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INTEGRATION OF WIRELESS MOBILE EQUIPMENT IN SUPERVISORY APPLICATION

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Abstract

In CERN accelerators, pumping group stations and bake-out control cabinets are temporarily installed close to vacuum systems for their commissioning.

The quality of the beam vacuum during operation depends greatly on the quality of the commissioning. Therefore, the integration of mobile equipment in the vacuum supervisory application is primordial. When connected to the control system, they appear automatically integrated in the synoptic. Mobile equipment are granted with the same level of remote control, diagnostics and data logging as fixed equipment.

The wireless connection and the communication protocol with the supervisory application offer a flexible and reliable solution with high level of integrity.

INTRODUCTION

The vacuum systems of the CERN's accelerators reach high (below 1.10^{-6} mbar) and ultra-high (below 1.10^{-9} mbar) vacuum. The vacuum systems of accelerators are divided into sectors, delimited by vacuum valves or windows. Vacuum sectors reduce and even stop the propagation of a sudden pressure increase and allow independent venting and interventions.

Only few sectors have pumping group stations [1] permanently installed; however, all the others do not have any. For these sectors, pumping group stations and optionally bake-out cabinets [2] are temporarily installed during interventions, commissioning and re-commissioning of the vacuum systems.

Pumping group stations are required to achieve high vacuum prior to the start of permanently installed pumps, such as ion pumps or Non-Evaporable Getter (NEG) pumps. A typical pumping group station is composed of a primary and a turbo-molecular pump, a gauge, several valves and a PLC that drives the process and manages the interlocks.

When ultra-high vacuum is required, a bake-out cycle is mandatory to decrease the outgassing rate of the vacuum vessel and to activate the NEG thin-film coatings, if present. Bake-out control integrates a Proportional-Integral-Derivative (PID) regulation, interlocks and troubleshooting management.

At the end of the intervention, mobile equipment (i.e. pumping group stations and bake-out cabinets) are removed from the accelerator facility.

Both mobile pumping group stations and mobile bake-out cabinets are locally driven by a PLC. This makes the integration of these equipment in the vacuum controls framework possible without the need of extra interface systems, more difficult to maintain.

A typical intervention on a vacuum sector requiring a bake-out cycle may take several days. Access to the LHC tunnel is not easy nor fast: more than 45 minutes are needed to reach some tunnel areas. In these cases, remote control is mandatory.

The remote control of mobile equipment is not something new. The same bake-out cabinet and a previous version of pumping group PLCs are remotely controlled using dedicated Profibus networks installed in the LHC tunnel. This remote control is used since the beginning of the LHC. However, it has shown some limitations: wired Profibus networks require a lot of maintenance, each connection/disconnection requires the intervention of a fieldbus expert as it may break the communication of other equipment already connected on the same network. This makes connection management difficult. A software consolidation has already been done to improve the reliability, but the architecture has several limitations. There were no alive counters from the pumping group or the bake-out cabinet PLCs, making some communication interrupts difficult to detect. Data was only archived locally and not in CERN central archiving system.

The new wireless mobile equipment control relies on alive counters to guarantee the system integrity. Alive counters are read in the local PLC of pumping group stations and bake-out cabinets. Pumping group stations and bake-out cabinets are managed in a very similar way as "fixed" equipment and so get all of their features, including the central archiving (lhcLogging). With the new wireless system, data logging of mobile equipment are now permanently archived.

SCOPE

Mobile equipment concerned are pumping groups and bake-out cabinets. The vacuum systems of the CERN facilities require more than 250 mobile pumping groups and more than 120 bake-out cabinets. Around 80 mobile pumping groups and 70 bake-out cabinets are hardware compatible with the wireless communication system. In addition, not all of them will be connected at a same time. For instance, for the LHC application, not more than 40 mobile equipment will be connected simultaneously.

CONCEPT

The first idea was to create data points on-the-fly and on demand in the supervisory application when mobile equipment are effectively connected. Even if this solution is technically possible, it shows two major limitations: creating, configuring and deleting data points during operation

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is not an usual process; it may be blocked by other processes and may affect libraries; the central archiving of such data points is not possible. Data points sent to central archiving shall be declared in advance in a not fully automated procedure.

The solution adopted was different; all the data points required are created in advance, though not configured, during the application update procedure.

First, we need to get all the possible positions of connected mobile equipment. For pumping groups, it is relatively easy as they are physically installed on specific flanges. In the LHC, names and positions of such flanges come from the Layout DB. In other machines, they are inserted in the Vacuum DB by the process engineer. For bake-out cabinets, the process is more complex. While bake-out cabinets are not installed on fixed points of the vacuum line, we need to display them on synoptic. A virtual bake-out port object has been created in the Vacuum DB. This port is used to create the required data points. The only difference between flanges for pumping groups and bake-out ports is that only one pumping group can be connected to a flange while several bake-out cabinets can be connected to the same bake-out port.

Pumping groups and especially bake-out cabinets are complex instruments and have large number of data point elements. Therefore, bake-out cabinets are not managed by a single device type but by a set of device types. A bake-out cabinet requires: one rack data point, 24 regulation channel data points and eight alarm channel data points.

The wireless communication system deployment increases significantly the size of the vacuum supervisory applications. For the LHC case (the vacuum largest application), it has currently 700k data point elements[1]. With the wireless communication system, this number increases by around 300k and the application reaches the million of data point elements. However, it remains far from WinCC OA[2] limitations (16 million of data point elements per data point element type) and far from the biggest WinCC OA™ application running at CERN (up to 8 million data point elements).

The amount of data point elements is not the only criteria to evaluate WinCC OA application performance. Other criteria such as the number of configurations and data point functions must be considered. Mobile equipment data points do not have any data point function and for most of data point elements only the archive configuration is set (address configuration is set when connected). In addition, data point elements are rarely changed because most of the time not connected. Figure 1 shows the architecture of the mobile equipment remote control system.

[1] Data point element is a data variable in the application DB

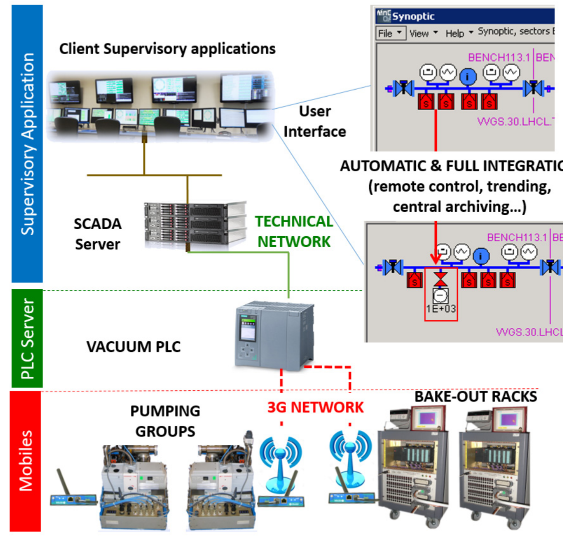

Figure 1: Data points for mobile equipment.

DEVICE CONTROL TYPES

First, new vacuum framework control types have been developed. Bake-out cabinets and mobile pumping groups are not new devices but they come with new specifications and therefore new features and communication registers. The control types described below are compatible with the mobile equipment wireless communication system but may be used as well for fixed devices if they matched the same specifications.

Pumping Group Control Type

This control type is compatible with both turbo molecular pumping groups and primary pumping groups. Instrument data shall fit with the communication registers defined in the specifications.

The pumping group is represented in the synoptic as a unique device. Figure 2 shows the widget of a pumping group. The icon of the widget is inserted in the synoptic of the vacuum beam pipe. If the pumping group has pressure gauges, the pressure value in mbar of the most relevant gauge is shown below the icon.

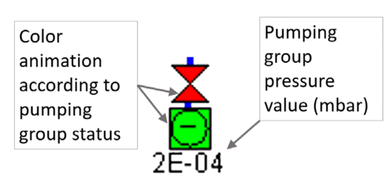

Figure 2: Pumping group widget.

The pumping group is composed of the following remotely controlled instruments: primary pump, turbo molecular pump (optional), set of valves (some optional), up to two gauges (optional), bake-out channel (optional). Figure 3 represents a typical pumping group faceplate.

[2] WinCC OA™ is a commercial Supervisory control and data acquisition application provided by ETM/SIEMENS™

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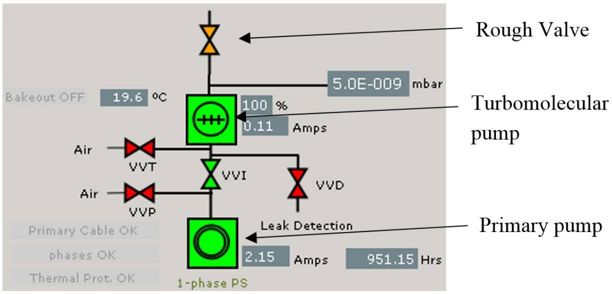

Figure 3: Pumping group faceplate.

Bake-out Control Types

Bake-out control types are quite different from usual vacuum instruments. First, because a bake-out rack is a more complex instrument, with 24 regulation channels and 8 alarm channels. Second, because in addition to global orders and statuses, there are many parameters and other statuses per channel. Controlling it as a whole would have required a heavy object with a low efficiency code. For these reasons, the control is split in three control types: the regulation channel (regulates the power of the heater to reach the temperature set point); the alarm channel (interlocks the regulation channel with an additional sensor); the rack (for global statuses and orders).

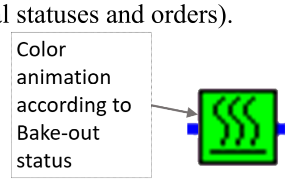

Figure 4: Bake-out rack widget.

The Rack control type is the parent of the regulation and alarm channel control types. Only the Rack object is shown on the synoptic, as on the Figure 4.

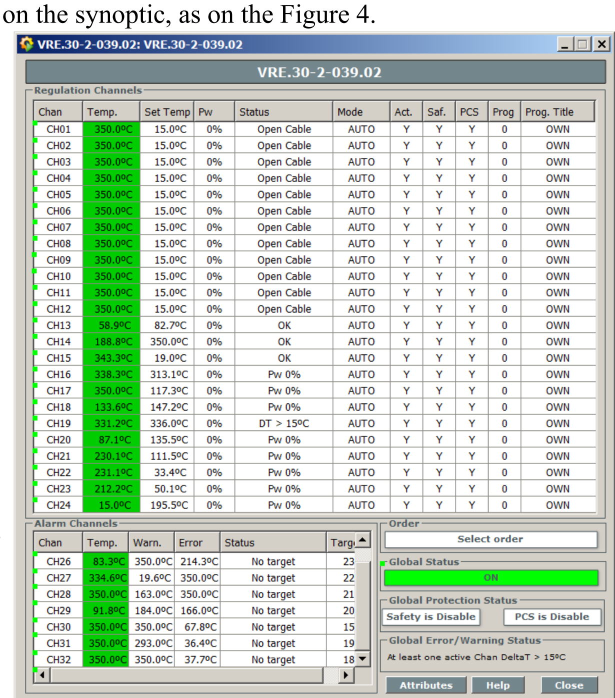

Figure 5: Faceplate panel of bake-out rack.

The bake-out cycle is a critical process, where the temperature can reach up to 350ºC. For safety reasons, only limited global orders are allowed remotely. The process is controlled according to the parameters in the faceplate panel (Figure 5).

From this panel, all the temperature process values, set points and power can be plotted into the same standard trend history panel as the fixed equipment. The global state of the rack and individual channel's state can be inserted into the standard state history panel.

ARCHITECTURE

Pumping group stations and bake-out cabinets are driven by a local "small" PLC: Siemens S7-1200, for the pumping group stations, and Siemens S7-300, for the bake-out cabinets. Both have an Ethernet communication processor. In addition, a wireless LTE/3G gateway module is installed. The supervisory application does not connect directly to these local PLCs. A "Server" PLC manages the front end communications [3].

At the supervisory level, mobile equipment are managed similarly to "fixed" and so inherit all their standard features. This means they are shown in the synoptic and device list, states appear in the standard state history and data values can be inserted in the standard history panel. Mobile equipment have faceplate panels, remote orders, central archiving and can be published to third-party services.

Usually, fixed devices are directly connected to a PLC device. For mobile equipment, we introduce a SIM card communication device. Mobile device's data points are connected to the SIM card data point, itself connected to the PLC server. The communication registers of the SIM card data point are used to connect or disconnect the mobile equipment. The SIM card data point gets the mobile connection status, the type of mobile equipment connected, their position and alive counter.

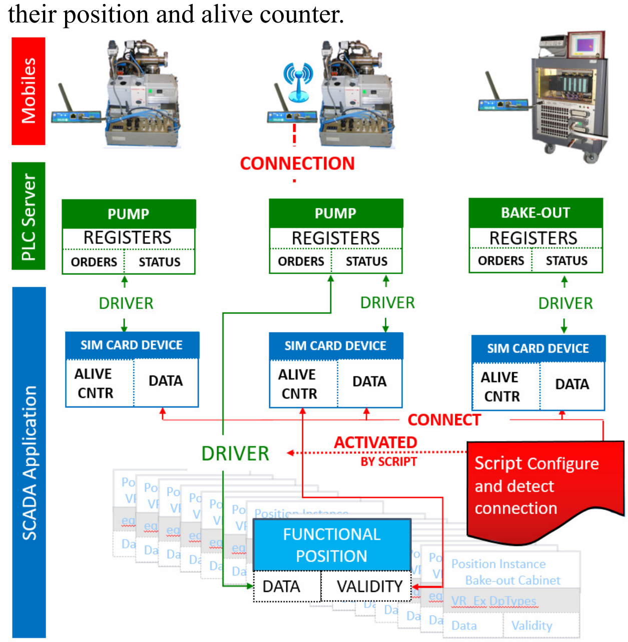

Figure 6: Communication Diagram.

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Then according to the SIM card communication registers, the mobile equipment script "connects" to the correct functional position instance of pumping group or bake-out cabinet data points. The process is described in Figure 6.

The remote control of mobile equipment has a reliable system integrity based on alive counters.

The integration of wireless mobile equipment in the vacuum supervisory application required two large developments. The first development is the update of the Database structure and the files generation script. The second development is the implementation of new libraries (WinCC OA libraries and Qt/C++ libraries).

DATABASE DEVELOPMENTS

The database developments comprised: definitions of new equipment control types in the master database; update of the Files Generation Script (Exporter) to include the pumping group and bake-out control types; insertion of the wireless mobile connection concept in the Exporter.

In addition to the pumping group and bake-out control types, two new objects have been created: SIM card object, which manages the communication with the PLC Server; port object, to generate the mobile equipment functional position instances with the correct geometry attributes.

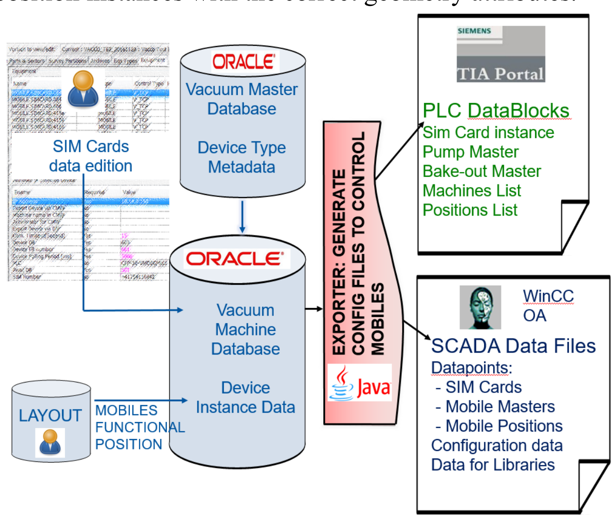

Figure 7: Databases and automatic generation.

The Exporter produces, according to the Vacuum databases, the list of functional positions where the mobiles (pumping groups or bake-out cabinets) may be connected, with the respective name and attributes. Figure 7 lists the new database inputs and the new files generated for the PLC Server and the SCADA application.

SCADA DEVELOPMENTS

This paragraph describes the developments required to manage the mobility functionality of pumping group and bake-out cabinet. This includes the update and creation of WinCC OA panels, the development of WinCC OA libraries, the development of C++/Qt libraries and the creation of a script for automatic connection of mobile equipment (mobiles script).

Import Panel

In the vacuum control framework, the import panel creates and configures SCADA data points from the import ASCII file generated by the Exporter.

The import panel creates data points of SIM Card devices. For each SIM card device it creates a pumping group master data point and a bake-out rack master data point. Finally, it creates the functional positions data points.

In the import ASCII file, functional position data points for mobile equipment are set with a specific flag, and the data points are created without address configuration. The address configuration will be set later by the mobiles script using the master data point. If the data points of functional positions already exist in the project, the import process will deactivate any output address configuration. If needed, the mobiles script will reactivate the connection when it restarts.

Mobiles Script

The SIM card data points are permanently connected to the PLC Server through the S7 driver. The script is connected to the SIM card data points.

In case a new mobile equipment connection is detected, the script gets the type of the mobile equipment (pumping group or bake-out cabinet) and the position from the SIM card data point. Then, the script copies the configurations of the master data point to the functional position data point. Configurations are peripheral addresses, alert handling settings, etc. Finally, the functional position is activated in the shared libraries data pool.

The process is described in Figure 8 and Figure 9.

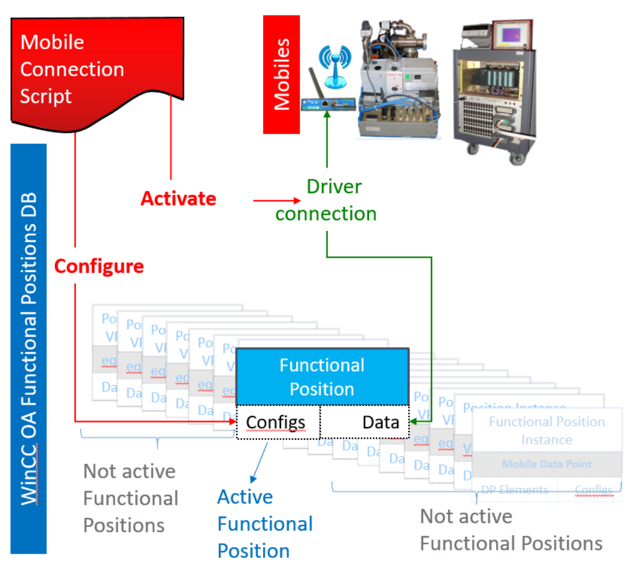

Figure 8: Activation of functional position instance.

Synoptic

In vacuum supervisory applications, synoptic panels are Qt dialogs. The synoptic is automatically built on the fly by a Qt/C++ library. There are two types of synoptic and associated libraries: single line layout library, and multiple lines layout library, for the LHC synoptic (up to 4 vacuum

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lines in parallel). Both have been updated to be compatible with the mobile equipment wireless communication.

When operators start the main user interface panel, the shared libraries build a data pool with class instances of devices. The mobile class instances are built with the "not active" flag, when connected this flag is activated and the icons are inserted in the synoptic as explain in Figure 9.

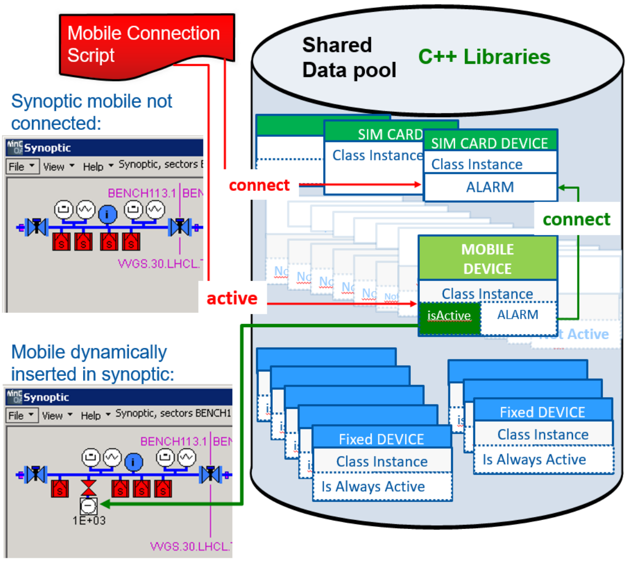

Figure 9: Dynamic update of synoptic.

The operator has access to all the diagnostics and history features. For example, mobile states can be displayed in the standard state history panel and mobile values can be plotted in standard trending panels. Mobile's icon has contextual menu and faceplate panel. They are controlled in the same way as fixed equipment.

Operators may also want to get the history of instruments not currently connected. However, icons are not shown when not connected. To solve this issue, two ways of access have been developed.

The first access is on the synoptic panel. In the View menu of the synoptic panel, the operator may select "Show mobiles not connected". Then as shown in Figure 10, all the possible mobile functional positions are displayed. As each position is dedicated either to pumping groups or to bake-out racks, the icons appear with the correct control type. The colour of the icons is blue because they are not connected and the current instrument data is not valid. It offers to the operator an access to name, attributes, states history and trends history of that functional position.

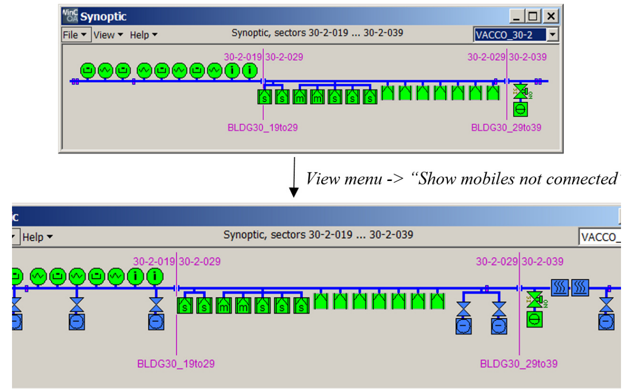

Figure 10: Show mobiles not connected (in blue).

The second access is through the device list. Device list C++ library has been updated to integrate new device list criteria. The criteria "Not Active", dedicated to mobile equipment control types, is used to list all the possible functional position data points of pumping group and bake-out rack.

Notification System

In addition to usual alert notification criteria, the criteria "disconnected" has been added, very useful for mobile equipment that may suffer of power cuts and network interrupts.

CONCLUSION

The system has been successfully deployed in the LHC and SPS applications at the beginning of the second CERN accelerators Long Shutdown (LS2). It offers remote control of mobile equipment with a high level of integrity. The permanent monitoring and data logging of mobile equipment contributes to the quality of the commissioning, and so to the quality of vacuum for the next physics run. This scalable integration in the SCADA, of complex processes driven by PLC-based mobile stations, required the development of new concepts to manage the connection and integrate automatically mobile equipment in the supervisory application with full features.

REFERENCES

[1] S. Blanchard *et al.*, "Vacuum Pumping Group Controls Based on PLC", in *Proc. PCaPAC'14*, Karlsruhe, Germany, Oct. 2014, paper WPO030, pp. 105-107.

[2] S. Blanchard *et al.*, "Bake-out Mobile Controls for Large Vacuum Systems", in *Proc. ICALEPCS'13*, San Francisco, CA, USA, Oct. 2013, paper MOPPC026, pp. 119-122.

[3] R. Ferreira, S. Blanchard, P. Gomes, G. Pigny, and T. R. Fernandes, "LTE/3G Based Wireless Communications for Remote Control and Monitoring of PLC-Controlled Vacuum Mobile Devices", in *Proc. ICALEPCS'17*, Barcelona, Spain, Oct. 2017, pp. 64-70. doi:10.18429/JACoW-ICALEPCS2017-MOCPL04