THE NEW CONTROL SYSTEM FOR THE VACUUM OF ISOLDE

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Abstract

The On-Line Isotope Mass Separator (ISOLDE) is a facility dedicated to the production of radioactive ion beams for nuclear and atomic physics. From ISOLDE vacuum sectors to the pressurized exhaust gas storage tanks there are up to five stages of pumping for a total of more than one hundred pumps including turbo-molecular, cryogenic, dry, membrane and oil pumps. The ISOLDE vacuum control system is critical; the volatile radioactive elements present in the exhaust gases and the high and ultra high vacuum pressure specifications require a complex control and interlock system. This paper describes the reengineering of the control system developed using the CERN UNICOS-CPC framework. An additional challenge has been the usage of the UNICOS-CPC in a vacuum domain for the first time. The process automation provides multiple operating modes (rough pumping, bake-out, high vacuum pumping, regeneration for cryo-pumped sectors, venting, etc). The control system is composed of local controllers driven by PLC (logic, interlocks) and a SCADA application (operation, alarms monitoring and diagnostics).

INTRODUCTION

The ISOLDE Facility

The On-Line Isotope Mass Separator ISOLDE [1] is an experimental facility located at the Proton-Synchrotron Booster (PSB), CERN, dedicated to the production of a large variety of radioactive ion beams for many different experiments in the fields of nuclear and atomic physics, solid-state physics, materials science and life sciences.

Description of the Vacuum System

In terms of vacuum, the ISOLDE facility is an array of beam lines used to distribute radioactive ion beams to a number of experiments. The beam lines are separated into sectors which are often generically represented by the equipment used in that part of the machine. For example, the front-ends refer to the two separate target stations where both heating and high voltage are an issue for the vacuum system and the separators refer to the sectors where the separating magnets are located.

The new vacuum control system replaces a fifteen year old control system based on old obsolete PLC (Programmable Logic Controller) without dedicated supervisory software. The old control system became difficult to maintain and was no longer adapted to present day upgrades of the facility.

The new control system has been installed in two steps:

- In 2010, installation of the vacuum control system for ISOLDE front-ends, separators and experiments
- In 2011, installation of the vacuum control system for the post-accelerator REX-ISOLDE [2] (Radioactive beam EXperiment at ISOLDE)

ISOLDE machine requires high vacuum(1) and ultra high vacuum(2) provided by turbo-molecular and cryogenic pumps respectively. An additional bake-out system allows achieving ultra high vacuum. All the exhaust gas from the pumping systems (with volatile radioactive elements) are collected and stored into pressurized tanks. This specification is unique at CERN.

In order to optimize the gas collection and reduce maintenance, the number of primary pumps is reduced to a minimum. There is a first set of nine primary pumps for the exhaust of fifty-four turbo-molecular pumps and four cryogenic pumps; and a second set of nine primary pumps for the rough pumping of thirty-one beam-line vacuum sectors. A complex process has been developed to control this pump configuration (Fig.1).

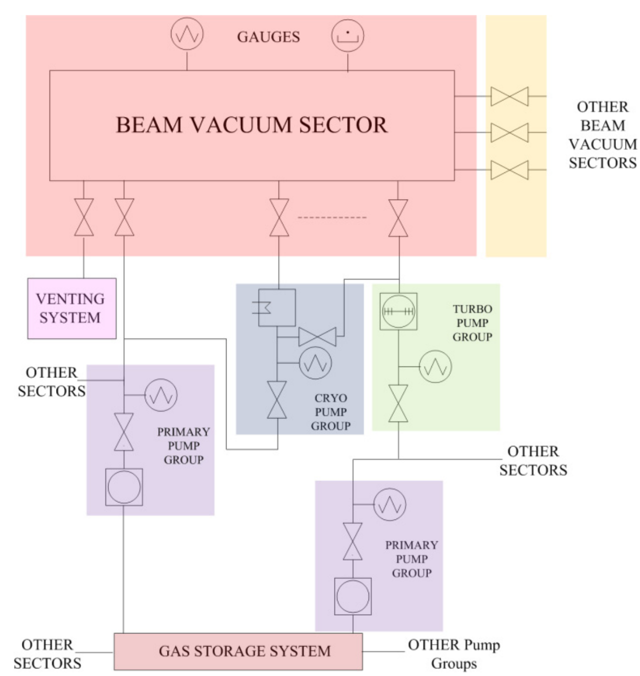

Figure 1: Typical pumps configuration.

(1) Pressures below 1.10^{-6}mbar
(2) Pressures below 1.10^{-10}mbar

CONTROL PROCESSES

The vacuum system is split in one hundred and twenty-seven processes of ten types (beam sector, turbo-molecular pump, cryogenic pump, primary pump, venting, storage, etc).

The pump process interlocks the client process (the client can be another pump or a beam-line sector). A pump process has several statuses: stop, starting, nominal (nominal pressure reached), recover (pressure increases after the pump has reached its nominal pressure), leak detection, etc. The pumping valve of the client remains closed if the pump process is not in “nominal” or “recover” status and the opening is disabled if the pump process is in “recover” status.

Some processes are multi-client (Fig.2); to avoid that two clients are pumped at the same time (retro-diffusion and contamination problems), a « token » system has been developed with low and high client priorities.

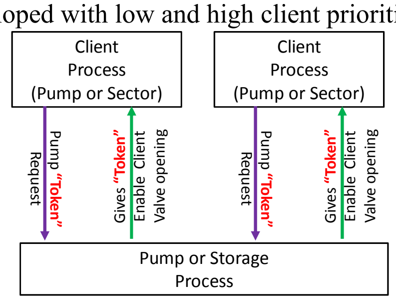

Figure 2: Pump and clients relation.

Processes are linked together with multiple interactions (Fig.3).

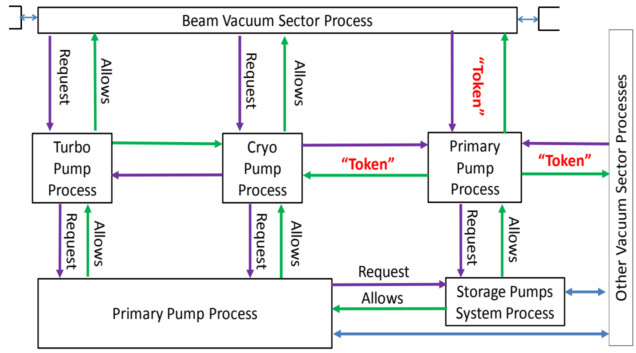

Figure 3: Processes interactions.

HARDWARE

Hardware Architecture

The hardware architecture (Fig.4) is based on Programmable Logic Controller (PLC). The vacuum control hardware is a five layer architecture: SCADA(1) Application, PLC, remote input/output, device controllers and field devices.

The remote input/output station and controllers are installed close to the field devices to reduce cabling.

Unfortunately, approximately a third of the vacuum equipments are located in radioactive and restricted areas. For these devices, specific radiation hard gauges, captors, local crates and cables have been installed.

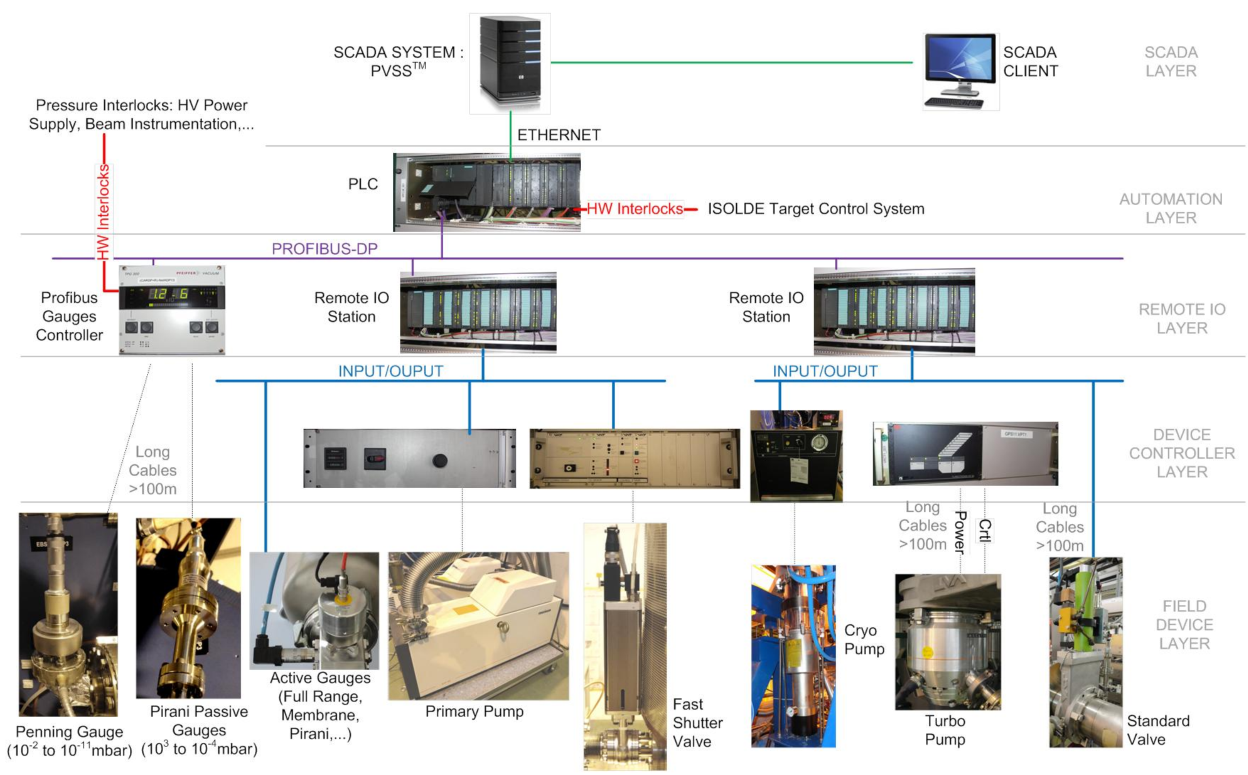

Figure 4: Hardware Architecture.

(1) Supervisory Control and Data Acquisition

Long distance cables (longer than one hundred meters) were installed and some specific cabling development for turbo-molecular pumps was required. The standard cable was replaced by two cables, one for the power of the pump motor and a second cable for the pump captors and signals.

ISOLDE and REX-ISOLDE vacuum controls are independent systems with two PLCs and two SCADA applications. The two SCADA applications and software are installed on the same Linux server.

The architecture is quite similar for the two systems and resumed by the Fig. 4.

Hardware Interlocks

The hardware interlocks are potential free relay contacts. The PLC provides hardware interlocks to other equipments like transformers, water cooling, target heaters, etc. The interlocks are the results of logic combinations of pressure levels and process status.

The gauge controllers provide fast pressure hardware interlocks to high-voltage power supplies. A PLC function has been developed for the asynchronous communication with the gauge controllers via the Fieldbus Profibus-DP™. This function allows to set, monitor and diagnose a large number of hardware interlocks.

SOFTWARE

UNICOS-CPC Framework

UNICOS (UNified Industrial COntrol System) [3] is a CERN framework to produce control applications. The UNICOS-CPC package proposes a method to design and develop complete industrial process control applications. It is based on the modelling of the process in a hierarchy of devices (e.g. I/Os, field and abstract control devices). These devices establish the base on which process engineers and programmers define the functional analysis of the process. The package is deployed both in the supervision layer (WinCC OA) and in the PLCs (Schneider and Siemens). UNICOS-CPC also provides tools to automate the instantiation of the devices in the supervision and process control layers and to generate either partially or completely the specific control logic code. The framework is flexible enough to be able to add customized devices to cover new client requirements.

Phases Sequencer

The ISOLDE vacuum control system largely uses Grafcet(1) to drive devices and activate alarms and interlocks.

The Grafcets are directly monitoring a SCADA panel (Fig.5). The operator can follow the process and see the active steps and transitions.

(1) Sequences of actions with conditions and time dependencies to achieve discrete event

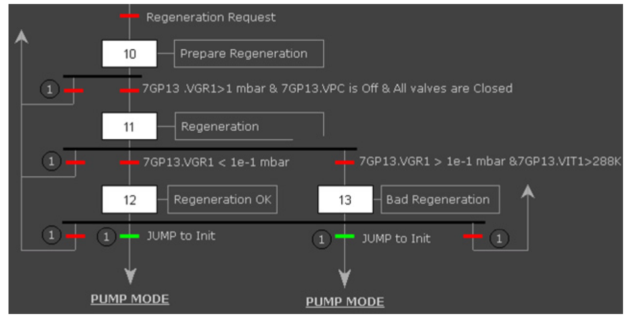

Figure 5: Part of a cryogenic pump process Grafcet (SCADA Panel).

Thirteen different Grafcets provide a fully automatic system with a large choice of operating modes: pump, leak detection, vent, bake-out, regeneration, etc. Transitions between modes can be automatic or manually requested.

Software Production

The process objects use phase sequencers to control the vacuum equipments. Physical values such as valve positions or gauge pressures are acquired through input objects and commands are set via output objects.

Phases sequencers (Grafcets) and PLC function templates are produced using the logic specifications. The "vacuum" library is composed of PLC functions developed for specific vacuum devices (analogue gauges with on/off commands, complex gauge controller devices, etc). This library was created especially for the vacuum system of ISOLDE (Fig.6).

The PLC source code is obtained using:

- Baseline code generated by UNICOS-CPC framework.
- Function templates, Grafcets and "vacuum" library.

The SCADA application is obtained using:

- Baseline application produced by the UNICOS-CPC framework.
- SCADA application objects automatically generated from the objects database and specifications.
- Fully configurable panel templates developed using the ISOLDE vacuum layout.

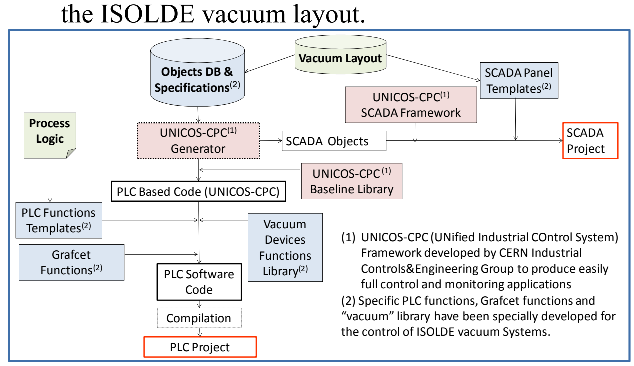

Figure 6: Software production diagram.

Software Interlocks

The project integrates phases sequencer time-out and alarm conditions to interlock devices and processes. The sector valves need to be interlocked in case of pressure increase. The PLC provides software interlocks for the sector valves, a low pressure threshold is set to disable the opening of a valve and a high pressure threshold is set for a fully interlocked valve (valve closure and inhibit opening). The SCADA panel (Fig.7) displays the detail and the source of the interlock providing a rapid and easy diagnostic.

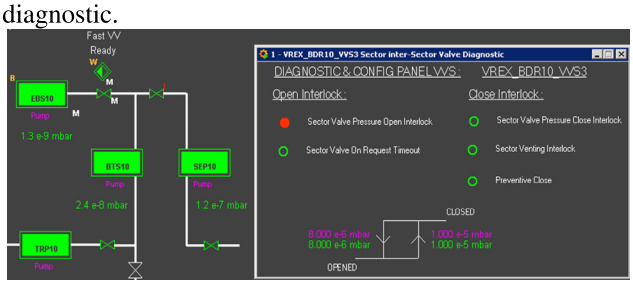

Figure 7: Sector valve interlock details panel.

SPECIAL CASES

Ultra High Vacuum: Bake-Out Control

The REX-EBIS sector is an ultra high vacuum sector and needs to be fully baked-out (Fig.8). The bake-out reduces the chamber's gas desorption and activates the in-house guetter pumps. The vacuum components are fragile and require an advanced regulation and control system. The bake-out control system is compact and mobile with PID (Proportional/Integral/Derivative) regulation, complex temperature cycles, interlocks, error management, remote control, alert and diagnostic tools. The bake-out control rack is composed of a PLC and electronic power components. This bake-out controller was developed previously by the Control Section of the VSC(1) Group for all the CERN accelerators[4].

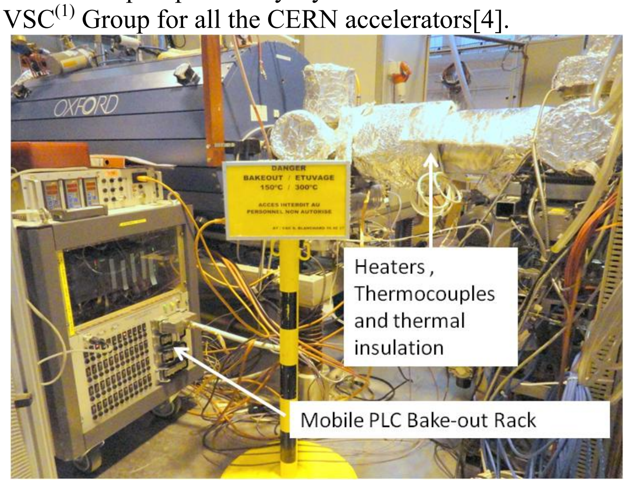

Figure 8: Bake-Out system of REX-EBIS sector.

(1) Vacuum, Surfaces and Coating Group (CERN)

Control of the Exhaust Gas Collecting and Storage System

The exhaust gas collection (Fig.9) and storage process is one of the most important processes as its failure would result in the complete shutdown of the ISOLDE vacuum system. The system is redundant and is not running permanently. Between the pump groups and the storage system, an array of decantation pipes and filters can independently accumulate gas up to a pressure of 700 mbar. The control has been designed to avoid stops or at least to prevent them. For example if the pressures in the storage tanks increase abnormally, the responsible client process is preventively stopped yet the storage system is still available for other processes.


Figure 9: Exhaust gas collecting station.

CONCLUSION

The vacuum control system of ISOLDE including REX-ISOLDE is the result of a successful CERN internal collaboration between the Control Section of the Vacuum, Surfaces and Coating Group and the Industrial Controls&Engineering Group. This system provides all the features to fully operate and monitor the vacuum system of ISOLDE. The diagnostic tools and the ability to access them remotely have considerably reduced the vacuum intervention time.

REFERENCES

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[4] S. Blanchard, CERN, Geneva, Switzerland "Bake-Out regulation System for the LHC", OLAVII, Warrington, March 2008; http://www.cockcroft.ac.uk/events/OLAVII/