LHC CRYOGENICS CONTROL SYSTEM: INTEGRATION OF THE INDUSTRIAL CONTROLS (UNICOS) AND FRONT-END SOFTWARE ARCHITECTURE (FESA) APPLICATIONS

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Abstract

The LHC cryogenics control system is based on the CERN Industrial framework UNICOS (Unified Industrial Control System). UNICOS covers aspects related to both the SCADA (Supervisory Control And Data Acquisition) and the PLC (Programmable Logic Controllers). The LHC cryogenic instrumentation must deal with the hostile radiation environment present in the accelerator tunnel preventing the use of off-the-shelves sensor signal conditioners. The conditioners are then realized with rad hard components connected to the control system thru a WordlFip fieldbus. A custom application using FESA (Front-End Software Architecture) framework has been developed in an industrial PC, the standard CERN solution for WorldFip interfacing. The solution adopted is based in custom generators which allow rapid prototyping of the control system by minimizing the human intervention at the configuration time and ensuring an error-free application deployment. This document depicts the control system architecture, the usage of custom generators within large systems and the integration of the CERN accelerator model software applications with a classical industrial controls architecture application.

INTRODUCTION

The LHC accelerator cryogenic technology uses superfluid helium to cool the accelerator magnets down to 1.9 K around the 27 km ring.

Eight large cryogenic plants produce the refrigeration of the LHC. Usually each plant supplies a whole LHC machine sector of about 3.3 km length via a cryogenic distribution line. The LHC accelerator cryogenics equipment is divided in 8 subsystems which can operate in an autonomous way. Each of this subsystem comprises production, distribution and finally usage in a ring sector of about 3.3 km of the refrigeration capabilities. Consequently the control system is highly distributed, radiation affected and holds heterogeneous equipments.

The instrumentation requires a large number of industrial sensors, electronic conditioning units and actuators (mainly heaters and valves) (Table 1). Those located in the tunnel must be radiation-resistant and they are conditioned by an in-house radiation tolerant electronics board based on the use of anti-fuse Field Programmable Gate Arrays (FPGA) and a WorldFip communications unit [1]. Such components must withstand the hostile radiation environment and provide reliable measurements. In the case of the control valves the intelligent positioner, normally located close to the valve, has been split allowing a relocation of the active electronics to protected areas. This development made by Siemens has become in an industrial off-the-shelve component.

Table 1: LHC Cryogenic Instrumentation

Instruments	Range	Total
TT (temperature)	1.6- 300K	9500
PT (pressure)	0-20 bar	2200
LT (level)	Various	540
EH (heaters)	Various	2500
CV (Control Valves)	0 - 100 %	3800
PV/QV (On Off Valves)	--	2000

The cryogenics control system architecture follows a standard automation pyramidal organization with components in the supervision, control and field layers (Fig. 1).

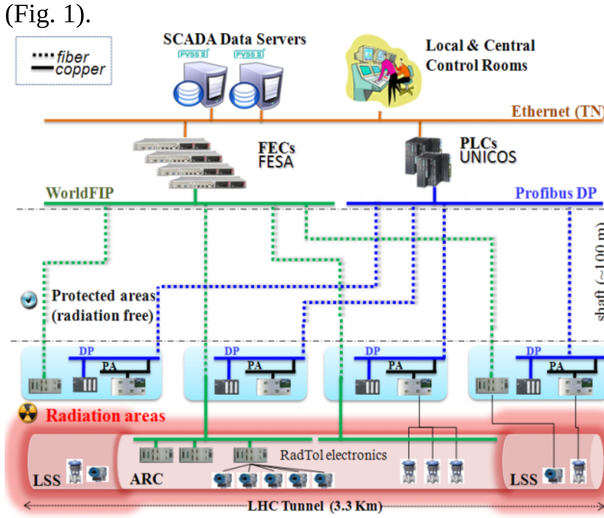

Figure 1: LHC Sector cryogenics control architecture.

FRAMEWORKS: UNICOS AND FESA

The cryogenics control system is based on the CERN Industrial frameworks UNICOS and FESA. UNICOS is used to create the application in the Programmable Logic Controllers (PLC) and its SCADA level counterpart. FESA is devoted to interface the signal conditioners via WorldFip through FECs (Front-End Computers) providing the control system with the expected engineering values for the different cryogenic devices (e.g.: thermometers, pressure sensors, , level, …).

UNICOS

UNICOS is an industrial framework developed at CERN to produce control applications for the typical approach of three-layer industrial control systems [2]. UNICOS proposes a method to design and develop the complete control application based in a specification dossier where all the I/O channels and field objects (e.g.: controllers, valves…) are described. High level objects (Process Control Objects) are defined during the design phase after an analysis of the plant (e.g.: Compressor, Coldbox…). They effectively allow driving the installations. Current UNICOS implementation targets Siemens and Schneider PLCs at the control level and PVSS II® at the supervision level.

UNICOS makes available mainly:

- A PLC and its counterpart Supervisory Control and Data Acquisition system (SCADA) applications.
- A dedicated place where the Automation Engineers can write down the process specific logic which will be implemented in the PLCs.
- A simplified tool to allow the Operation Engineers to create their own process synoptics.
- Tools to diagnose the process and the control system
- Interfaces for any client/server CMW connections, CERN long-term archiving and central LHC alarm system

In addition, generation tools have been produced to automate the instantiation of the objects in the supervision and process control layers and generate logic sections of the PLC code.

FESA

FESA is a real time object-oriented framework to design, develop, deploy and test Linux/LynxOS equipment software [3]. It creates source code to be deployed to FECs machines allowing users to design their classes, implementing their custom code and generating a complete application.

FESA provides also a mechanism to import the user devices in a convenient XML format. It also allows rapid testing of the deployed devices instances with a generic JAVA tool through a common middleware (CMW) communication by subscription or just simple polling.

CONTROL SYSTEM

Industrial Communications

To cope with the device distribution, the technologies employed are industrial fieldbuses (WorldFip and Profibus) and a protected Ethernet network.

The signal conditioners uses a WorldFip (1 Mbit/s) controller because of its radiation tolerance characteristics. Profibus PA (Process Automation) is extensively used for the cryogenics control valves which includes a compliant PA intelligent positioner. It's interfaced to Profibus DP (Decentralized periphery) networks (1.5 Mbit/s).

The Ethernet network is involved not only in interfacing the supervision and the control layers but also in the communication between PLCs and FECs, hence implicated in the close control loops. Special attention has been focused in the network realization to optimize traffic presence in the network to those actors who really exchange data by means of appropriate components (e.g. switches)

Finally, the link length imposes the extensive use of fiber optic to cover distances up to 3.3 km.

Control Equipments

About 80 PLCs are deployed to accomplish the automation tasks of the cryogenics process control. Two suppliers has been selected and deployed: Siemens and Schneider. Table 2 shows I/O channels and close control loops counts.

Table 2: LHC Cryogenic I/O and CCL

	Tunnel	Production	Total
Analog Inputs	12136	9200	21336
Analog Outputs	4856	2152	7008
Digital Inputs	4536	13820	18356
Digital Outputs	1568	2644	4212
Close Loop Controllers	3680	1024	4704

PLCs manage the control logic and FECs capture signal conditioners raw signals transforming them in reliable engineering sensor information.

FECs calculations are done at the WorldFip 500 ms cycle considering 1s sensor time response in most cases. The same cycle duration is used in the PLCs.

Some 4700 control loops reflects the complexity of the applications. During the design phase, the LHC sector was divided in several control modules reaching in the lowest level an object coping with 2 standard machine 200 meters cells (Fig 2).

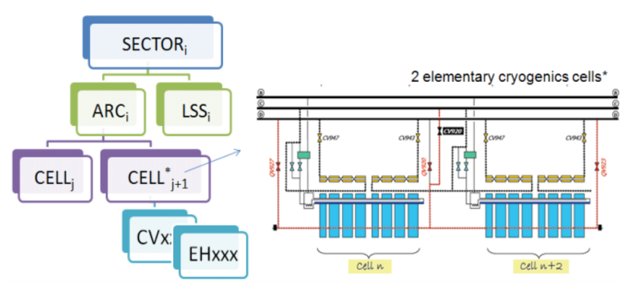

Figure 2: Tunnel UNICOS design objects breakdown.

Supervisory Control

The whole cryogenics control is managed by several data servers running the PVSS II® SCADA system. The data servers are off-the-shelves HP ProLiant machines with RAID hard disks and running Linux SLC4. (Fig. 3)

Several windows PC machines have been deployed as HMI (Human-Machine Interface) clients both, in local and in a central control rooms to operate the cryogenics facilities.

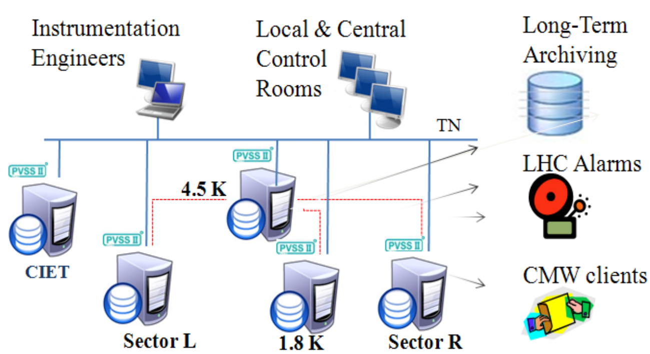

Figure 3: SCADA structure: LHC Cryogenics Point.

A dedicated Cryogenic Instrumentation Expert Tool (CIET) has been deployed based also in the UNICOS framework (Fig. 3). It gives to the instrumentation engineers an alternative view of the process where all the instrumentation data is available. This tool is extensively used during the commissioning phase allowing setting up and diagnostics of the electronic signal conditioners.

AUTOMATIC GENERATION TOOLS

Availability of generation tools is a key factor when developing very large control applications. Both UNICOS and FESA frameworks are designed with this functionality.

The cryogenics control system is to some extend automatically generated using such facilities. Starting from the specifications database custom generators creates the PLC source code, the SCADA configuration and the FEC devices. (Fig. 4)

The generation procedure is accompanied by a versioning mechanism allowing tracing and components generation at different speeds (PLCs and FECs instances).

Ensuring coherence between the information exchanged between the FECs and the PLCs is crucial to the reliability of the control system. Automatic generation tools minimize hand code activities and then concentrate effort in custom development maximizing the efficacy of the automation engineers.

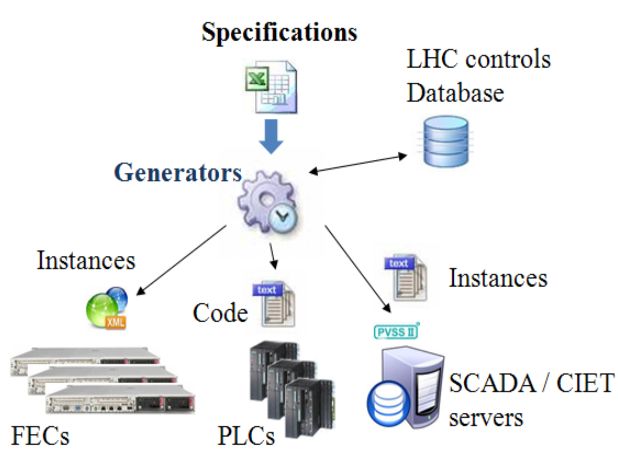

Figure 4: Generation mechanism.

CONCLUSIONS

An industrial and an accelerator frameworks have been successfully integrated in the cryogenics control system showing their highly complementarity.

The employed control and communication technologies are highly conditioned by the complexity, decentralized and radiation environment of the cryogenics system.

The generation tools available within FESA and UNICOS frameworks allowed automation engineers a rapid prototyping avoiding synchronization tasks between the different actors and focusing in the specific process control logic.

Applications maintenance becomes a rather effortless task due to the existing diagnostics tools and to the comprehensible structure of both frameworks, UNICOS and FESA.

A first prototype has been deployed and fully commissioned during the cool down to 1.9K and commissioning of the LHC sector 78. The existent project integration challenge has become in a successful example to follow giving entirely satisfaction to cryogenics and hardware commissioning operators.

REFERENCES

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