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Developments on the SCADA of CERN Accelerators Vacuum

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Abstract
During the first 3 years of LHC operation, the priority for the SCADA (Supervisory Control And Data Acquisition) of vacuum controls was to attend to user requests, and to improve its ergonomics and efficiency: access & presentation of information simplified and normalized; coherent functionalities & menus across all accelerators; automatic scripts instead of fastidious manual actions; enhanced tools for data analysis and for maintenance interventions.

Several decades of cumulative developments, based on heterogeneous technologies and architectures, have been asking for a homogenization effort. The first LHC Long Shutdown (LS1) provides the opportunity to further standardize the vacuum controls systems [1], around Siemens-S7 PLCs (Programmable Logic Controllers) and PVSS SCADA.

Meanwhile, exchanges with other Groups at CERN and outside Institutes have been promoted: to follow the global update policy for software libraries; to discuss philosophies and development details; and to accomplish common products.

Furthermore, while preserving the current functionalities, a convergence towards the CERN UNICOS framework is under preparation.

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INTRODUCTION

Vacuum Controls Architecture

For half a century, the architecture of vacuum controls in CERN accelerators has been following the availability of new technologies, at the time of construction or renovation; cumulative developments, from different generations, often coexist in the same machine.

Started in the year 2000 with the renovation in SPS, followed by the LHC construction and the partial renovation in the PS complex, vacuum controls are being upgraded to a PLC-based architecture with Siemens™ S7 and PVSS® (now called WinCC®-OA).

The application software for both PLC and SCADA has been developed within the vacuum group, as a custom framework [2]; it has integrated an increasing number of elements from the CERN-wide UNICOS [3] framework.

Communication between the PLCs and the PVSS Data-Servers is performed through the Ethernet Technical Network (TN), which is restricted to the control & operation of accelerators and technical infrastructures. Office computers, on the General Purpose Network (GPN), may have limited access to the TN, for monitoring.

During the LS1, the homogenization of the vacuum controls systems will be extended to the rest of the PS Complex (PS Ring, AD), and to some experimental areas (NA62, nTOF). The new Linac4 is also being built in the same way; it will later evolve closer to UNICOS. The ISOLDE facility, already using UNICOS, will be extended into HIE-ISOLDE.

Security Chain: Interlocks, Alarms & Warnings

In case of vacuum degradation, when the pressure readings (Penning Gauge-VGP and Ionic pump-VPI) rise above given thresholds, an Interlock is sent to the valve (VVS) controller; depending on the logic combination, the neighboring valves will automatically close.

This information is also hardwired as Alarms to other control systems: Beam, Cryogenics, RF, Kickers. Less critical issues, but nevertheless important to other systems, are sent from SCADA to the LHC Alarms Service (LASER), for the care of the accelerator operators.

If the attention or intervention of a vacuum expert is required, SCADA Warnings are sent by email or SMS, to the appropriate list of experts.

Furthermore, the SCADA provides a wide set of visual Warnings, to draw the attention of the on-line operators in case of unusual conditions.

Data Sharing

The SCADA publishes the process values & status through the middleware interfaces CMW [4] and DIP [5]; these channels can be used by any CERN control system to publish / subscribe data, synchronized with the global Accelerators Timing.

The PVSS historical data is locally stored, and periodically sent to a central repository: the LOGGING-DB.

Databases & Software Generation

A set of ORACLE databases (VAC-DB) contains the information necessary to automatically generate the equipment descriptions for the PLCs and SCADA.

The information about the geographical distribution of all vacuum equipment is imported from Layout-DB [6] or Survey-DB.

A Java application (DB_editor) allows the manual entering or modification of any individual attribute. The DB_export_tool combines the information from those databases to produce the configuration files for both PLC (DataBlocks) and SCADA (DPs, CMW, DIP, Logging, LASER).

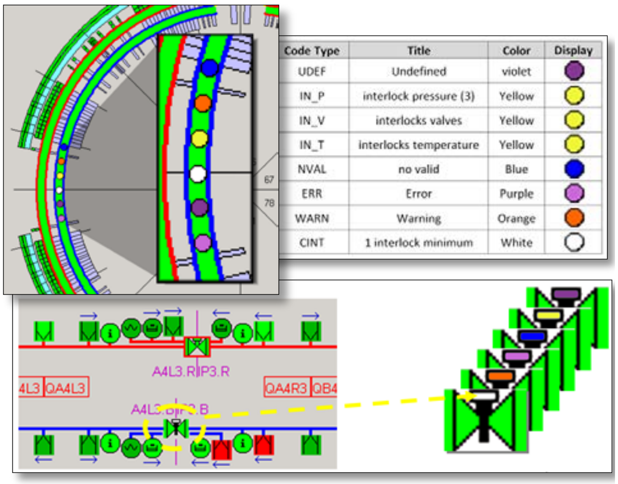
SCADA DEVELOPMENTS

Several new features, implemented in the first years of LHC operation, were already reported [2]:

- new summary-panels, web-server, & monitoring room;
- improved security, redefinition of access rights;
- user-defined configurations for: email/SMS notifications, historical trends, device lists;
- PVSS migrations: graphics from ActiveX to QT.

Synoptics

For each machine, the main SCADA panel has been enriched with information on the current state (errors & interlocks) of every VVS; these are represented by circles, color-coded in the same way as the widgets in synoptic views (Fig. 1).



Code Type	Title	Color	Display
UDEF	Undefined	violet	
IN_P	interlock pressure (3)	Yellow	
IN_V	interlocks valves	Yellow	
IN_T	interlocks temperature	Yellow	
NVAL	no valid	Blue	
ERR	Error	Purple	
WARN	Warning	Orange	
CINT	1 interlock minimum	White	

Figure 1: Interlocks Information

In order to easily locate a device from its name in the "device-list", a direct link is now available from the right-click pop-down menu, to the synoptic panel where that device will appear horizontally-centered and selected.

Warnings

The mail/SMS notifications have been significantly improved. Given the increasing amount and variety of pre-defined Warnings, care must be taken to avoid duplications, typing errors, and non-uniform descriptions: the Warnings configuration can now be imported from an externally prepared table, following a well-defined format; each notification consists of a clear and easily identifiable text (ID + customizable text).

Furthermore, the generation of any Warning may now take into account the current operating mode of the LHC machine, from the point of view of vacuum (Fig. 2).

VAC Mode	Color	Beam mode and Accelerator Mode combinaisons
ACCES		No BEAM and ACCES
SHUTDOWN		No BEAM and SHUTDOWN
MACHINE SETUP		No BEAM and (MACHINE CHECKOUT xor MACHINE TEST xor CALIBRATION)
CRYO		No BEAM and (COOLDOWN xor WARM UP xor RECOVRY)
RUN PHYSICS		/No BEAM and (BEAM SETUP xor PROTON xor ION xor TOTEM PHYSICS)
MACHINE DEVELOP.		/No BEAM and MACHINE DEVELOPMENT

Figure 2: Combined Machine Mode State for LHC

To prevent its degradation, a Penning gauge should not be kept powered if the pressure is too high; it may be periodically turned ON & OFF, to sense if the pressure is already suitably low. Also, in some occasions vacuum may not be stable, while near the upper limit of the measurement range. In both cases, a Warning was being sent every time the Penning goes OFF.

To avoid repetitive and worthless messages, an adjustable threshold can be set, far enough from the unstable zone; this way, the Warning is generated only if the gauge was reading pressures in the range of interest.

Noisy Devices

Noise-polluted channels may quickly saturate the archive files with meaningless data, thus limiting history depth. A PVSS script merely stopped recording any further, when fast and wide signal variations were detected; unfortunately, this excluded any readings from such channel, for an indefinite length of time.

This script now comprises an archive smoothing with adaptive parameters; the archiving will only be blocked if the algorithm cannot decrease the amount of meaningless values; furthermore, each night all blocked channels are restarted. Naturally, any parameter evolution and archive blocking are traced.

Additionally, in VAC-DB there is now the possibility of predefining the default parameters for archive smoothing, per device type or individually.

Trends

The user-defined trends configuration now includes parameters like: title, window position, multi-windows.

When in linear mode, the vertical axis scale can now be adjusted in small and large steps.

To better identify the evolution of noisy pressure trends, a new filter can select only the minimum values at given rate; this setting can also be saved.

The trend charts can be exported as xls, csv or png.

Gauge Controllers

In order to faster access the interlock thresholds stored in the Pfeiffer-Balzers TPG300® controllers, the PVSS communication script has been improved. The parameters of several TPGs connected to a given PLC, can now be loaded and displayed at the same time. The daily traceability of user changes on interlock thresholds has been extended from the LHC into the other machines

Bake-out Controllers

In order to allow reaching ultra-high vacuum at room temperature, a "Bake-out" heating cycle has to be previously applied to the vacuum chambers; this releases volatile components and will thus reduce outgassing when under high vacuum. For the sectors coated with Non-Evaporable Getter (NEG), the coating activation is combined with the Bake-out, within the same heating cycle.

The PLC-based control system [7] is integrated in mobile racks (VREMA). These are connected to the main vacuum controls system through a Profibus network, which is reserved to mobile control equipment; in this way they are remotely accessible through the SCADA, for control and monitoring.

The new version of the Bake-out rack includes more channels, a safety general power cut, an Ethernet communication facility, and a new PID regulation with auto-tuning. The SCADA has been updated accordingly, also including the specific mail/SMS Warnings.

Furthermore, some other developments are in progress: automatic on-the-fly positioning of the mobile racks within a synoptic; homogenization of the trend panels; data archiving or exporting.

VPG Controllers

The control software (VPG6A) for the turbo molecular pumping group has been improved: already using a state machine sequencer, new parameterized functionalities were introduced. The most significant are the auto-restart and the safe auto-venting of the turbo pump, after a power-cut. According to these new functionalities, the SCADA panel has been updated (Fig. 3).

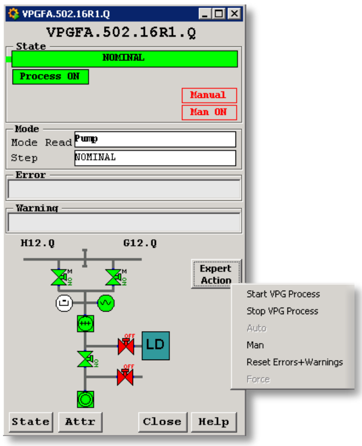


Figure 3: VGP6A Control Panel

Replay

A useful Replay function runs the past animation of a synoptic or bar-graph. Its renovation is in progress, with the goal to illustrate the global evolution, and to help with post-event analysis and on newcomers training (Fig. 4).

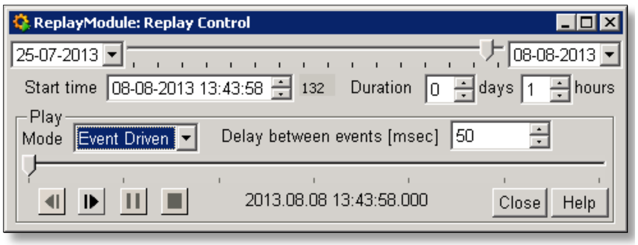


Figure 4: Replay panel

Other Functionalities

To enforce the protection against manual operations, in the line of improving security of operation, certain SCADA commands can only be issued by a user with a very high level of privileges, and who has acknowledged the appropriate alert messages.

Additional topics developed were:

- the PLC Remote-Reset functionality is now integrated in the SCADA;
- the map with the zones under access and the Device-list were improved with additional information and filters;
- errors on server-client communication are now visible;
- the vacuum lines/parts under maintenance can now be temporarily hidden.

VAC-DB

The information about the geographical distribution of all vacuum sectors and equipment lies either in the Layout or Survey databases. In the case of the LHC machine, the position of vacuum instruments can be automatically retrieved from Layout-DB by a synchronization script into VAC-DB; in 2012, a more robust version was put into place.

Launching a simulated synchronization is now possible, with the production of a report pointing to potential data problems. Moreover, before launching a real synchronization, several validation steps must be followed. If needed, a synchronization can be partial, regarding only a fraction of the Database.

The interface and procedure were revised, so that non-database experts can easily import/export data into VAC-DB; and obviously, all actions are traced.

Layout-DB

Currently, the only vacuum controls information available in Layout-DB is the position of the instruments of certain accelerators (started with the LHC).

Over the coming years, a substantial effort is still needed to fully benefit from Layout-DB [8]:

- definition of the data architecture and level of details;
- collect, update and organize information about the components and topology of all machines;
- upload all that information, including racks layout;
- migrate VAC-DB contents to Layout-DB;
- adapt the generators of PLC & SCADA configuration files to both Layout-DB and UNICOS;

FURTHER ACTIVITIES

Standardizations

Exchanges are being promoted with other groups at CERN and outside Institutes, to discuss philosophies and development trends, and to engage in a global update policy for software libraries.

For instance, in tight collaboration with EN-ICE (SCADA support) and BE-CO (Data-Servers support), the migration of the PVSS Data-Servers from Windows to Linux was performed in 2012; this led to the VAC-SCADA application now being fully integrated and operational in the CCC (CERN Control Centre).

In the same line, the Data-Server machines were physically moved into the CCR building; version 3.6 was updated to 3.8; new functionalities were incorporated (e.g. MOON: a PVSS-based tool by EN-ICE, for monitoring and management of control systems [9]).

In collaboration with the CERN IT security team, a “TN Disco test” was held on March 2013; the objective was to find which control systems on the TN depended on external services (on GPN); and also to determine how long those systems were able to run autonomously, while the GPN was not available.

Prior to the test, a known issue was corrected by EN-ICE, by the global deployment of a corrective patch, from a centralized management tool (MOON).

The results have been better than expected: none of the observed issues concerned exclusively the vacuum applications. This highlights and rewards the efforts on collaboration and normalization, regarding the security recommendations at CERN.

The Software Versioning service (SVN) started to be used in 2012, to follow software development within the team, and to ensure the consistency throughout versions.

All improvements or changes on the SCADA are now listed and sent to the users, thus enhancing the communication policy. The most important actions are described in detail and recorded in EDMS; examples are: SMS notifications; archiving parameters settable according to equipment type or individually.

Next Steps

Scheduled for early 2014, the SCADA will be upgraded to the WinCC®-OA version 3.11. This will provide compatibility with Windows-7 (for lab stand-alone applications), and with Win-Server 2008 (for Terminal-Servers). Consequently, these new versions of windows will finally be deployed.

Currently, the local storage on the Data-Servers can accumulate more than one year of history archiving. With the new SCADA version, the archiving will be moved to an external and independently maintained Oracle server. This will ensure the preservation of the archives during hardware or software upgrades, which are sometimes complicated by the tricky handling and configuration of a large and complex set of files.

To accomplish common products, while preserving the current functionalities, a full convergence towards the CERN UNICOS framework is being prepared. A partnership between VSC-ICM, GSI and Cosylab has been launched by EN-ICE, for the development of new UNICOS libraries (objects & functions), tailored for vacuum.

These collaborative and normalization efforts will ensure to be in conformity with CERN best practices, security rules, and recommendations, and will allow to benefit from reliable and first-rate centralized support.

CONCLUSIONS

The SCADA applications for vacuum are under significant improvement, regarding their ergonomics, configurability and standardization.

The major objective for the end of LS1 is to have all upgrades ready for the restart of the LHC & injectors, in the best conditions to ensure three years of seamless operation up to 14 TeV.

The next step will be the preparation of the convergence with the UNICOS framework; having it ready, for Linac4 in 2015, will be the first full-scale experience, before the deployment on the whole accelerator chain during LS2.

In parallel, several new user requests, about automatic tools for data mining and data analysis, are currently being investigated, with the target of being operational during 2015.

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