacity at 4.2K, increased lately to 18kW to meet the needs of the LHC, and to reach today's LEP-2000 energy. Each installation was divided into five parts: The compressor stage CPR with the local control room and the Upper Coldbox UCB on the surface, and, 40m to 140m below in the tunnel the Lower Coldbox LCB and the two loads Left (LCR) and Right (RCR) Cryostat, each with its 8 or 10 RF modules. The contract included these four 12kW units and two smaller ones of 6kW. The delivery of these refrigerators started in 1991 and extended through 1994.

2 THE PROCESS CONTROL TENDER

The gradual delivery of the equipment to be controlled called for the same to be done with the control system. A second decision was to outsource the software with CERN retaining only the responsibility for the process description and the commissioning of the control system. The call for tender established the overall costs of the future control system. Delivery and installation of both hardware and software would however be done only when and where needed. The contract run for six years to the end of 1996, with an option, exercised, to extend it through 2000.

The technical specification for the LEP 200 Process Control System was based on the experience gained with smaller 1.2kW refrigerators and an earlier ABB contract. The hardware specification was the customary list of IOs with their geographical distribution and their linkage. For the software we had to quantify somehow the software effort. Analog and digital process units PU were defined. They subsequently became today's objects. With these PUs one tried to describe a largely unknown industrial process, as the planned liquefiers were about 10 times the size of the existing ones. In addition one had to estimate Operator interfaces. Neither P+I nor signal flow diagrams nor motor lists were available. Based on the resulting technical specifications ABB, in March 1991, again won this Cryogenics controls contract. It called for the delivery of goods and services not to exceed just over 10 MCHF. Both software and hardware run to about half of that total.

3 CONTRACT EXECUTION

The call-up of hardware with "Release Orders" did not pose any problems. ABB delivered in general on or almost to the desired day. ABB automatically would furnish the latest hardware revision, together with the latest basic software. But as the installation grew in we had to specify the exact versions to be delivered. With more than thirty controllers and workstations the free interchangeability of controllers and their basic software became impossible.

The two partners agreed early to go beyond the usual customer-supplier relationship in instituting bi-annual "Advance Information and Coordination Meetings", alternating at CERN and in Västerås. The latter place indicates the importance ABB gave to this partnership. The coordination part of the meetings would be dedicated to current affairs. The "Advance Information" part was used to inform about upcoming projects, such as the LHC. Once ABB had established the confidentiality of their partners, CERN was regularly informed about new ABB projects. This became very important for CERN's contract managers: ABB's openness allowed planning ahead for purchases knowing about upcoming product improvements. CERN also was named one of ABB's select "Beta Tester" customers. In February 1994 we took delivery of one of the first AC450 controllers for testing. Three months later we put it into daily operation. The unit was not replaced until two years later during a general upgrade program. From 1994 onwards, all our planning was based on these new controllers, more than one year ahead of their official introduction to the markets. The same was true for the new Advant-OCS® line of Operator stations (OS) and Information Management stations (IMS). The early knowledge about all these products allowed us to arrive at the end of the contract with an up-to-date installation. The extended installation of the refrigerators brought with it increasing demands and extensions of the originally planned system. These later extensions profited from new fieldbus type equipment, such as Profibus®, hence decentralizing the control system. Where new AC450 controllers replaced older ones, the recuperated equipment served as upgrade for older installations from the same company dating back to 1986. The output devices are fully compatible throughout the three generations of controllers, [1], and [2].

The schedule called for the installation of six liquefiers in two different sizes (6 and 12kW), from two suppliers (Air Liquide and Linde/Sulzer), over a four-year period. This complicated the software production. We were faced with four different layouts. A serious flaw, the refrigerator schedule did not provide enough time to establish and produce the basics of the user application programs. Only three months into the contract, the first application software for testing the first refrigerator had to be delivered. Despite great efforts from all sides, we never really recovered from this unfortunate beginning. We however stuck to the initial decision that object-oriented programming would be used. The main advantages are well known: it allows teams of programmers to write various segments of application software concurrently in a coherent way. It facilitates its maintenance, as such software shows only minimal "personal" traits.

The objects were classified into four hierarchical levels, in ascending order of importance called III, IIb, IIa and I.

Level III provides the connection with the equipment. We find here the several types of valves, heaters, pumps, and other basic devices. Self-checking, self-protection and alarm analysis for higher levels are carried out. It allows manual device operation and testing. No external interlocking is done on this level, as our basic definition did not allow such horizontal Level III connections.

On Level IIb, several Level III objects are combined into higher order objects, such as a turbine consisting of the three objects input valve, break valve and gas bearings. On this level one tries to avoid external interlocks, but they are not excluded. Within such an object, interlocking between its components is allowed.

Level IIa consists of whole plant segments such as the Compressor stage, or the individual parts of the Coldbox. Whole sequential activities such as "Start Compressor Stage", "Cooldown Coldbox", "Cavities Warm-up" may be programmed and carried out.

On Level I the different plant segments are coordinated. Global orders are carried out such as "Start Cooldown", "Emergency Stop and Recuperation", or others. [2], [3].

The three months mentioned earlier were too short for the specification, definition and production of even only a rudimentary version of Level III objects. Then we had to deal with an industrial firm and its different professional environment compared to the CERN. ABB was unable to accommodate our sudden demands within the desired time. A first object version was available at the end of 1991. It met all defined criteria and almost all cases, creating the first of two memory shortages, this one solved by doubling the memory capacity, and the creation of "light objects". The other shortage occurred when trending requirements for optimization of refrigerator operation surpassed by far initial estimates. The necessary retrofit of 30 controllers was a major deviation from the original proposal; the two partners had to negotiate a technical and commercial solution acceptable to both.

Other problems surfaced when the two refrigerator suppliers used different approaches for the liquefaction process. Differences in objects resulted. Once all plants were operating routinely, a consolidation program was started to unify object types throughout. Better overall planning would certainly have contributed to economies. However the investment of time and money into the objects started to pay off these past few years when complete overhauls were made for the 6kW refrigerators, and today for the first 18kW LHC unit, with less than a quarter of the original costs for the respective user application programs.

4 OPERATIONAL EXPERIENCE

The overall layout is described in detail in [4]. Each of the four sites, located on a circle of about 9km diameter, has its own local control room, essentially independent of the other three installations. Each site counts some 2600 I/O channels, plus 120 trend curves from each of the five controllers. The CPR controller handles the linkage towards the central Cryogenics control room. [3], [4].

Local operation is used only during the yearly maintenance and on loss of communication. The cool-down or warm-up of the cavities can take several days. On loss of the compressor stage within 10 seconds helium gas will boil off at a rate of several liters per second and the local supply (9600 kg) is lost within 6 hours. Therefore extremely high reliability of the control equipment is very important. The equipment met fully these high expectations: Since the first refrigerator became operational in 1992, the MP200/1 and AC4x0 controllers logged over 625'000 hours during machine operation. In only four instances the loss of cryogenic facilities, resulting in loss of beam time, was due to the ABB control system. We experienced three CPU failures plus a general communications breakdown. Two more capital breakdowns occurred just after the start of a general shutdown. There were the customary defects, without incidence on beam-time, such as unexplained suppression of tasks, loss of trend data, or the occasional destruction of an I/O channel.

The Cryogenics control network always was a closed environment with separate links to its own control room. Earlier, a DEC based machine provided the interface to the CERN world. With the new Advant line, HP-UX based IMS stations provide the bridge to the CERN-wide used Oracle® database system for retrieval of information from the ABB system. The operator stations provide remote access possibilities via their X-Workplace facility from Macs and PCs. With the opening up of the proprietary software small firms start to produce tailor-made products. Tests are currently under way to replace our in-house produced user application programs providing for rapid transfer of ABB data into CERN's Oracle® databases. We are introducing Aspen Technology Inc.'s 'CIM-IO for ABB's Advant IMS Interface'. Again, in exchange for ease of maintenance, we shall be faced as elsewhere with the version and upgrade problem.

5 SOFTWARE UPGRADE ISSUES

With the Master system we had a generally stable situation, moreover so, as it was an integrated, closed and proprietary system. This has changed with the Advant-OCS® (Open Control System) system. ABB's software too became tributary to external software upgrades. Whilst this may be of minimal importance in a normal single-vendor environment, it became a major problem in CERN's wide-open multi-vendor environment where many companies and products do and must coexist. This issue of upgrades, revisions, bug releases and their financial consequences had not been addressed within the original contract framework. Furthermore CERN wants to control the time frame, frequency and size of upgrade operations. The cryogenics being a crucial part in the successful LEP operation, a general hands-off policy exists for a smoothly running control system. Only new requirements or external compatibility problems such as the data archives would trigger upgrades. And this only during the annual shutdown. After protracted negotiations a mutually satisfactory agreement was found: CERN is free to choose the upgrade version, and the equipment affected, and pays a reasonable percentage on that specific system software.

Another issue to be addressed before signing a contract is the one on tags, I/O signal counts etc. where one pays for signal handling limits. In a large installation it is impossible to use tailor-made counts. One wants to reach an agreement for a uniform number throughout the system. It facilitates greatly replacement procedures. The solution would be an all-inclusive multi-user, site-wide license encompassing all the material concerned. At least at present most industrial partners still shy away from this.

6 COMPATIBILITY ISSUES

Since 1986 ABB has marketed three hardware generations and their connected software. The backward compatibility has been excellent. Old and new MMI interfaces, MP200/1 and AC4x0 coexist within the same installation. This will not change with the next controller generation. The UAP software normally was recoverable to 95%. The only total break was encountered when we replaced the MasterViews® with ABB's new HP-UX based Advant-OCS® Operator stations. The porting of the CERN objects to the OS520s took some time and efforts. Based partially on our experience, ABB today proposes software that eliminates this problem of adoption. But the decision to create the objects is still correct.

ABB's Master/Advant-OCS® control system is integrated from top to bottom. This has been a most appreciated feature of their products. There is no need whatsoever for special software to adapt different software products, such as between controllers and SCADA, or SCADA and MMI interfaces, as is often required when purchasing control systems from integrators or from smaller hardware producers. The possibly higher initial costs are definitely offset when considering the lifetime of the equipment. Our oldest, still running ABB control system dates back to 1986. For basic accelerator services such as cryogenics, such longevity of installations is not uncommon, and must be strongly considered when making the initial investment. Also the association with a supplier of an integrated product improves the probability that one will not be faced with a sudden loss, interruption in service or disappearance altogether of products or even suppliers.

7 REVIEW OF EXPERIENCE

When working as closely with an industrial partner as it was done in this project, it is essential that both sides understand the partner's environment: Here it is primarily of commercial, there of academic nature.

Limited changes in managing personnel establish a higher degree of confidentiality. ABB provided advance information earlier. Conflict resolution is facilitated.

The Beta test agreement provided valuable insight for us about future products, and for ABB equal valuable input for improved design. CERN's environment provided a most welcome rugged test site for their new equipment.

Today's industrial equipment is of excellent reliability. The integrated control system enabled us to execute this project with a minimum of personnel. CERN staff only configured the MMI process displays and wrote the interface to its Oracle® database.

Uniformity of basic software (as for tags, artificial I/O signal limit handling, limitations due to pricing aspects) is an important operational and maintenance aspect. This pricing issue must be settled at the outset of a contract.

The bi-annual meetings in Geneva and Västerås were essential for problem solving in an informal framework and as forum for the development of long-term strategies.

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