THE UNICOS-CPC VACUUM CONTROLS PACKAGE

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Abstract

The vacuum control of the Large Hadron Collider and its injectors is based on PLC and SCADA off-the-shelf components. Since late '90s, CERN's vacuum group has developed a dedicated control framework to drive, monitor and log the more than 10 000 vacuum instruments. Also, in 1998, CERN's industrial controls group developed the UNICOS framework (UNified Industrial Control System), becoming a de facto standard of industrial control systems and gradually deployed in different domains at CERN (e.g. Cryogenics, HVAC...). After an initial prototype applying the UNICOS-CPC (Continuous Process Control) framework to the controls of some vacuum installations, both teams have been working on the development of vacuum-specific objects and their integration, together with new features, into the UNICOS framework. Such convergence will allow this generic framework to better fit the vacuum systems, while offering the advantages of using a widespread and well-supported framework. This paper reports on the experience acquired in the development and deployment of vacuum specific objects in running installations, as a prototype for the vacuum controls convergence with UNICOS.

INTRODUCTION

At CERN, the European Organization for Nuclear Research, industrial control systems have been developed and deployed to operate accelerator systems such as cryogenics, gas flows, vacuum… Most of these control systems have the same type of top level architecture based on Programmable Logic Controller (PLC) and Supervisory Control and Data Acquisition (SCADA), i.e. WinCC-OA™ application.

The cryogenics control team developed a software framework (first version of UNICOS framework) based on generic I/O field objects [1]. The vacuum control team developed a software framework dedicated to vacuum instruments [2]. The vacuum control framework is used in all the CERN accelerators except the ISOLDE complex. UNICOS is not only used in cryogenics but also for the control system of LHC Collimators interlocks, Cooling&Ventilation, Experiments gas flows, Detector cooling… UNICOS has become the CERN standard framework for industrial controls.

In 2011, the vacuum control system in ISOLDE had been completely refurbished [3]. The old control system was not using the vacuum framework and was totally outdated. For this renovation, it was decided to use UNICOS-CPC framework [1] and not the vacuum framework. Later, was raised the question of migrating other vacuum installations to UNICOS. The advantages would be:

- standardisation of vacuum controls to CERN industrial controls. Also GSI institute is using UNICOS framework for the vacuum control of the FAIR facility.
- global reduction of effort for maintaining code.
- central Support from the CERN industrial controls.

These are major advantages but on the other hand the vacuum framework already offers a high level of process control, supervision and diagnostics:

- PLC code is dedicated to vacuum instruments, simple and much optimized (a small PLC can control a large number of instruments).
- Supervisory application has dedicated widgets for vacuum instruments and a large number of user friendly features.
- SCADA instance data files and PLC instance data blocks are generated from a vacuum ORACLE database. The database has high level of interaction with CERN layout database and asset management database.

The migration of vacuum control system to UNICOS must be very smooth to vacuum control users and shall not depreciate any functionalities offered by the current vacuum framework.

At the end of 2016, the vacuum control team, in collaboration with UNICOS team, has started to develop a set of new UNICOS components, dedicated to vacuum application called "unVacuum". The goal of this package is to preserve the level of services from vacuum framework to UNICOS framework. The unVacuum package focus on CPC objects development and SCADA features.

VACUUM CPC OBJECTS

Why Do Vacuum Applications Require Specific Objects?

Figure 1: Turbomolecular pump widget without and with the vacuum package.

UNICOS-CPC framework is very flexible because it manages I/O generic field objects. These objects combined together are able to control most of the instruments

installed in an accelerator. But for complex instruments the implementation is very heavy and it is not possible to control the instrument as a whole. The Figure 1 illustrates the control of a turbomolecular pump without and with a dedicated object.

The Figure 2 lists the first set of UNICOS-CPC objects developed in the unVacuum package.

Symbol	Name	Description	Type
	VP_TP	**Turbomolecular Pump**	Field Object
	VG_PT	**Passive Gauges (TPG300)**	Field Object
VRGP	VR_GT	**TPG300 Controller**	Field Object
	VP_I	**Ion Pump (Profibus interface)**	Field Object
	VV_S	**Sector Valve (Profibus interface)**	Field Object
	OnOff, widget VP_P	**Primary pump widget (OnOff field object)**	Widget panel
VRPI	VR_PI	**Ion Pump controller (Profibus interface)**	Field Object
	VR_AH	**Hardware Alarm (generated by field controller)**	Field Object
	VP_G	**Pumping Group**	Process Object

Figure 2: First set of objects developed.

Widgets

Vacuum device widgets follow UNICOS animation standard. These vacuum devices have more than binary on/off state. The development of vacuum device types introduces a new state variable called object status. Object status is an enumeration, the meaning depends on the device type. For instance the object status of a vacuum gauge can be: off, measurement ok, over range, under range, I/O error. In addition most of the vacuum devices have analogue feedbacks; the main analogue feedback is called position status. For instance the position status of an ion pump device is the pressure equivalent measurement (unit = mbar); ion pump devices have other analogue statuses: the High Voltage output value and the current measurement value.
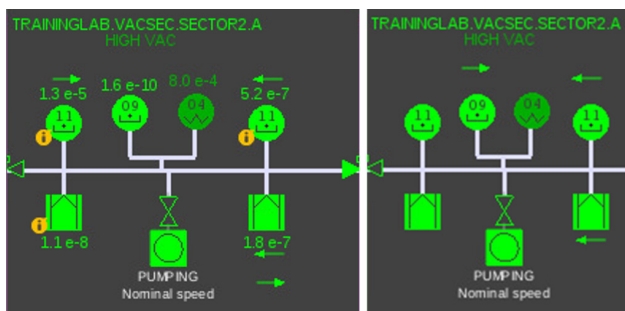

Figure 3: Device widgets.

For each device type we developed several widgets. In Figure 3, the left screen shows a widget animated according to the object status (animation of the symbol body) and the position status (pressure value above or below symbol body); the right screen shows a widget animated according to object status only.

The contextual menu of vacuum widgets is very similar to the CPC core widgets. The standard items remain in the menu. In addition, the following items have been added:
- object status or position status value.
- links to web interface of layout DB and asset DB.
- methods to insert device in state history panel or vacuum trending panel.

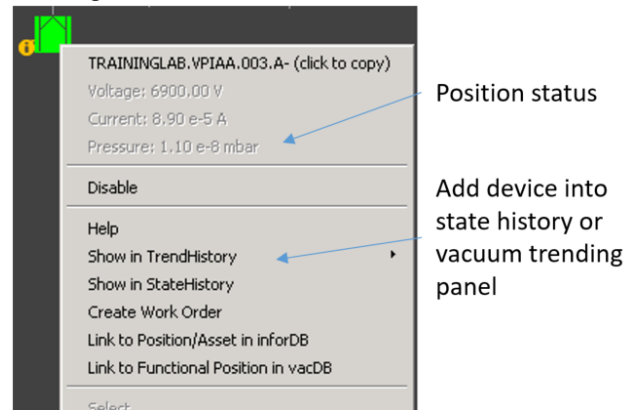The contextual menu of an ion pump widget is illustrated in Figure 4.

Figure 4: Ion pump contextual menu.

Faceplates

A dedicated faceplate has been developed for each vacuum CPC object. Faceplates offer high level of control and diagnostics. The faceplates for gauge and ion pump controllers are especially complex. Faceplates of controller are used to configure and setup instruments but not only; controllers host relays used as sources for hardware interlocks. The controller's faceplate is used to set and read the pressure thresholds and the instrument source of hardware interlocks. Figure 5 illustrates the gauge controller faceplate.
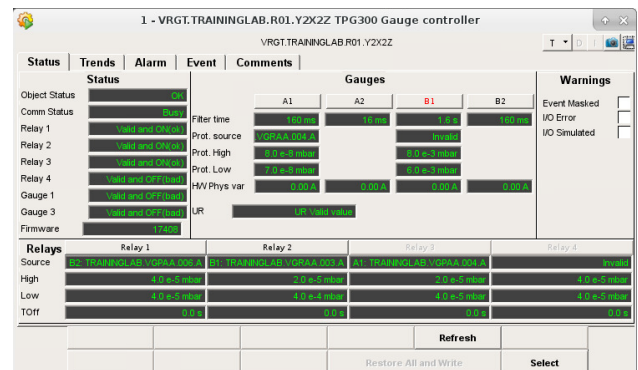

Figure 5: Gauge and HW interlock relay controller (TPG300).

Process Object

In Vacuum systems, pumping groups are very common. In the LHC there are more than 220 pumping groups with the same process logic. Vacuum applications need a dedicated pumping group process object for easy parametrization and deployment. The widget of the pumping group process reports the status of the pumping group and the

position of its top valve. The operational mode of the process and the object status are displayed.

In the faceplate, in addition to the status, order and alarm status, a small diagram showing the slave device widgets and the sequencer panel is automatically generated (sequencer is identical for all pumping groups). Figure 6 shows the widget, faceplate and sequencer of the pumping group process object.
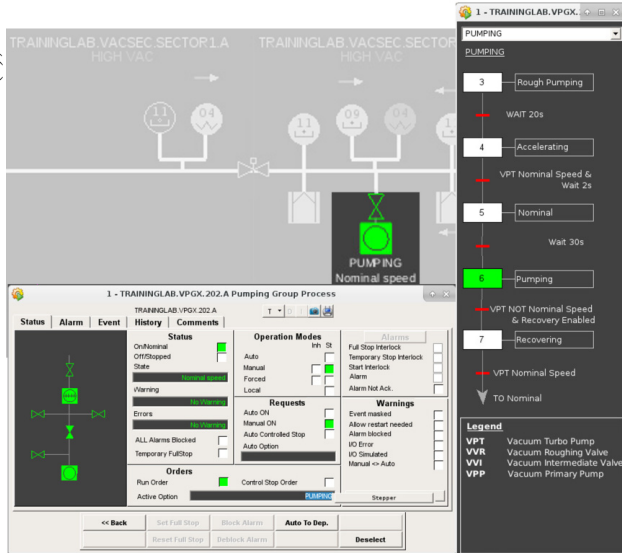

Figure 6: Faceplate and stepper of the pumping group process.

SCADA FEATURES

In addition to the development of new device types for vacuum instruments, some SCADA features have been developed. We started with three essential features for a vacuum application: automatic synoptic, state history and pressure profile.

Automatic Synoptic

The UNICOS framework implicitly assumes that synoptic view of the installations are built manually. In vacuum framework, the synoptic views are built automatically on the fly, based on geography information of the vacuum system. The main goal of this development is to automatically build synoptics with UNICOS-CPC widgets.

It is difficult to automatically build a good looking synoptic for complex installation. However, vacuum systems for accelerators in most cases look very simple: long vacuum pipe with vacuum instruments (valves, pumps, gauges) connected to that pipe. A synoptic is a one-dimensional view. Basically, in order to build such view automatically, only instrument coordinates and widget size are required. From such information a relatively simple algorithm can be built, which will produce good looking results.

In reality vacuum systems are not only one pipe – typically there are several pipes connected together – for example, ring accelerator plus injection/dump lines. But within one line (ring line, injection line or dump line) the

synoptic is one-dimensional view. Then the combination of all the lines produces single result.
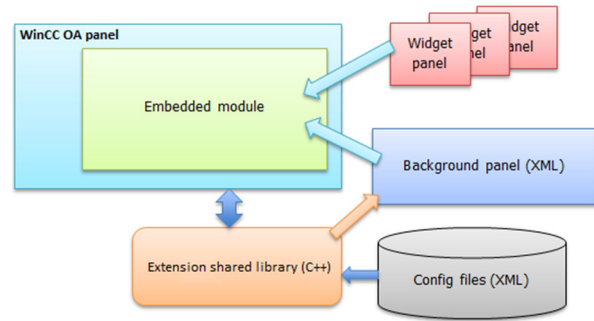

Figure 7: Implementation of automatic synoptic.

The WinCC-OA CTRL language is not very suitable for processing large arrays of data. Geography information is really a number of large arrays, especially for large machines. Fortunately, WinCC-OA allows to write extension shared libraries, in C++, within functions that can be called from WinCC-OA CTRL language.

First, the extension library function initializes geographical information for machine by reading and parsing XML configuration files. Resulting geographical information is stored in memory of shared library for fast access during synoptic building.

Then WinCC-OA panel calls extension library function to prepare synoptic, supplying geography range for synoptic and which natures of device shall be shown in the synoptic.

The result is:

- panel with background elements of synoptic; this includes beam (vacuum) pipes, rectangles representing magnets, borders between sectors etc.
- positioning of all device widgets which are calculated and stored in shared library variables.

Generated panel with background is loaded into embedded module and thus becomes visible. Only widgets located in visible part of background panel are added. The WinCC-OA panel receives Resized/Scrolled callbacks of embedded module, calculates size and coordinates for visible area of background panel and passes this information to the extension library function. Finally this function returns list of widgets to be shown or hidden and WinCC-OA panel adds or removes widgets. The implementation of automatic synoptic is illustrated in Figure 7.

State History Panel

State history panel is a very popular panel in vacuum framework. The concept does not exist in UNICOS or JCOP framework [4]. State history is the very first panel developed in unVacuum package.

As shown in Figure 8, state history panel displays the archived values of device states in a table. Rows correspond to moments in the past when one of device state changed. If other device state does not change at this time its cell is left blank.

The text in a cell reports the main state of the device, i.e. the meaning of the object status for vacuum objects

(c.f. paragraph *Widgets*). In order to generate short state description, new function has been added to each equipment type in unVacuum library. CPC core objects can also be used in state history provided such function is implemented for them. The functions calculate the string value according to the device status register, e.g. for an on/off object representing a valve the return value is either: "open", "close" or "undefined". These functions will be later integrated in CPC core device type libraries. The color of cell reports the alarm state of the device.
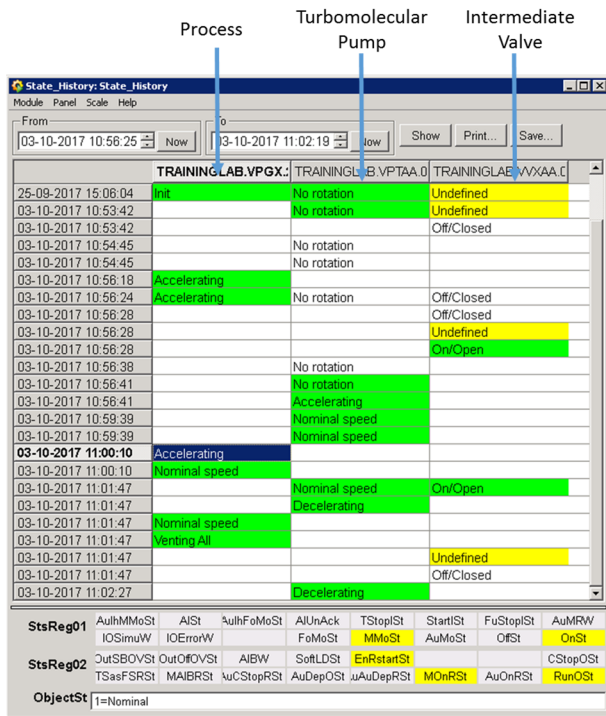

Figure 8: State history panel.

This panel is an advanced tool for post mortem analysis. User has a fast look of meaningful device events and their chronology without any minor events reported.

Pressure Profile Panel

Pressure profile is another popular panel in vacuum framework.

This panel is a bar graph with individual bars, corresponding to pressure measurement devices in the vacuum system; the order of devices in the graph corresponds to geographical sequence of devices along the beam line. The user specifications require functionality not found in standard bar trend of WinCC-OA. For instance, the vacuum sectors are presented as areas with different background colours.

The panel has two modes. The first mode is an online status mode. The colour and filling of each bar is calculated from current state of device using the same rules which are used to calculate colour and filling of device widget. The second mode did not exist in vacuum framework, it is a new functionality called pressure raised detection mode. The colour of each bar corresponds to the maximum growth since a chosen moment in the past and

current time. The meaning of colour is given by an external widget. This external widget is sitting on the bottom of the panel. Figure 9 illustrates the pressure raised detection mode.
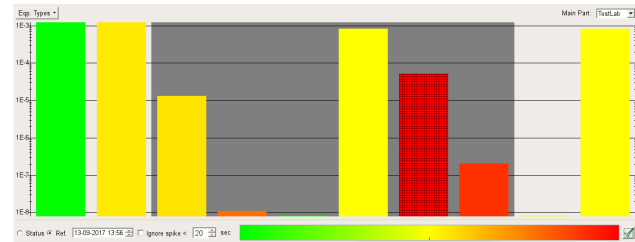

Figure 9: Profile panel in pressure raised detection mode.

CONCLUSION

The first set of vacuum objects has been developed jointly by the vacuum control team and the Industrial Controls and Safety group. The widgets have been developed according to UNICOS standard and vacuum control user requirements. SCADA features – i.e. automatic synoptic, state history panel and pressure profile panel – have been redesigned from vacuum framework in a more portable version and compatible with UNICOS-CPC objects. All the features are scalable. They have not only been refactored but upgraded with new functionalities. The goal is to provide a smooth migration to UNICOS and limit the impacts for users. The only change for users is relative to standardization of widget's animation and panel layout. The new SCADA panels remain user friendly with same look as vacuum framework panels.

The first version of the UNICOS vacuum control package has been tested, it will be released soon after a review with vacuum control users. In order to migrate large vacuum system to UNICOS framework, the vacuum control package needs to be complemented with additional CPC device types (ion gauge, fast valve, bake-out cabinet, mobile pumping group…) and SCADA features (device list, vacuum trending, replay…).

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