Upgrade of the control system for the NA48 LKr Cryogenics with S7-UNICOS

Accelerator Technologies Department – Cryogenics Group
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Objectives and Main Challenges

The purpose of cryogenics in the NA48 is to provide stable thermal conditions to 9 000 liters of liquid Krypton (120K) when the calorimeter is on operation and to ensure safe and loss-free of the liquid during long idle period. The system has operated over the last ten years, controlled by Siemens S5 PLC and FactoryLink SCADA system.
To face support and expertise problems concerning front end hardware and supervision, a complete upgrade project of the control system for the cryogenics with Siemens S7 PLC has been managed, to ensure its durability for the next physics proposal.

It aims at introducing LKr Cryogenics in the CERN standard control architecture: UNICOS.

The upgrade has to face several challenges as controlling the liquid nitrogen distribution, providing the insulation vacuum and feedthough heating, and more particularly, ensuring the stability of 10m^3 of Liquid Krypton.
A complete analyse and technical studies have given an entire overview of the control system modifications and improvements, required by such challenge. Because the system cannot tolerate programming failure and long time shut down, the process logic, the PLC reaction and the analog conversion needed to be fully tested .

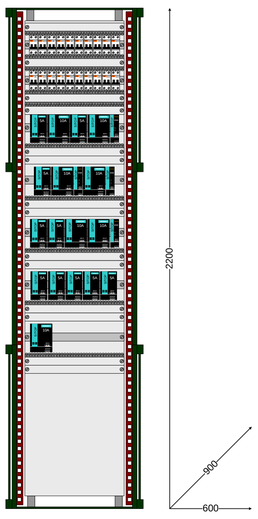
Technical study

Process Control

The technical objective was to convert the original Siemens S5 PLC architecture into S7 PLC to integrate S7-UNICOS standard. The overall LKr cryogenics system contains more than 1600 inputs/outputs and the final system will be managed by an S7-416 CPU with an IM463 communication card for temperature acquisition from S5 analog modules to avoid recabling tasks on the 26 analog cards dedicated to temperature measurements in the cryostat.

Each card range and specificity had to be respected and tested for the conversion. The original functional logic was rearranged to an object-oriented programming structure with process control objects architecture respecting the original division. Calculus for temperature estimation have been improved by polynomial approximation.

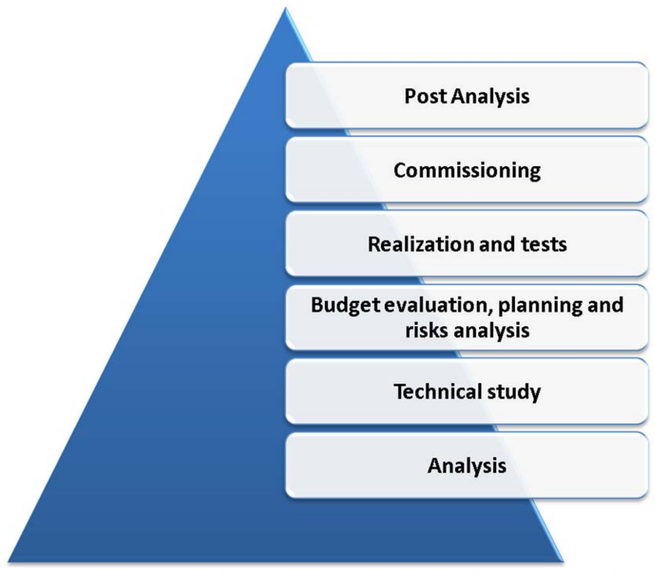
Electricity



A complete review of the drawings and their transcription were the first steps of the electrical tasks. The intregality of the schematics have been redesigned with SEE Electrical Expert 2005 and uploaded to EDMS to standardize the application.
The major interventions consists in replacing the 24V power supplies, and to integrate them in a new low voltage distribution rack.
To facilitate the recabling tasks of the new I/O cards, Phoenix Connection Units have been added to provide sectionnement facilities, to separate command and power for Lucifer electrovalves, and to supply analog transmitters. New cables were also necessary to Pt100 sensors for 4 wires measurements, and to new nitrogen distribution valves command.

Intrumentation and Actuators

Local displays for LN2 dewars filling has been upgrade to replace indicators electronics. Mecanic relays for feedthrough heaters command have been substituted by solid-state switching devices to support a large communitation numbers. At the same time, 220V valves in the LN2 storage area have been replaced to prevent future mecanical interventions.

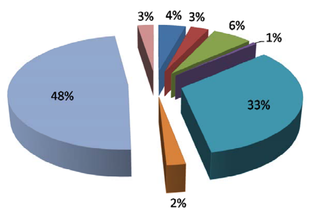


Hierarchical procedure of control system upgrade

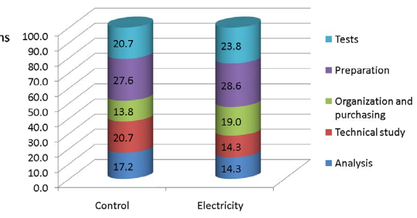
Budget and Planning

Budget and Costs

The upgrade budget encompassed as well human resources as the required equipments to replace and update the control system.
The project necessitated a full-time project associate, a cryogenic engineer, an electrical engineer, two electricians and an apprentice for SCADA development. The shut down requires two extra electricians and a control technician more.



Budget allocations



Time allocated in percentage over 18 months

Planning

On the overall project time (August'06 to March'08), tasks have been divided into two main themas: Part 1 refers to LKr control system and part 2 to LKr temperature monitoring system with S5 analog modules integration.
The Planning had to take into account the run period from April'07 to November'07.

Commissioning

Integration

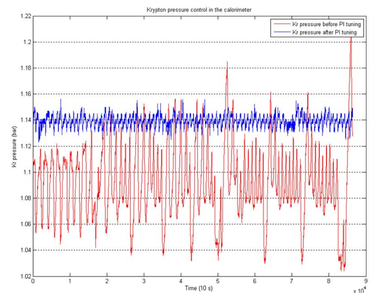
To achieve aims and minimize plant shutdown, installation has been divided into 5 steps to proceed to partial comissioning and to enhance safety of the overall system :

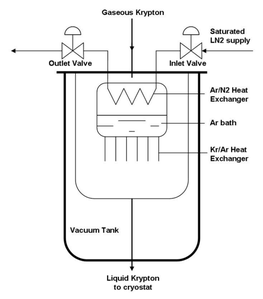
LN_2 Storage – Vacuum – LKr Dewar – Calorimeter – Measures

Nitrogen storage has been upgraded first to be able to fill LN_2 dewars for the rest of the work from a temporary PLC. Vacuum system has been added then to control both critical system.
The integration represented almost 2 months of work, reaching steady state point at the end of each system upgrade. Steps has been realized in the allocated time, including electrical and signals commissioning. TIMBER archiving system register now calorimeter data since april 15th.

Controller tuning

One of the main requirement of the system is the krypton pressure stability (around 1.15 bar ±0.01 bar). This is achieved by a cascade PID controller, the external loop giving the argon bath pressure setpoint and the internal loop controlling nitrogen mass through the inlet valve command of the argon cooler. Off-line tuning is based on RELS (Recursive Extended Least Square) multivariable identification on the inlet and outlet valves (model inputs) and argon / nitrogen pressures (model outputs).





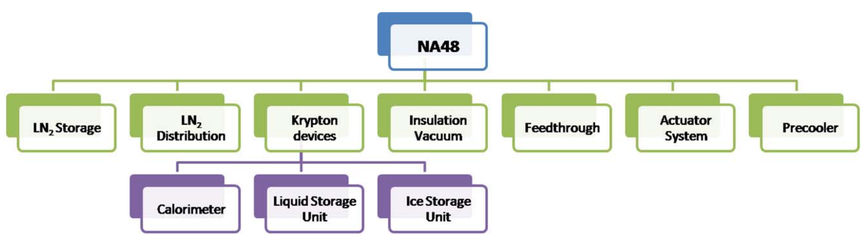
Argon Cooler unit

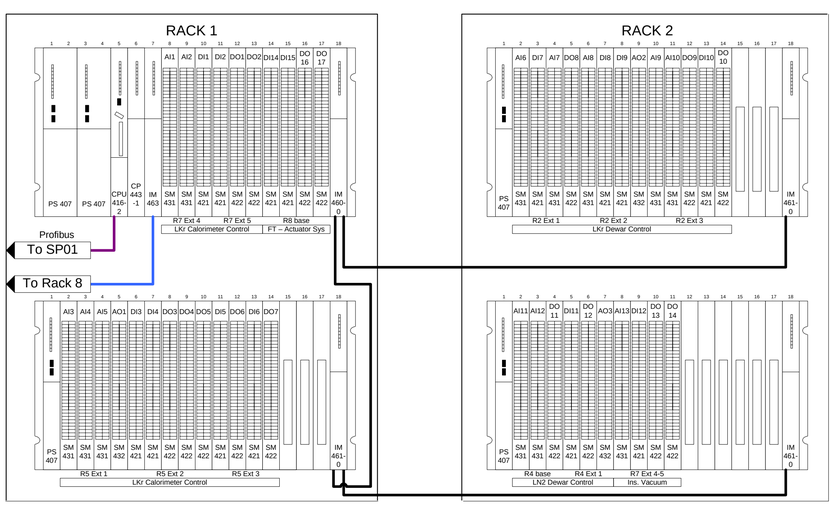
Safety

High level of reliability was necessary for the integration. At each step, process key values (krypton pressure in cryostat, nitrogen tanks level, vacuum gauges measures) had to be observable and alarms transmission frame available. A temporary S7 PLC ensured nitrogen storage control for nitrogen tanks filling operation and insulation vacuum.

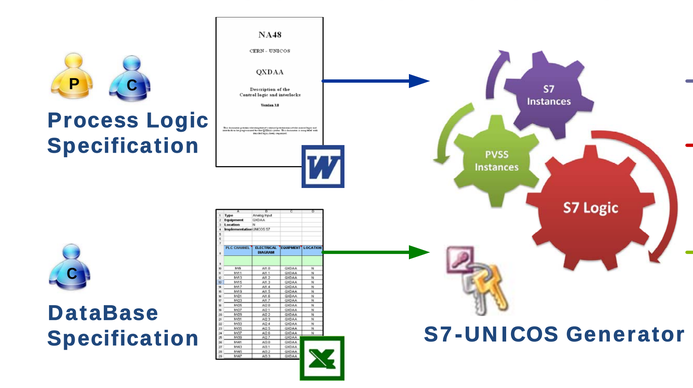
S7-UNICOS application

Modular Process Control Objects respects the hardware structure cutout for a progressive upgrade and an easiest commissioning.





Based on the cryogenics for the LHC sector standard, NA48 is the second biggest installation in terms of inputs/outputs which will use Siemens S7-416 CPU and the S7-UNICOS PLC development tool.
The installation will benefit of an entire support thanks to the standard hardware devices, the UNICOS application, and 24/24h shift in the CERN Control Centre.



S7 Generator running with MS Access, produces instances files for PLC and SCADA.
Customized templates give the possibility to generate the process logic as well.