LHC Cryogenics Control: INTEGRATION OF THE INDUSTRIAL CONTROLS (UNICOS) AND FRONT-END SOFTWARE ARCHITECTURE (FESA) APPLICATIONS

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Outline

1. Cryogenics
2. Control System
3. Frameworks (Automatic Generation)
4. Conclusions
1.- LHC Cryogenics

Architecture

LHC cryogenics overview

Cryogenic point

- Helium storage
  - 4.5K Refrigerator
  - 1.8K Units
  - Interconnecting box

Cryogenic plant

LHC tunnel (27 km)

LHC tunnel (27 km)
2.- Cryogenics Control System

- Large number of sensors and actuators.

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

- Tunnel instrumentation exposed to **radiation** (custom development to withstand the hostile environment)
2.- Cryogenics Control System

Tunnel Architecture

- SCADA Data Servers
- Local & Central Control Rooms
- Ethernet (TN)
- LHC Tunnel (3.3 Km)
- Protected areas
- Radiation areas
- WorldFIP
- Profibus DP
- FECs FESA
- PLCs UNICOS
- TT, PT, LT, EH, DI
- Ehsp, LTen
- LSS ARC LSS
- RadTol electronics
- EtherCAT TN
- Profibus DP
- FESA FECs
- WorldFIP
- Local & Central Control Rooms
- Ethernet (TN)
- LHC Tunnel (3.3 Km)

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2.- Cryogenics Control System

Industrial Communications

- WorldFip Copper cable
- WorldFip Fiber
- Profibus DP Copper cable
- Profibus Fiber
- Ethernet UTP

Sector 78 TUNNEL

Alcoves

Tunnel

Ethernet: Protected technical network

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3.- Frameworks

- **Front-End Software Architecture***
  - ✓ CERN accelerator real-time software model
  - ✓ Deployed to Front-End computers (FECs) running Linux/LynxOS

- **Cryogenics application processes**
  - ✓ **WorldFip**: Read/Write Worldfip agents
  - ✓ **Real-Time** action
    - ✓ **Device**: Calculates devices data (Minimize electronics cards calculations)
    - ✓ **Segment**: Groups devices and communicates to the PLC
  - ✓ **Server**: CMW Exchange data

* Ref: "Front-End Software Architecture", M. Arnat, et all. (ICALEPCS 07)
3.- Frameworks

**UNified Industrial COntrol System**

- **I/O Channels**
- **Field Objects** *(Valves, Heaters, …)*
- **Process Control Objects** *(Compressors, feedbox, …)*
- **Instances**
- **Specifications**
- **Logic**
- **PLC and SCADA Baseline**
- **Generates PLC and SCADA Devices**
- **Placeholders where the control engineer must write the process logic**
- **Simplified HMI tool to create process synoptics (drag & drop)**
- **CMW interface**
  - Long-Term archiving
  - LHC alarm system
- **Diagnostics tools**
  - **Operators**
  - **Process Engineer**
  - **Control Engineer**

UNICOS
3.- Frameworks

UNICOS Objects design breakdown

Sector Cryogenics Process Control Objects

2 elementary cryogenics cells*

• Process Decomposition exercise (e.g.: Tunnel):
  • Control a basic tunnel equipment (bi-cell)
  • Reduce the amount of logic to create by using a few templates which will be parameterized and generated automatically (e.g.: Controllers)

I/O objects + Controller (field objects)

<table>
<thead>
<tr>
<th>Objects</th>
<th>Tunnel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analog Inputs</td>
<td>12136</td>
</tr>
<tr>
<td>Analog Outputs</td>
<td>4856</td>
</tr>
<tr>
<td>Digital Inputs</td>
<td>4536</td>
</tr>
<tr>
<td>Digital Outputs</td>
<td>1568</td>
</tr>
<tr>
<td>Close Loop Controllers</td>
<td>3680</td>
</tr>
</tbody>
</table>

Process Decomposition: Controllers example

<table>
<thead>
<tr>
<th>LHC</th>
<th>Sector</th>
<th>Arc</th>
<th>Bi-cell</th>
</tr>
</thead>
<tbody>
<tr>
<td>3680</td>
<td>500</td>
<td>250</td>
<td>20</td>
</tr>
</tbody>
</table>
3.- Automatic generation Tools

UNICOS & FESA integration

- Minimize hand code activities and focus on specific control logic
- Versioning mechanism to trace all the instances and allow different generation speeds
- Generation time of a complete LHC sector: ~ 1 day

Control Engineer

Generator

Specifications

LHC controls (Poster RPPA03)

Deployment:

Control Engineer

Generator

Specifications

LHC controls (Poster RPPA03)

Deployment:

Control Engineer

Generator

Specifications

LHC controls (Poster RPPA03)

Deployment:
3.- Frameworks

UNICOS SCADA Structure

[Diagram showing SCADA structure with labels for Sector R (4.5 K), Sector L (1.8 K), Cryogenics, Instrumentation Engineers, Operators, CIET, and Ethernet connections.]

CIET: Cryogenics Instrumentation Expert Tool

LHC cryogenic point

Operators

Instrumentation Engineer
3.- Frameworks

UNICOS SCADA Structure

CIET: Cryogenics Instrumentation Expert Tool

Instrumentation

Sector L  Sector R

CIET

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3.- Frameworks

UNICOS SCADA Structure

Calculations
- Temperature: 295.1 K
- Resistance: 108.615 ohm
- Offset: 0.000 ohm
- Gain Constant: 100

Flags
- Config: b7 b6 b5 b4 b3 b2 b1 b0
- Gain: 0 0 0 0 0 1 0 0
- Diag HF: 0 0 0 0 0 0 0 0
- Diag LF: 0 0 0 0 0 0 0 0

WFIP Infos
- GTWV Name: CFC_SH4_QRFOP__P
- Bus: CBMWB_SH4_QRF
- Agent: 11
- Channel: 6

Measurements
- Sensor Voltage: -2762 -20.06 mV
- Reference Voltage: -2542 -18.46 mV
- Reference Voltage Typical: 10 mV

Raw data
- B0 B1 B2 B3 B4 B5 B6 B7
  - F5 37 F6 11 02 04 00 00

Warnings
- Disable
- IO Error
- Reset
- Bad configuration
- Filtering Active: Median

CIET: Cryogenics Instrumentation Expert Tool

CIALEPCS 07 Enrique Blanco [CERN AB/CO IS]
4.- Conclusions

- Successful integration of UNICOS and FESA frameworks
  - Industrial approach
  - CERN accelerator software model

- Generation tools
  - Avoid synchronization tasks and concentrate on the specific control logic
  - Rapid prototyping & optimal regeneration mechanisms

- Cryogenics control system fully commissioned (LHC Sector) [1/8 machine]
  - Highly distributed and radiation environment
  - Heterogeneous control equipments
  - Scalability and openness (LHC services)
  - Currently in production giving entire satisfaction to cryogenics and hardware commissioning operators
World's largest superconducting installation cooled by helium!

- 271.25 C  |  -456.25 F

Thanks to all people involved in the project:

CERN: AB/CO, AT/ACR

AB Controls Group (Industrial Systems Section)  
UNICOS  
FESA  
Cryogenics Group @ CERN  
LHC commissioning

http://ab-dep-co-is.web.cern.ch/ab-dep-co-is/  
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