# LHC GCS: A HOMOGENEOUS APPROACH FOR THE CONTROL OF THE LHC EXPERIMENTS GAS SYSTEMS

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### Abstract

The LHC Gas Control System (LHC GCS) project has been initiated to provide the 4 LHC experiments (ALICE, ATLAS, CMS and LHCb) with control for their 21 gas systems. To reduce the effort in the development, maintenance and operation phases, a homogenous approach has been selected. It is based on industrial components: a Supervision Control And Data Acquisition (SCADA) system (ETM's PVSSII), Schneider Programmable Logic Controllers (PLC), Profibus, CAN and a library (UNICOS) to develop applications in both PLCs and PVSS.

This paper describes the milestones that have been achieved: feasibility study, analysis, design and the results obtained with the first system. In addition details will be given about the LHC GCS framework.

# **INTRODUCTION**

The development and maintenance of the control systems of the four LHC experiments will require non-negligible resources and effort. The Joint COntrol Project (JCOP) [3] has been set-up to find common solutions for the four LHC experiments.

A CERN team, EP-TA1-GS [2], has been mandated to produce all the LHC experiment gas systems. Although these systems are all different, they have been designed in a modular way. They will be built from the same 10 modules (e.g. Mixer, Distribution chain, Pump, etc.). These modules can be fitted with optional devices.

In this context, the LHC GCS project [1] aims to provide LHC experiments with end-user applications for the control (supervision and process control layers) of their 21 gas systems.

#### ANALYSIS

The user requirements have been captured in a User Requirements Document (URD) that is applicable to any of the 21 Gas Control Systems (GCS). The URD covers needs for the gas modules, which will be the constituents of most gas systems (e.g. Mixer, Distribution). The requirements for the special modules (e.g. CO2 removal) will be added when their respective hardware architecture will be fully defined. Where the operation of a given module was more complex to define, dedicated Use Cases have been developed.

As the 21 gas systems are not fully identical, their differences have been captured in a simple Excel document listing all the options of all the modules of the gas systems. The URD makes reference to these options to describe variations in the control if any.

Mock-ups have been produced to prototype the Human Machine Interface required for a GCS.

#### STRATEGY

As the process to be controlled is very industry-like, it has been decided to use industrial tools and principles. PLCs handle all the critical tasks and implement the process control by accessing devices by means of Profibus and CANOpen fieldbuses. PLCs can run without any connection to the supervision layer. The supervision is implemented with a SCADA system, ETM's PVSSII. The SCADA to PLC and PLC to PLC communications are based on the Modbus TCP-IP protocol.

In order to easily produce and maintain the largest part of the 21 systems, it has been decided to build an application framework from which the process control and supervision layers of the 21 GCS would be instantiated. This framework would consist of common components covering the PLC and the PVSS parts. The instantiation of a GCS would be, in the worst case, manual but following procedures, in the best case fully automatic. Hence the correction of software bugs or the improvement of module's features would only be implemented in the framework and spread across all the GCS instances.

#### **FEASIBILITY STUDIES**

The strategic choices have been validated by the development of several small gas control systems with Profibus, Siemens, Schneider and Wago PLCs, EPICS and other SCADA systems.

While doing this development a library (UNICOS) produced for the control of the LHC cryogenic plants has been identified as a potential solution for GCS. As this library was not fully ready and initially developed for a SCADA no longer supported at CERN, we have ported a beta version of UNICOS to Schneider Premium PLCs and interfaced it to the National Instrument's LabView.

The feasibility studies proved that the industrial tools could be used; UNICOS has been selected with the Schneider PLCs. Since then the UNICOS developers have ported the UNICOS supervision layer to PVSS.

#### DESIGN

The overall software design is based on the UNICOS two-layer architecture.

The process control layer UNICOS objects implement access to the inputs/outputs, operation of field devices, handling of the interlocks and operation modes to deal with access to objects by operators (Manual) or by higherlevel parts of the PLC logic (Automatic). We have added Finite State Machines to this layer in order to provide automatic behaviour and alarm management as defined in the LHC GCS URD. The process control of each gas system will be hosted in dedicated PLCs.

The SCADA is used to offer only standard supervision facilities (e.g. alert reporting, access control, archiving) with all the application logic being implemented in the PLCs. Proxies of the PLC objects are instantiated in PVSS to let operators access the PLC objects from the PVSS console in manual mode. A unique PVSS system will be used for all the gas systems of a given LHC experiment gas plant.

The objects are organised in hierarchies to structure the control and operation of the process.

The design of the process control of the standard modules is completed. It has been prepared to cover the options of these modules. GCS object types have been added to the UNICOS types in order to control the gas specific devices (e.g. Mass Flow Controllers), to provide recipe handling down to the PLCs and to offer a fine grain alarm handling in the PLCs.

A common look and feel for the HMI of GCS has been defined: representation of FSM states, hierarchy of gas synoptic views, parameterisation by recipes, HMI to the GCS specific objects.

#### **A FIRST IMPLEMENTATION**

EP-TA1-GS has built the racks of a gas system for the TPC detector of the ALICE experiment. EP-TA1-GS goal is to validate its modular approach to the gas system design. The ALICE TPC gas system is representative of the LHC gas systems; it has 6 modules (Mixer, Distribution, Pump, CO2 absorber, Purifier and Gas Analysis) of a reasonable complexity as far as the gas system options are concerned.

We have developed a complete GCS for ALICE TPC. Our goal was to validate the LHC GCS user requirements and design choices before the mere part of the LHC GCS framework is produced and before starting the mass production of the 21 instances of LHC GCS.

# ALICE TPC GCS

The process control hardware of ALICE TPC GCS consists of a Profibus segment, and two Schneider PLCs: a Premium and a Quantum. The devices are connected to Profibus directly or through Wago bus couplers. The supervision hardware has been limited to a single Windows 2000 PC.

The process control software has been implemented by means of final UNICOS PLC objects. The application logic has been developed with STL (for the FSM) and ST, two of the five standard PLC programming languages. We have extended the PLC UNICOS library with all the GCS objects types described in the previous section.

The supervision layer has been developed with the UNICOS PVSS library. Animated symbols (widgets) and control panels (faceplates) a la UNICOS have been

developed to provide GCS extensions with a PVSS HMI. We have modified the PVSS recipe facility to connect, in a reliable way, PVSS recipe elements with the recipe objects located in the PLCs.

### Feedback

The ALICE TPC GCS has been commissioned to the EP-TA1-GS members. Although they plan to test the operation of this system during a total period of six months, they already provided us with feedback.

The definition of the automatic behaviour of the various modules has been confirmed. No additional operational states neither any modifications of the state transitions have been requested. Although some alarm conditions (thresholds and domain of validity) have been modified, the state-oriented alarm definitions have been confirmed. The use of software PID for the closed loop regulations proved to be accurate enough.

We received very positive feedback from the experts about the operation implementation. Although felt questionable during the analysis phase, the UNICOS access control mechanism has been widely accepted by the users, who could access any pieces of information or devices in manual mode without any conflicts with the automatic behaviour. This was particularly appreciated during the beginning of the commissioning when experts could tests configurations that were not implemented by the automatic behaviour of the system. The experts adopted the state-oriented operation of the modules; it appeared very easy to be handled by the standard UNICOS HMI. Finally the concept of recipes proved to be easily manageable by the experts. They were able to tune the closed-loop regulations implemented in 4 of the modules without having to program the PLCs: all PIDs parameters have been made accessible through recipe elements.

Experts proposed enhancement of the HMI and its hierarchical organisation. After having operated the modules independently, they specified additional requirements to automate the synchronisation of the operation of these modules.

As far as the development was concerned, we have validated the design of our objects, our modules process control and supervision. We verified in addition that the UNICOS libraries were flexible enough to be adapted to the needs of the LHC GCS.

# **GCS FRAMEWORK**

# Principle

To produce and maintain more easily the 21 instances of GCS, we have decided to build an application framework. The application framework consists of a database to keep all information about the gas systems and the objects required to build the GCS applications, and a set of templates and scripts for PLC and PVSS to produce, from the database, the source files of a GCS instance.

# *Components*

The database contains configuration information for all UNICOS and GCS objects to be instantiated in the PLC and PVSS (e.g. names, Profibus addressed, ADC conversion factors, operational ranges).

Application developers can edit the parameters of the objects by means of dedicated forms. They can also import object parameters from Excel documents filled by technicians. It has been quite easy to define a model for the LHC experiment gas systems. They are described in the database in terms of modules and options identified during the analysis phase of the project. Once application developers have defined the options of a system, they will then automatically instantiate all the UNICOS and GCS objects of the GCS of the gas system.

The PLC code templates will contain, on the one hand the code required to instantiate all the objects in the two types of PLC, and on the other hand the application logic. In order that statuses and commands for an object can be exchanged between two PLCs and between a PLC and PVSS, it is essential that the UNICOS objects are instantiated at a defined memory location. There will be a template per object type. The generation of the code is application specific and more delicate to produce. There will be a template for each of the gas modules. The scripts of the PLC application generator will browse the database and generate the actual source code from the templates and the database.

The generation of the PVSS layer will follow a very similar approach. PVSS scripts will be used at configuration time to generate the actual PVSS supervision layer from templates and data extracted as CSV files from the database described above.

Templates will be developed for all the graphical views required for each type of modules. The templates will contain all the possible options. CSV files will be generated from the metadata to specify the relevant options, scripts will then be used by these files to remove from templates the irrelevant options and create the actual synoptic views. A hierarchy of views will be produced from the database and generated by means of dedicated scripts.

All the PVSS objects will be generated from CSV files containing all relevant parameters in particular the address of the corresponding objects in the PLCs, the descriptions, the alert messages, etc.

PVSS recipes will as well be created from CSV files extracted from the database.

# Status

A part of the framework has been already prototyped or developed on ALICE TPC. The object types added to the PLC and PVSS UNICOS libraries are the first low level components of the GCS framework. Other objects may be added later if required for the integration of CANOpen devices specific to LHC GCS. In addition to these low level components, the database has been already prototyped with Excel: ALICE TPC objects have been fully described in Excel documents.

These Excel documents have been used to generate PLC source code for the object instantiations in both Schneider Premium and Quantum PLCs. A prototype of the model-based PLC source code generator for the application logic has been developed in LISP.

The Excel documents have been as well used to generate CSV files for PVSS. Scripts have been developed to generate the PVSS objects, recipes and synoptic views. The templates for the modules present in ALICE TPC have been developed. They are our first final GCS framework components.

The final application generator is being prepared in collaboration with the authors of the UNICOS library. The database schema, templates and scripts will be a common development. We are working on the definition of our metadata schema and scripts to generate the data from this metadata. The UNICOS team could adopt this approach for their next developments. We are developing our application logic templates for PLC that are GCS specific as well as the missing components for the PVSS layer.

#### **CONCLUSION**

Since the project has been started, several milestones have been reached. The analysis for the standard modules have been completed and allowed to select the project technical solutions: Schneider PLCs, PVSS and the UNICOS library. A first system has been developed with the selected industrial components and the UNICOS library. This system validated the main choices and the design of the LHC GCS.

The project is now in a crucial phase: the development of the GCS framework to prepare the mass production of all end-user control applications for the LHC experiment gas systems

#### REFERENCES

- [1] http://itcofe.web.cern.ch/itcofe/Projects/LHC-GCS/
- [2] http://detector-gas-systems.web.cern.ch/detector-gassystems/HomePage/homePage.htm
- [3] http://itco.web.cern.ch/itco/Projects-Services/JCOP/