VACUUM PUMPING GROUP CONTROLS BASED ON PLC

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Abstract

In particle accelerators, high vacuum is needed in the beam pipes and for thermal isolation of cryogenic equipment. The first element in the chain of vacuum production is the pumping group. It is composed by: primary pump, turbo-molecular pump, valves, gauges, process and interlocks devices. At CERN accelerators, the pumping groups may be found in several hardware configurations, depending on the environment and on the vacuum system used; the control is always based on Programmable Logical Controllers (PLC) communicating with the field equipment over a field bus; pumping groups are controlled by the same flexible and portable software. They are remotely accessed through a Supervisory Control and Data Acquisition (SCADA) application and can be locally controlled by a portable touch panel. More than 250 pumping groups are permanently installed in the Large Hadron Collider, Linacs and North Area Experiments.

INTRODUCTION

This paper describes the new control software for the turbo molecular pumping group of type “VPG_6A”. It is based on operational modes and phase sequencers. It includes sequential process for pumping, leak detection and venting modes. Optional features for automatic restart and automatic venting are also available.

The mechanical layout of the pumping group is illustrated by the Fig. 1.

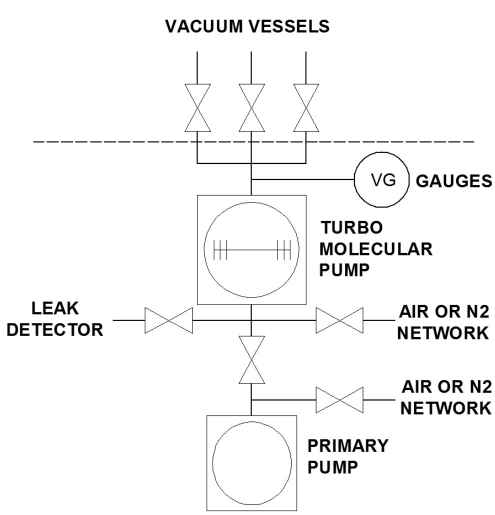

Figure 1: Pumping Group Layout.

CERN Accelerators have more than 120 km of beam and thermal isolation vacuum vessels. Turbo molecular vacuum pumping groups are used for rough pumping, for leak detection and to maintain the vessels under high vacuum. The primary pump performs initial pumping from atmospheric pressure to rough vacuum (between 10 and 0.1 Pascal) then the turbo molecular pump achieves high vacuum (between 1.10^{-4} and 1.10^{-7} Pascal).

HARDWARE

The new software is compatible with any hardware control crates based on Siemens® PLC S7-300 or S7-400 series with a minimum of 64Kb working memory. That includes the recently designed prototype shown in Fig. 2 but also with the 15 years old crates.

Pumping group devices are controlled using direct PLC Input/Output or Profibus® fieldbus.

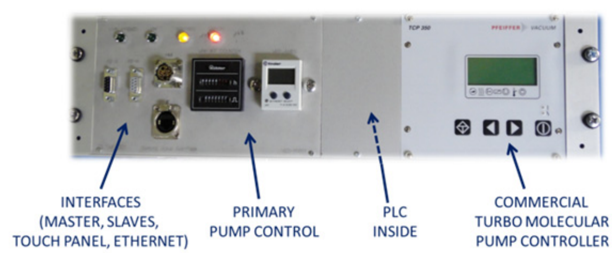

Figure 2: Prototype Pumping Group Controller Crate.

The controller crate commands the pumps and valves; and gets the feedback status from them: opened / closed from the valves, and a minimum of 3 status bits from the pumps.

For the primary pump: “ON” status is the feedback of the pump power supply actuator; “NOMINAL SPEED” status is given by the motor current monitor and “ERROR” status is the feedback of the circuit breaker.

For the turbo molecular pump: “ON” status is the pump rotation detected feedback; “NOMINAL SPEED” status is given when the pump rotor reaches nominal speed threshold (in the most of the cases, 80% of the maximum speed) and “ERROR” status occurs when load is too high, when no rotation is detected, or when the rotor acceleration time is too long.

The standard hardware architecture, as shown in Fig. 3, is composed of a local crate, a control crate, a touch panel (local Human Machine Interface), a gauge controller, a PLC master and a SCADA server.

A Profibus® network connects the touch panel, the control crate, the gauge controller and the PLC master.

ISBN 978-3-95450-146-5

The touch panel can be connected either to the local crate or to the control crate. It is easily removable, not to remain in radiation area and to limit the total needed number of touch panels.

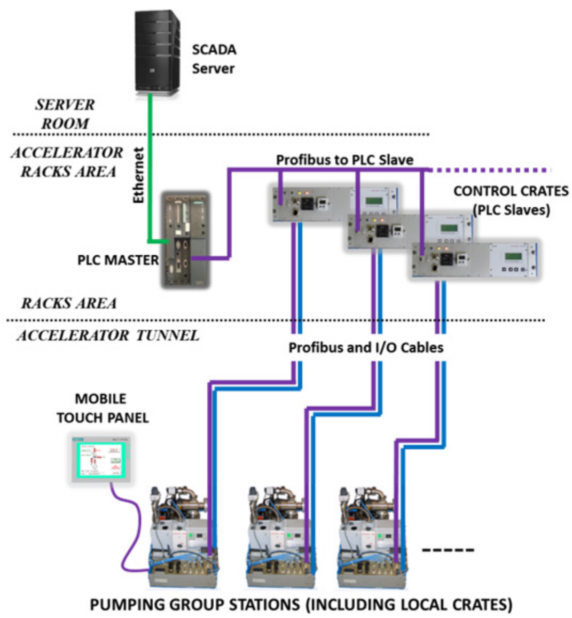

Figure 3: Typical Hardware Architecture.

PLC SOFTWARE

Vacuum devices are defined in a global Vacuum Database (VACDB), and classified by "families", "types" and "sub-types". The family classifies actual physical devices (valves, mechanical pumps, active gauges, passive gauges…) and virtual devices (pumping group process, software interlock…).

The type defines the control behaviour, as programmed by a common PLC function (Function Block, FB). The sub-type is used to manage minor differences of behaviour and to set the correct SCADA widget.

The PLC software comprises a set of functions which are part of the generic Vacuum Controls Framework [1], [2]. They are written with SIEMENS-SCL Language, a textual high-level language that follows the standard IEC 61131-3 ST (Structured Text) definition. This language allows to program complex algorithms, arithmetic functions and data processing tasks.

A PLC software project is composed of organisation blocks (OB), functions blocks (FB, FC), and instance or generic data blocks (DB).

Function Block (FB): Programs routine working with instance memories; one routine (FB) per device type and one instance memory block (DB) per device. The OBs, FCs, FBs, and generic DBs are copied from the baseline SVN repository folder, provided by the CERN central repository service. Device instance DBs are automatically generated by the vacuum database editor and compiled within the PLC project.

Process

Valves, pumps and gauges have a "MANUAL" and an "AUTOMATIC" control mode. In "MANUAL" mode, the device is directly driven by an operator order, in "AUTOMATIC" control mode the device is driven by a process running in the PLC.

Two kinds of software interlock override the orders given in any mode, either "MANUAL" or "AUTOMATIC". The "start-interlock" disables any new actions on the device and; the "full-interlock" switches off the device.

When in AUTOMATIC control mode, the behaviour of the process managing the pumping group depends on the operational mode. There are 6 operational modes: 1 pumping mode, 3 service modes, and 2 venting (stop) modes.

Transitions between modes can be requested either by the operator or by the process itself, according to Fig. 4.

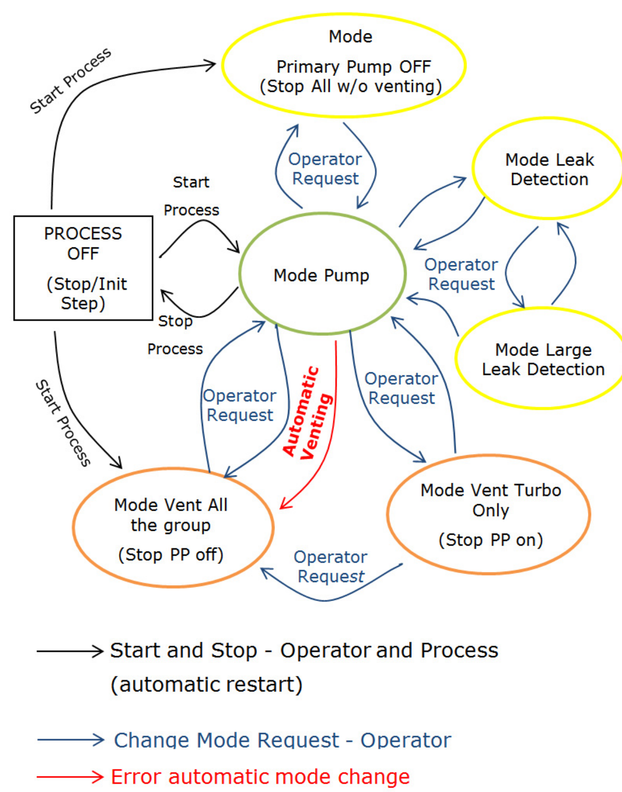

Figure 4: Operational modes and available transitions.

The phase sequencer follows a series of steps, through transition conditions and time dependencies; it sends "AUTOMATIC" orders to the devices within the pumping group, in order to reach a final state according to the operational mode.

The phase sequencer software is developed with the graphical language SIEMENS-GRAPH.

The pumping group process provides automatic venting (to avoid oil contamination from the primary pump), automatic restart and automatic re-opening of the valves to the vacuum vessel, in case of power cut.

Alert information

Troubles and unexpected events are classified to:

- Minor: warning status is set and the warning code is updated; the process continues to run.
- Major: error status is set and an error code is updated; the pumping group is automatically vented or directly shifted to the Initial step ("safety state"), according to user specifications.

SCADA APPLICATION

The pumping group control is included in the Vacuum SCADA vacuum application [3].

The details panel, as shown in Fig. 5, provides a state monitoring and a remote control to operators.

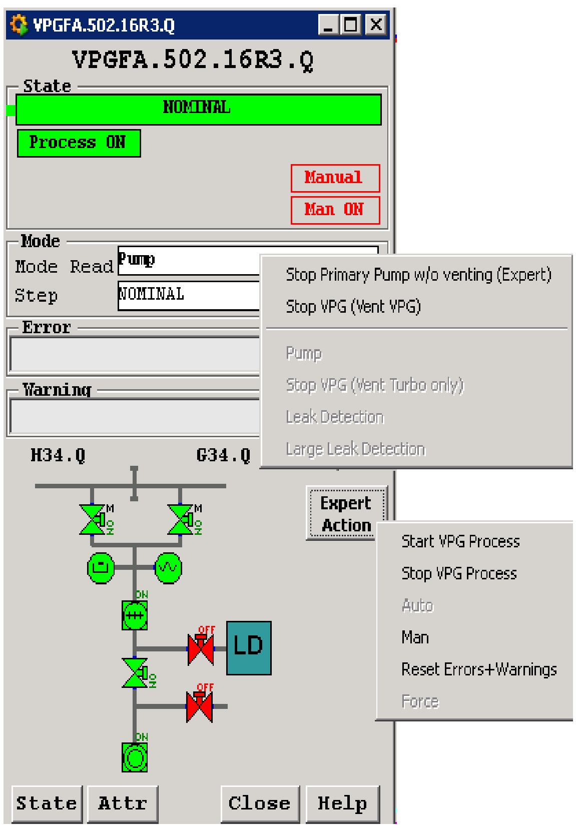

Figure 5: Pumping Group Details Panel.

The state history panel, as shown in Fig. 6, allows comparing archived values of status, operational mode and sequencer step of pumping group; it is very useful for a post-mortem diagnostic.

The pumping group pressure gauges history, as shown in Fig. 7, is an additional tool to check pumps efficiency, analyze pumping speed and detect leaks.

Operators may configure in SCADA e-mail/SMS notifications to be notified in case of pumping group error, stop or unexpected pressure increase.

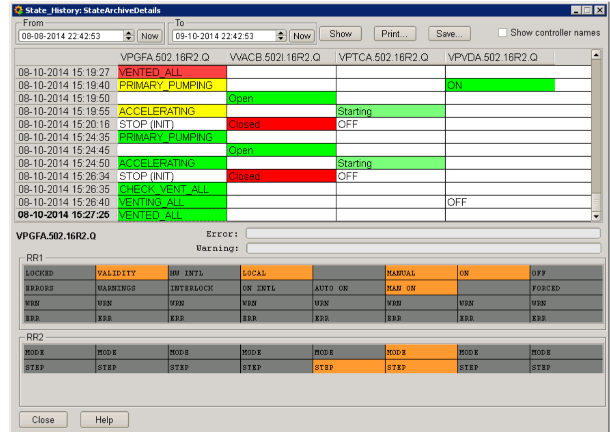

Figure 6: Pumping Group State History.

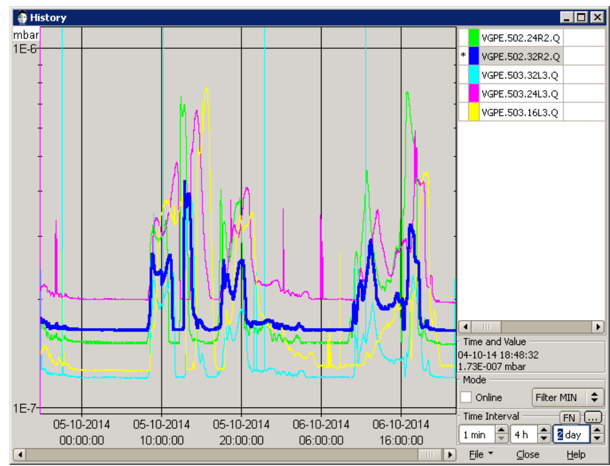

Figure 7: Pressure History.

CONCLUSION

The vacuum pumping group control offers a robust solution to drive a large variety of different turbo molecular pumping groups. It has been successfully deployed to more than 250 pumping groups and is foreseen to be installed in future CERN vacuum systems as a standard solution. The identical software for all turbo molecular pumping groups has reduced the maintenance and facilitated intervention. It has improved flexibility, remote control, diagnostics and data logging.

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ISBN 978-3-95450-146-5