RE-ENGINEERING CONTROL SYSTEMS USING AUTOMATIC GENERATION TOOLS AND PROCESS SIMULATION: THE LHC WATER COOLING CASE

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ABSTRACT

CERN (European Organization for Nuclear Research) will **re-engineer** the **control systems** dedicated to the **LHC** (Large Hadron Collider) **water cooling** systems during the 1st long shutdown (LS1) of the LHC in 2013-2014. These cooling systems are composed of **cooling towers**, **chilled water production** units and **water distribution** systems. Due to the very **short timescale** for these re-engineering projects, each PLC had to be **completely re-commissioned on-site** within only **three weeks**. To achieve this challenge, **automatic generation tools** were used with the CERN control **framework UNICOS-CPC** (Unified Industrial Control System for Continuous Process Control) to produce the PLC code. Moreover, **dynamic process simulations** using the software **EcosimPro™** were also developed to perform **virtual commissioning** of the new control systems.

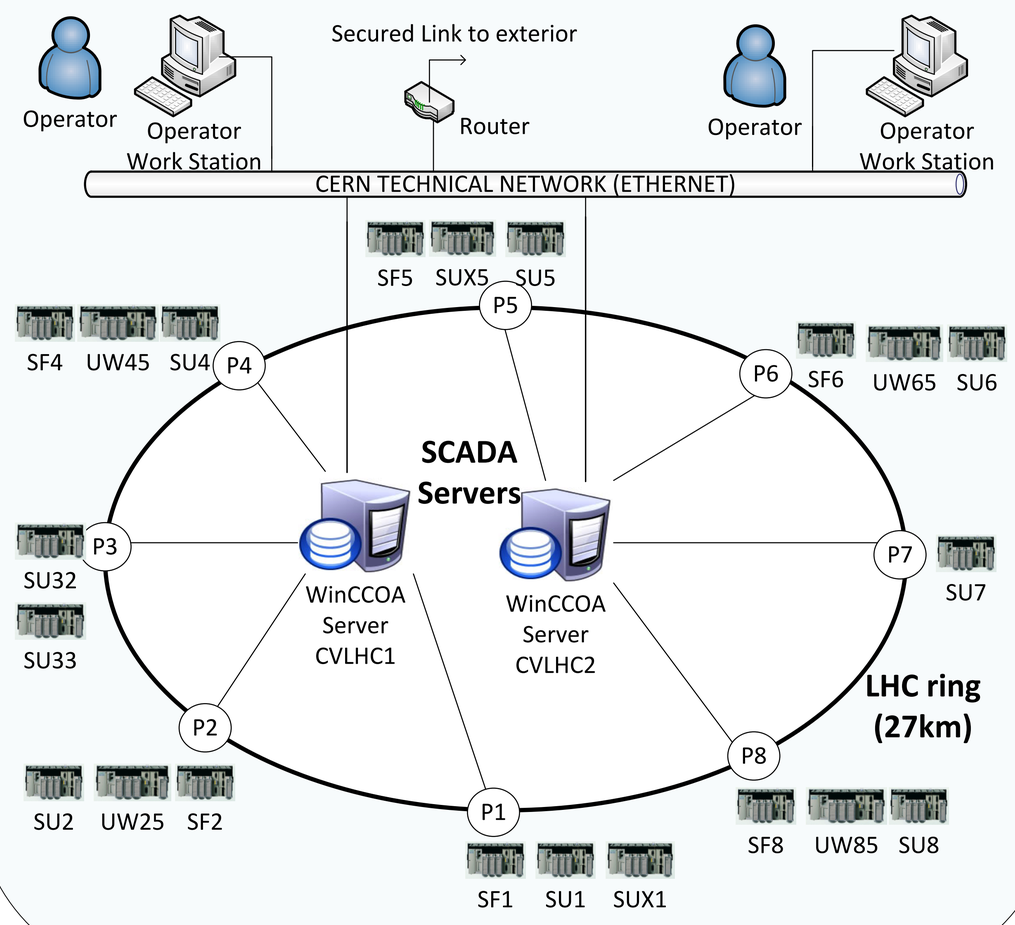
LHC WATER COOLING SYSTEMS

- **160 MW** of heat to extract from LHC between 24 °C and 34 °C
- **21 cooling plants** along the 27 km ring:
  - **SF (x6)**: Primary water cooling systems using **cooling towers** and providing cooling capacity for cryogenic plants, demineralized water plants and chilled water plants.
  - **SU (x11)**: **Chilled water production** and distribution, mainly for ventilation and air conditioning of the LHC tunnel.
  - **UW (x4)**: **Distribution of water** to the LHC tunnel 100 meters underground for different clients (power converters, collimators, power cables, etc.).

SF4: Cooling tower of LHC point 4

CONTROL SYSTEM ARCHITECTURE

- **Supervision:** 2 SCADA Data Servers (HP proliant) for 8 **WinCC-OA** projects
- **Control:** 21 PLC **Schneider PREMIUM** using Unity V7.0
- **Field:** 11 000 Inputs/Outputs using **FIPIO** periphery



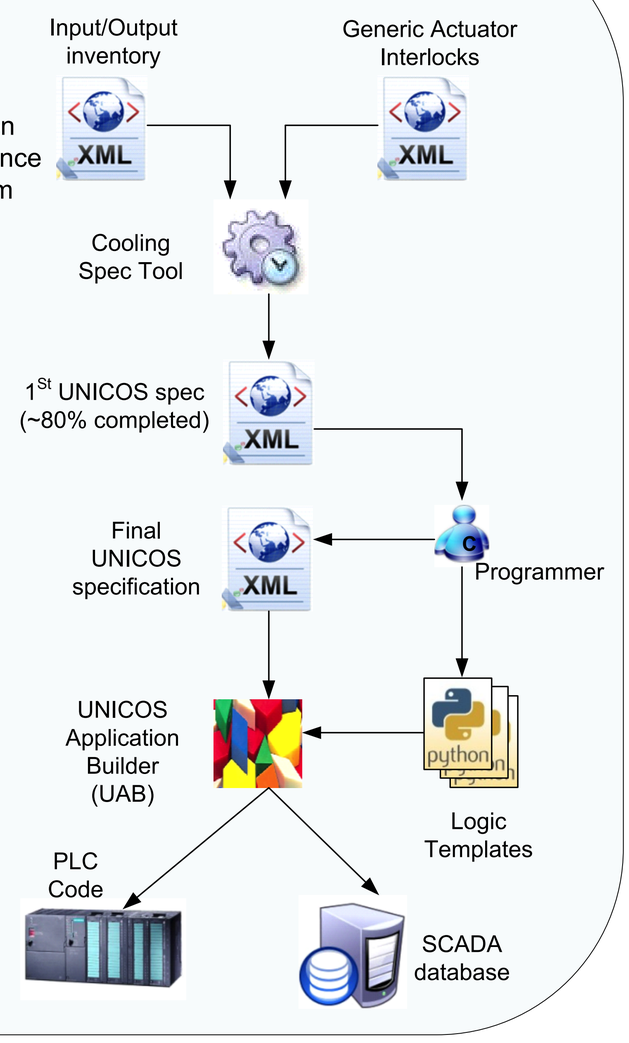
Code Generation with UNICOS-CPC tools

Project phases

1. Recovery of **I/O** and **P&ID** of existing plants
2. **Functional Analysis** from the existing PLC application
3. Add **additional functionalities** per operation experience
4. **Validation** of the functional analysis by operation team
5. **Control development** using **UNICOS-CPC**
6. **FAT**: Factory Acceptance Test
7. **SAT**: Site Acceptance Test
8. **Commissioning**

Control Development

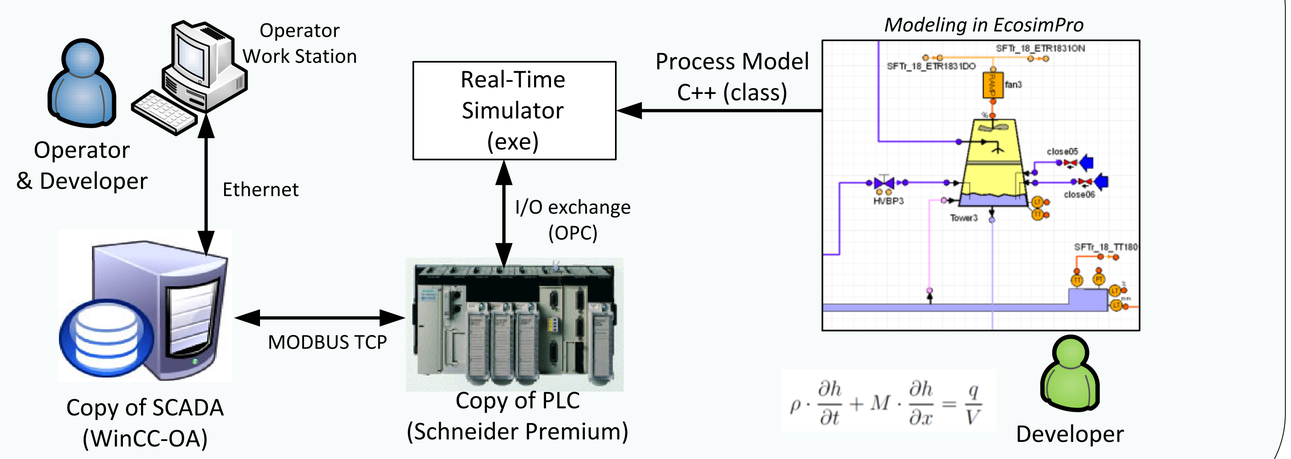
1. Description of **Input/Outputs** (xml file)
2. Identification of all similarities in:
   - **actuators**
   - **process units**
   - **interlocks**
3. Writing of **generic actuator interlocks** (xml file)
4. Generation and completion of the 1st UNICOS spec with **Cooling Spec Tool**
5. Writing of **logic templates** for actuators and process units (python scripts)
6. Generation of the PLC code with **UAB**



VIRTUAL COMMISSIONING

- *Only 3 weeks available to commission control system on site*
- *Need to validate control applications in advance*
- *Setup hardware-in-the-loop simulation to check PLC code*

- **Static Simulations for SU and UW plants**
  - Performed directly inside the PLC in a dedicated function
  - PLC is connected to a copy of the SCADA
  - Actuator feedbacks are simulated based on actuator orders
  - Regulation loops are simulated with simplified dynamics
  - Can be setup automatically by UAB
- **Dynamic Simulations for SF plants**
  - Copy of the PLC is connected to a copy of the SCADA
  - A physical model of the plant is built in simulation software (*EcosimPro*)
  - Need to develop the model based on physics (hydraulic, heat transfer…)
  - Model development simplified with use of "Cooling Library" developed at CERN
  - The model is integrated in an executable connected to the PLC by OPC



CONCLUSION

Today, 7 out of 21 PLCs have been reengineered and the **upgrade will be completed by mid-2014**. The complete project will employ a total of **6.5 Man-Years** (MY) (3.5 MY on control activities and 3 MY on process analysis and validation). Each commissioning is taking the expected 3 weeks thanks to the **virtual commissioning**. The re-engineered LHC cooling plants follow the **standard UNICOS-CPC approach** allowing a coherent control and providing the same interfaces and operation principles.

We would like to thank the **CERN Cooling and Ventilation (EN-CV) group** and especially the operation and control teams, for their participation in **capturing requirements** and during the **commissioning** phase thereby making this project a **success**. We would also like to thank the members of the **UNICOS development teams** in the **CERN Engineering Industrial Controls (EN-ICE) group**.

After this positive experience, all the **LHC ventilation systems** have been scheduled to be re-engineered during the **2nd Long Shutdown (LS2) in 2018**. A "Ventilation Spec Tool" already exists to facilitate the generation of the UNICOS specification, and dynamic models for ventilation systems are currently being developed in order to achieve virtual commissioning for HVAC systems.

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