

Deployment and integration of industrial controls : the case of LHC cryogenics controls

P. Gayet, C-H. Sicard

CERN, Geneva, Switzerland

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The second phase of this project will involve its integration with the LHC accelerator controls, both at the information exchange level (alarms, data logging) and at the device configuration level.

This phase takes advantage of the integrated design at PLC and SCADA level, leading to the use of configuration tools which can be easily connected to the generic device configuration model of the accelerator controls.

DEPLOYMENT AND INTEGRATION OF INDUSTRIAL CONTROLS: THE CASE OF LHC CRYOGENICS CONTROLS

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1 BACKGROUND

Cryogenics will be extensively used in LHC, both in the accelerator and in the detectors. In order to rationalize the control effort a common project was launched in 1999. This project called UNICOS for UNified Industrial Control System, provides an homogeneous control system for the cryoplants supplying liquid helium to the LHC accelerator, the cryogenic equipment in the machine tunnel, and the ATLAS & CMS cryogenic systems.

The technical design took advantage of accumulated expertise on previous cryogenic systems such as for LEP2, also based on industrial control systems.

2 UNICOS DESIGN CONCEPTS

The hardware design relies on a three-layer model using distributed I/O connected via field-networks to a process control layer and a supervision layer.

The software design builds a model of the complete process as a hierarchy of process components or devices (I/O channel, actuator, set of sensors and actuators constituting a process entity).

Process components are implemented in two parts, one in the process control layer and one in the supervision layer, which communicate together. The PLC layer takes care of all facilities to drive the device either by the

operator (Manual mode) or by the logic of a higher-level device (Auto mode), in addition to its response to external inputs such as interlocks.

The corresponding part in the SCADA layer is provided for the operator to view and manipulate the devices.

3 UNICOS FOR LHC CRYOGENICS

3.1 LHC Machine Domain:

At the time of publication, half of the process control systems for the cryoplant side (warm compressor stations, surface and underground 4.5 K refrigerator Cold Boxes, 1.8 K Cold Box and Cryogenic Interconnection box) have been developed. Their actual implementation and commissioning in the five LHC points where cryoplants are located has reached more than 35% of the total, the remainder will follow the hardware delivery schedules until 2006.

The concepts of the tunnel cryogenics controls have been validated on the LHC String2 magnet test facility in June 2003.

3.2 LHC Experiment cryogenics

This concerns the CMS superconducting solenoid and its cryoplant, the ATLAS toroids, central solenoid and end-cap magnets with their associated Helium cryoplant, plus the cryoplant for the Liquid Argon Calorimeter.

For these systems, development work is being shared between industrial firms, CERN and external labs - LAL Orsay (F), Brookhaven National Lab (USA), Rutherford Appleton Lab (GB).

To give an estimate of the size of these control systems, there are around 42,000 I/O points in total, managed by about 70 process control units.

4 DEPLOYMENT METHODS AND TOOLS

The above design has been concretised with the following implementation. As far as possible, the deployment is subcontracted to teams in charge of common services such as consoles, servers and network.

4.1 Hardware architecture

The three layers of control architecture are implemented as follows (figure1):

- The Supervision Layer: The implementation relies on the Operator Workstation (OWS) as human interface and client of a redundant data server holding the real time database. The SCADA supervision software is based on PVSS-II® from

ETM AG, which is the CERN-wide selected SCADA product.

- Control Layer: All process control duties are performed in this layer in Schneider Quantum PLC; the object model is implemented in that PLC.
- Field Layer: Schneider Premium PLCs are used to implement I/O objects. An alternative solution using Quantum remote I/O can also be used.

In the LHC tunnel, WorldFIP fieldbuses collect the magnet cryogenic instrumentation data, while a Profibus fieldbus connects the valve actuators which are implemented with a Profibus-PA interface.

- The communication relies on the Ethernet TCP/IP CERN infrastructure provided by the CERN Network service. This network must be highly reliable as control loops are closed through it.

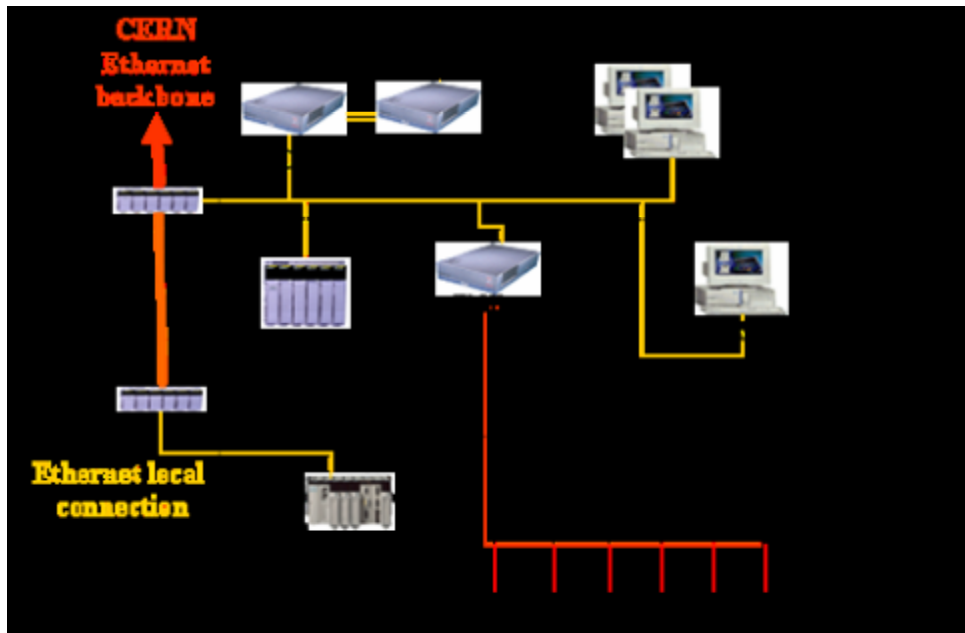


Figure 1. Actual Hardware implementation scheme for LHC Machine

4.2 Software production

Implementation and maintenance constraints

Due to the cryoplant hardware commissioning scheduling, the process control of a cryoplant is progressively built from several subsystems. This requires the capacity of the process and supervision layers to be extended in multiple steps without a negative impact on the subsystems that have already been commissioned.

The implementation is shared by multiple teams, who are geographically distant and work independently.

The process software will need to be maintained by a small team, that has taken only a limited role in the implementation.

The above constraints have led us to impose, in addition to the design methodology and specification format, strong common rules in the process coding and organisation [1].

Process engineers, educated in the Unicos specification method, provide their specification as a Word template for the process logic and an Excel template for the I/O definitions.

Generation tool

The need to guarantee coherency between addresses of objects in PLCs and their corresponding variables in the SCADA has required, from the start of the implementation, the use of a generation tool.

This tool has been progressively extended, in order to automatically build the instantiation of process variables in the PLC and their hierarchical interconnections for the I/O and Field objects. This reduces the PLC configuration work and allows us to provide supervision panels for the commissioning of I/O and Field objects without the need of any manual programming in either the PLC or the supervision layers.

The specific process logic still requires to be manually programmed from the specification documents.

A PVSS-based framework reduces most of the application development to configuring synoptic panels, as most of the functions required by operation are integrated in this framework (navigation, trending...)

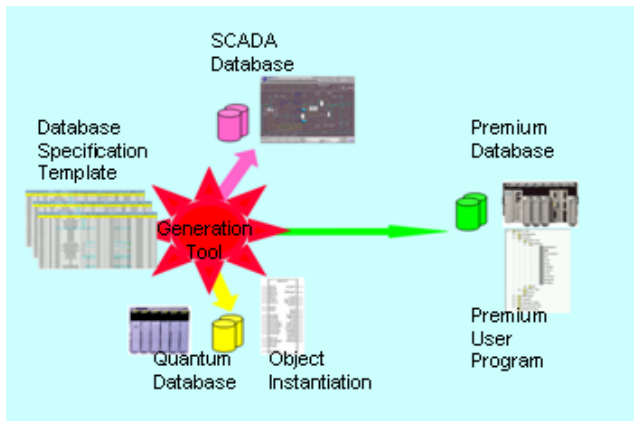


Figure 2: Generation tool

5 INTEGRATION

During the whole of the cryoplants commissioning phase, the SCADA supervision provides all the necessary facilities needed by the cryogenic process engineers.

However, from the time where complete LHC sector commissioning starts - 2nd quarter 2005 - the cryogenics controls will need a complete integration with other systems of the accelerator.

The main objective of this integration is to allow accelerator operators to view and control all accelerator subsystems (cryogenics, power supplies, quench protection, vacuum, etc) in a unified way.

The SCADA supervision middle layer is the source point for integration with accelerator control general services:

Operator display:

General-purpose accelerator consoles will be able to view and interact with the cryogenic system. This shall be done via a SCADA client, within the general frame of console management. Some work in common with the Accelerator Application programming team is planned, in order to provide similar look and feel on the operator User Interfaces.

Alarms:

A subset of the cryogenics alarms shall be sent to the central alarm service ('LASER').

Data logging:

The SCADA system contains natively an archiving tool. For long-term storage, and for correlation of data between different systems, a central data-logging system will regularly receive from the cryogenics controls a time slice of a pre-defined number of data items.

Data exchange:

Other devices (such as the vacuum system) will need to exchange information with the cryogenic system. This will be implemented via a CERN-wide Data exchange protocol ('DIP') which is currently being defined.

Monitoring:

The monitoring tools used by the controls exploitation team for the accelerator control system will also allow the monitoring of the PLCs, fieldbuses and Supervision PCs used for cryogenics controls. In case of faults, generic

procedures can be applied (such as remote reset of processors or restart of tasks).

This integration work is shared with other systems using PVSS as their supervision layer, such as the LHC Vacuum system. Deployment of this integration is in progress. It should be fully available before mid-2004.

Future integration topics are planned, such as the linking of the Unicos generator to the ORACLE-based Controls Configuration database planned for all LHC controls equipment.

To ensure a proper management of the controls equipment for LHC (more than 1000 I/O boards are required for the cryogenics alone), we are preparing to use an asset management tool, already deployed for the LHC accelerator equipments.

6 CONCLUSIONS

The Unicos project is now well in the deployment phase, and basic developments have reached a stable state. A large number of applications remain however to be implemented and improvements in tools can still provide valuable productivity gains.

The integration of Unicos within the accelerator controls frame is in progress, to prepare a seamless integration for the accelerator operation team.

The Unicos concept is used in areas outside cryogenics, its framework and tools are open for the integration of new features, e.g. recipe handling, developed specifically for the LHC Gas Control System [2].

7 ACKNOWLEDGEMENTS

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